

April 2, 1940.

W. A. KNOOP

2,195,864

ELECTRO-OPTICAL IMAGE PRODUCING SYSTEM

Filed Nov. 20, 1935

2 Sheets-Sheet 1

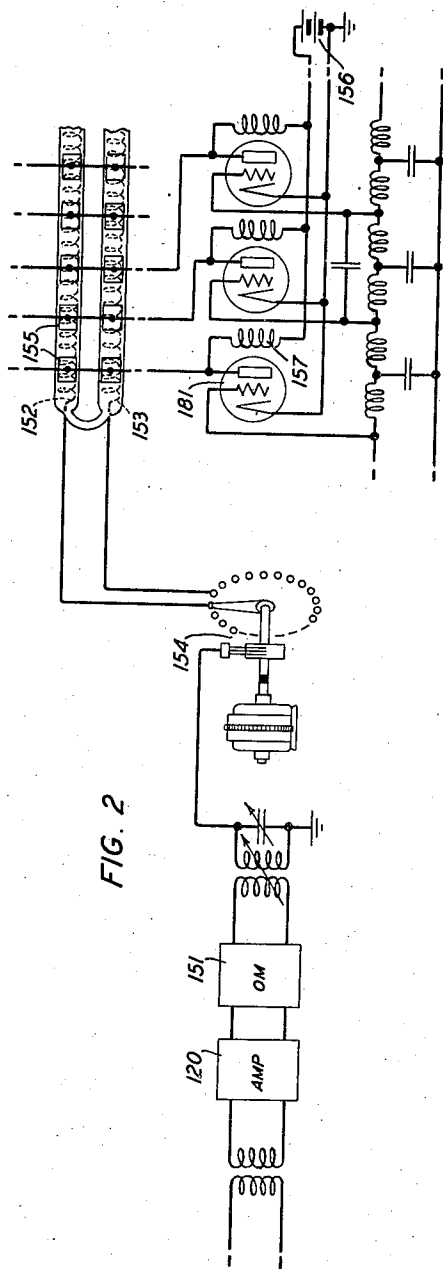


FIG. 2

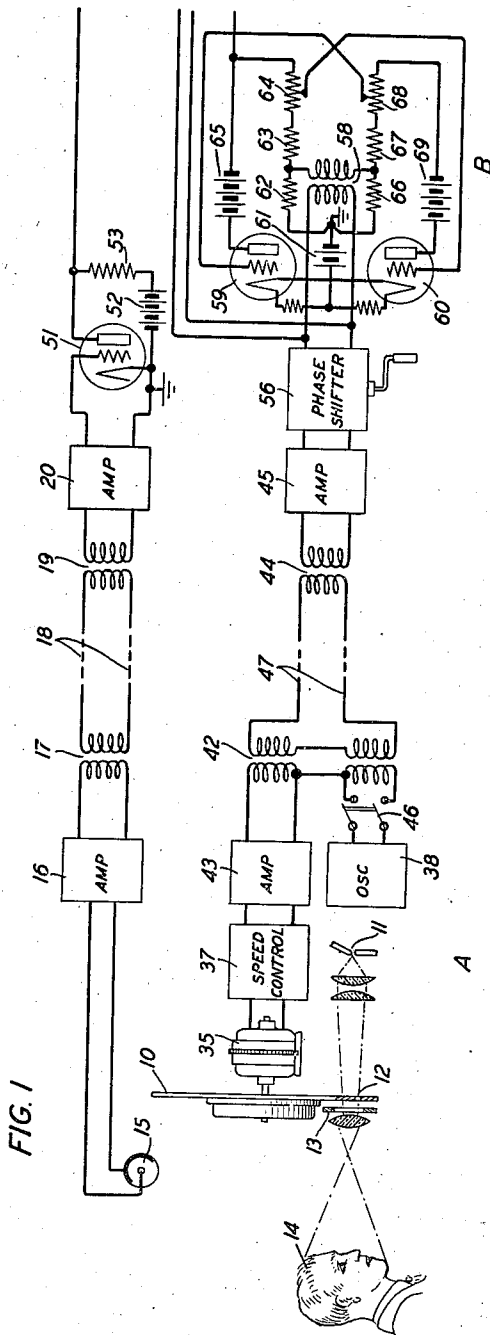


FIG. 1

INVENTOR
W.A. KNOOP
BY
Chas. Sprague
ATTORNEY

April 2, 1940.

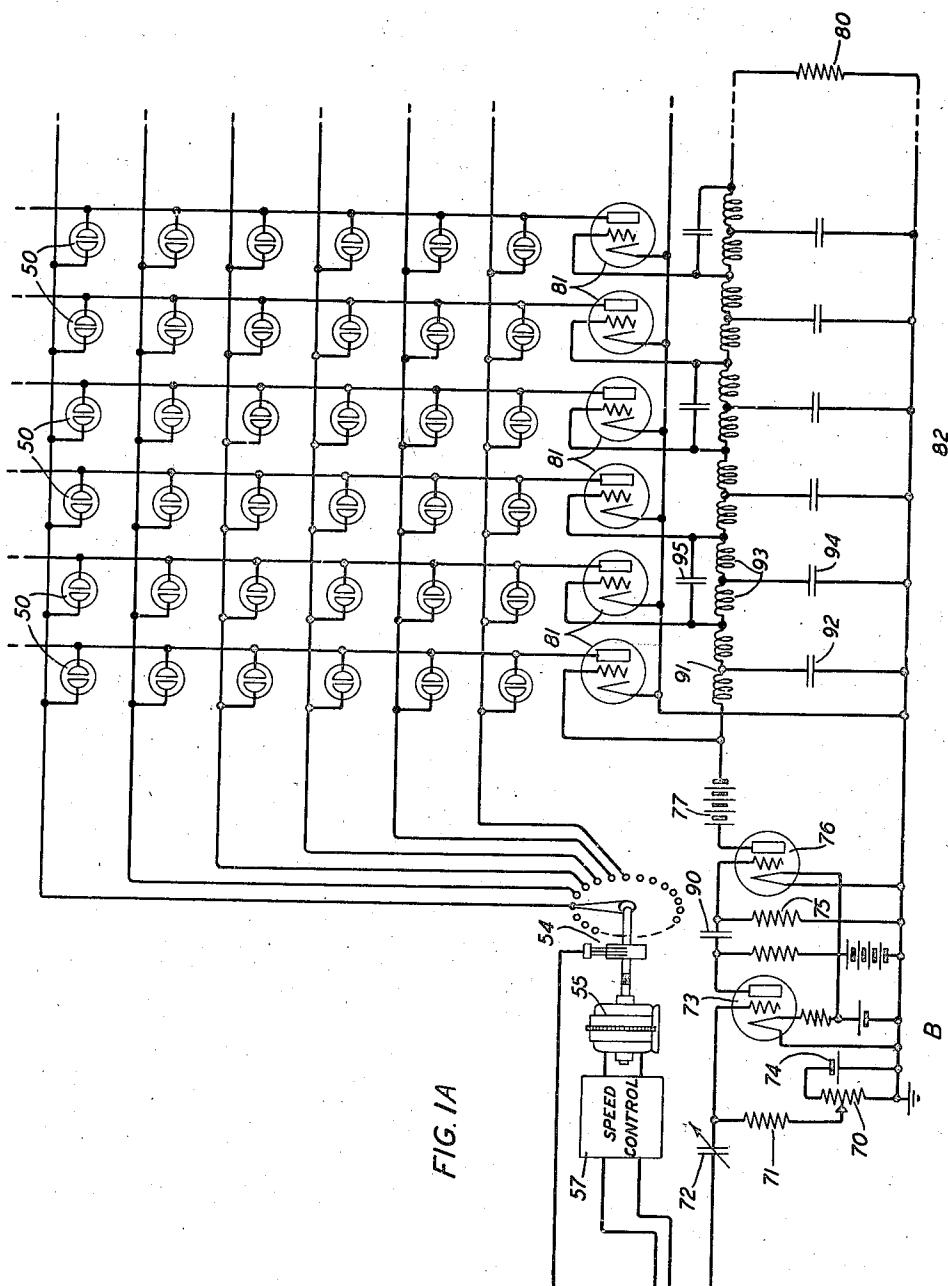
W. A. KNOOP

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INVENTOR
W. A. KNOOP
BY
C. C. Sprague
ATTORNEY

UNITED STATES PATENT OFFICE

2,195,864

ELECTRO-OPTICAL IMAGE PRODUCING
SYSTEM

William A. Knoop, West Hempstead, N. Y., as-
signor to Bell Telephone Laboratories, Incor-
porated, New York, N. Y., a corporation of New
York

Application November 20, 1935, Serial No. 50,653

22 Claims. (Cl. 178—7.3)

This invention relates to electric signaling and particularly to apparatus for and methods of producing television images.

An object of the invention is to provide an improved arrangement for energizing, in accordance with a varying signaling current, a plurality of signal responsive elements in rapid succession at a predetermined rate.

Another object of the invention is to convert a current of sine wave form into current impulses of rectangular wave form, the duration of each impulse being small compared to the period of the sine wave.

In accordance with a specific embodiment of the invention herein shown and described for the purpose of illustration, there is provided at a transmitting station apparatus for repeatedly scanning the elemental areas in succession of a field of view along successive parallel lines to produce a television image current, each complete scanning of the field of view taking place within the period of persistence of vision. At the receiving station there is provided a bank of light emitting elements arranged in rows corresponding to the parallel scanning paths at the transmitter, there being one lamp corresponding to each elemental area of the field of view. For example, there may be one hundred lamps in each horizontal row and one hundred lamps in each vertical column, making ten thousand lamps in all. One set of terminals of the lamps of each row is connected together to a contact of a mechanical distributor, while the other lamp terminals of each column are connected together to the anode of a three-electrode thermionic tube, thus making a coordinate system. A mechanical commutator selects the rows of lamps in synchronism with the scanning of successive lines of the field of view at the transmitting station. The source of image current is impressed upon the horizontal rows of lamps in succession through the mechanical distributor.

The vertical column of lamps must be selected in sequence at a rapid rate and this is done by a non-mechanical commutating arrangement. If a lamp bank of ten thousand lamps is to be commutated in one-twentieth of a second, for example, there is employed a transmission path or relay network having characteristics such that an impressed impulse will be transmitted from one end to the other of the network in .0005 second without appreciable attenuation or distortion. The network will be made up of one hundred sections, each having inductive and ca-

pacitive elements. The control electrodes of the thermionic devices are connected to different network sections, respectively. The control electrodes are normally negatively biased to such a degree that the lamps emit no light or only a very small amount of light. A high amplitude impulse of a duration preferably equal to the time required for scanning a single elemental area, .000005 second in the above example, is periodically impressed upon the delay network at a rate equal to the line scanning frequency and this impulse increases the grid potential of the thermionic tubes in succession to zero, for example, thus causing the lamps in succession to emit light of an intensity determined by the amplitude of the image current.

The periodic starting impulses impressed upon the delay circuit are derived from a source of alternating current, the frequency of which is equal to the line scanning frequency. Each alternating current cycle is converted into a square-topped unidirectional current having a duration approximately equal to one-half cycle of the alternating current and each square-topped current impulse is converted into an impulse of electromotive force of logarithmic wave form having a high amplitude and the top of this wave is cut off, thus forming an approximately rectangular wave having a duration less than the time required for scanning a single elemental area.

Any suitable arrangement may be employed for maintaining synchronism between the scanings at the transmitting and receiving stations and for maintaining the correct relationship between the rate at which the logarithmic impulses are generated and the speed of the mechanical commutator at the receiving station. For example, a constant frequency vacuum tube oscillator may be employed for generating the alternating current from which the logarithmic impulses are derived and current from this oscillator may also be supplied to a circuit for controlling the speed of a motor which drives the mechanical commutator at the receiver and to a circuit for controlling the speed of a motor which drives a scanning disc or other apparatus for scanning the field of view at the transmitting station.

In Figs. 1 and 1A of the drawings there is disclosed, for the purpose of illustration, a complete television system embodying the features of the invention.

Fig. 2 shows a modification of the system shown in Fig. 1.

Referring to Figs. 1 and 1A of the drawings,

at the television transmitting station A the scanning disc 10 is driven by the motor 35 at a speed of 16 or more revolutions per second to cause light from source 11 directed through the spirally arranged apertures 12 of the scanning disc to illuminate the elemental areas in succession of a field of view defined by the opening in screen 13 and including the subject 14. Elemental areas of the field of view are thus illuminated in succession along successive parallel lines. Light reflected from the subject 14 impinges upon one or more light sensitive cells 15 and the varying current produced by the action of the light sensitive cells, after being amplified by the vacuum tube amplifier 16, is transmitted to the distant station B through a transformer 17 and a transmission channel 18.

A source of alternating current of constant frequency produced by an oscillator 38 may be connected to a winding of transformer 42 by means of a switch 46. Current from this constant frequency source, after being amplified by the vacuum tube amplifier 43 is impressed upon the speed control apparatus 37 for maintaining the motor 35 at a constant speed under control of the constant frequency current from source 38. This speed controlling arrangement is disclosed more in detail in Patent No. 1,999,376, granted to H. M. Stoller, April 30, 1935. Current from the constant frequency source 38 is also transmitted to the image producing station B over the line 47 to maintain the image production at station B in synchronism with the scanning of the field of view at station A.

At the receiving station B television images of the field of view scanned at station A are produced upon the image producing lamp bank comprising a plurality of lamps or lamp elements 50, one for each elemental area of the field of view. These lamps may be glow discharge lamps, for example. Each transverse row of lamps corresponds to a scanning line of the field of view and if the field of view is square, the number of rows of lamps are equal to the number of vertical columns, as shown. While only six rows and columns of lamps are shown, any desired number may be employed. If, for example, the field of view at the transmitter is scanned along 100 parallel scanning lines, a lamp bank having 100 rows of 100 lamps each may be employed.

The television image current received from station A over line 18 is transmitted through transformer 19 and amplified by vacuum tube amplifiers 20 and 51. The output circuit of vacuum tube amplifier 51 comprises a battery 52 the negative terminal of which is grounded and a resistive element 53. The anode of amplifier 51 is connected to the anodes of the rows of glow discharge lamps 50 in succession by means of the mechanical distributor 54. This distributor has a number of contacts equal to the number of rows of lamps 50 and is driven by a motor 55 in synchronism with the scanning disc 10 at the transmitting station. Current from the constant frequency current source 38 received over line 47, after being transmitted through transformer 44, amplified by amplifier 45, and transmitted through the phase shifting transformer 56 is impressed upon the speed control apparatus 57 like apparatus 37 for controlling the speed of motor 55.

The constant frequency current received over line 47 after being amplified by the amplifier 45 and transmitted through the phase shifter 56 is also impressed upon the primary winding of

transformer 58 for controlling the circuit comprising the similar vacuum tubes 59 and 60 to produce a square-topped unidirectional voltage having a fundamental frequency equal to the frequency of the constant frequency current source 38. The grids of each of the tubes 59 and 60 are negatively biased by the battery 61. The grid of tube 59 is also biased due to the potential drop across resistive elements 66, 67, 68 in response to anode current from source 69 and the grid of tube 60 is biased due to the potential drop across resistive elements 62, 63, 64 in response to the flow of anode current from source 65. The cathode-anode circuit of tube 59 comprises resistive elements 62, 63 and 64 and battery 65, while the cathode-anode circuit of tube 60 comprises resistive elements 66, 67 and 68, like resistive elements 62, 63 and 64, respectively and battery 69, like battery 65. An adjustable contact on resistive element 64 is connected to the control electrode of vacuum tube 60 while an adjustable contact of resistive element 68 is connected to the control electrode of vacuum tube 59. One terminal of the secondary winding of transformer 58 is connected to a common terminal of resistive elements 62 and 63 and the other terminal is connected to a common terminal of resistive elements 66 and 67. The circuit elements are so chosen, that when current flows in the anode circuit of vacuum tube 59, the grid of vacuum tube 60 is negatively biased to such a potential that no current can flow in the anode circuit of vacuum tube 60 and that when current flows in the anode circuit of vacuum tube 60 the grid of vacuum tube 59 is negatively biased to such a potential that no current can flow in the anode circuit of vacuum tube 59. There is thus generated between the negative terminal of battery 65 and ground a unidirectional electromotive force of square-topped wave form, one such square-topped impulse being produced for each cycle of the current impressed upon the transformer 58.

During the periods that current is flowing in the anode circuit of vacuum tube 59, a portion of the anode current from battery 65 flows through the potentiometer winding 70 and resistive element 71 to charge the condenser 72. When anode current is not flowing through tube 59, the condenser is discharged through a circuit including resistive elements 62, 63, 64, 70 and 71, one terminal of resistive element 62 and one terminal of resistive element 70 being grounded. The circuit elements may obviously be so chosen that the condenser is charged at a rapid rate to a high potential less than the potential drop across resistive elements 62, 63 and 64 during one-half cycle of the current from source 38 and is rapidly discharged during the next half cycle of the current from source 38. The charging-discharging current of logarithmic wave form flowing through the resistive elements 70 and 71 produces an electromotive force of corresponding wave form which is applied to the input circuit of three electrode vacuum tube 73. The grid of this vacuum tube is negatively biased by the battery 74 to such an extent that current flows in the anode circuit of vacuum tube 73 only when discharge current of considerable amplitude is flowing from condenser 72 through resistive elements 70 and 71. Moreover, the anode current of vacuum tube 73 reaches saturation when the amplitude of the condenser discharge current is less than its maximum value. Therefore, during each cycle of the alternating current from source

38 there is produced in the anode circuit of vacuum tube 73 a current impulse of extremely short duration and of considerable amplitude. The wave shape of this impulse is substantially rectangular. The output circuit of vacuum tube 73 is connected to the input circuit of vacuum tube 76 through a coupling condenser 99 and resistive element 75.

In the output circuit of vacuum tube 76 there is connected a battery 77 and a delay network 82 of a plurality of sections. The delay network is so designed that the different sections, respectively, introduce substantially the same delay and so that the phase distortion introduced by one section is compensated for by the phase distortion introduced by an adjacent section, thus making any pair of sections substantially free of phase distortion. If desired, each section may be so designed as to introduce the same delay for all frequencies over a wide range. As shown in the drawings, the T-type sections each comprise two equal inductive elements 91 and a capacitive element 92, while each of the bridged T-type sections comprise the two equal inductive elements 93, capacitive element 94 and capacitive element 95. Satisfactory results have been obtained by employing a network of this type in which the inductive elements 91, comprising two windings on a single core tapped in the center, has a total inductance of .0232 henries, the capacitive elements 92 .00575 microfarads, the inductive elements 93 each .01162 henries, the capacitive elements 94 .00576 microfarads, and the capacitive elements 95 .00144 microfarads. The value of the terminating resistive element 80 was 2010 ohms. The input circuits of the vacuum tubes 81 are connected to the terminals of different sections respectively of the delay network 82. There are as many vacuum tubes 81 as there are columns of neon lamps 50, the cathodes of the lamps of a column being connected to the anode of the vacuum tube 81 which controls the lamps of that column. Due to the potential of battery 77, the grids of vacuum tube 81 are normally negatively biased to such an extent that the current from battery 52 flowing through the lamps 50 of a row connected in circuit by the commutator 54 and the anode circuits of vacuum tubes 81 is of such amplitude that the lamps emit no light or only a small amount of light such as would be produced to represent black tone value. The negative bias is the same for all of the vacuum tubes, in the absence of a starting impulse impressed upon the vacuum tube 76, because the resistance of inductive elements 91 and 93 is small compared to the resistance of the terminating element 80.

When a voltage impulse is now impressed upon the input circuit of vacuum tube 76, a corresponding voltage impulse is impressed upon the delay network 82. This impulse is of such polarity that the biasing of the grids of vacuum tubes 81 becomes successively less negative, zero for example. By adjusting the condenser 72 to a suitable value of capacity the impulse impressed upon the delay network 82 may be made sufficiently brief so that the grid bias of only one of the tubes 81 at a time is rendered less negative than the normal negative biasing potential with the result that only one lamp 50 at a time will emit light in accordance with the tone value of the elemental area of the image to be produced under control of the image potentials impressed upon the input circuit of vacuum tube 51.

It is thus apparent that the lamps 50 of the

image producing lamp bank are energized one at a time in succession in synchronism with the scanning of the successive elemental areas of the field of view at the transmitting station, the intensity of the light produced by each lamp corresponding to the tone value of the corresponding elemental area of the field of view. The image may be "framed" by operating the phase shifter 56 which, when operated, changes the frequency or phase of the current from source 38 supplied to the speed control circuit 57 for motor 55 and to the impulse generator 59, 60. A phase shifter of this type is disclosed in Patent 1,999,376, granted to H. M. Stoller April 30, 1935.

Instead of employing a large number of individual lamps, one for each elemental area, a plurality of multi-electrode lamps of the type disclosed in Patent 1,759,504, granted to F. Gray May 20, 1930, one for each line, may be employed as shown in Fig. 2. In this arrangement, instead of impressing a direct current having the image current variations upon the circuits of lamps 50 through the distributor 54, as shown in Fig. 1, the received image current after being amplified by the amplifier 120 is impressed upon an oscillator-modulator 151 to produce in its output circuit a high frequency alternating current modulated in accordance with the variations of the image currents. This high frequency modulated current is impressed upon the common electrodes 152, 153, etc., of the multi-electrode lamps, one for each line of the image, in succession by means of the distributor 154. The ends of the glass tubing forming the gas chamber for the lamps are preferably connected together so as to form a continuous chamber in which the gas pressure may be maintained constant.

The individual electrodes are preferably formed on the glass tubing forming the gas chamber by first covering all portions of the tube, except the portions at which the electrodes are to be formed, with a suitable material, such as adhesive tape. The exposed portions of the glass tubing are sand blasted to roughen the surface of the glass and these portions are then covered with a suitable metal by means of a Schoop gun. The adhesive tape is then removed and contact is made with each electrode 155 by tying a fine wire around the glass tube so as to make contact with the electrode. The electrodes 155 of each column are connected to the anode of one of the three-electrode vacuum tubes 181. The cathodes of these vacuum tubes are connected to ground as is also one side of the source of modulated high frequency image current from oscillator-modulator 151. As in the arrangement shown in Fig. 1, the control electrodes of the vacuum tubes 181 are connected to different sections, respectively, of a delay network 182. The anode of each vacuum tube 181 is also connected to a source of direct current 156 through a choke coil 157 which prevents the high frequency modulated current from flowing to ground through the battery 156. It is thus apparent that when the anode-cathode impedance of one of the vacuum tubes 181 is reduced, due to a positive impulse impressed upon its grid, a circuit is completed from the grounded source of high frequency modulated image current at the output of oscillator-modulator 151, through a contact of distributor 154, one of the common electrodes 152, 153, one of the individual electrodes 155, the anode of one of the vacuum tubes 181, and thence to grounded cathode of the vacuum tube 181. As will be understood from a consideration of the above description in

connection with Fig. 1, a glow discharge is thus produced at different positions in succession of the multi-electrode lamp bank to produce an image.

What is claimed is:

1. In combination, a plurality of electric discharge tubes, an input and an output circuit for each of said tubes, a plurality of signal responsive means each connected in the output circuit of one of said tubes, a source of electromotive force the amplitude of which varies in accordance with signals connected in said output circuits, a delay network having a plurality of delay sections connected in series, the input circuits of said electric discharge tubes being connected to different sections respectively of said delay network, and means for impressing an electric impulse upon said delay network to cause said signal responsive means to be energized in succession in accordance with the amplitude of said signaling electromotive force.

2. In combination, a source of alternating current, means for converting said alternating current into a unidirectional current having a square-topped wave form and a fundamental frequency corresponding to that of said alternating current, means for converting said current of square-topped wave form into current impulses of logarithmic wave form, and means for converting said current impulses of logarithmic wave form into current impulses of high amplitude and of brief duration compared with the duration of said square-topped wave impulses.

3. In combination, a transmission network having a plurality of sections directly connected in series, each comprising inductive and capacitive elements, means comprising an electric discharge device for generating periodic impulses, means for impressing said periodic impulses upon said network, and a plurality of devices responsive to said impulses associated with different sections of said network respectively, each impulse having a duration less than the time required for transmitting it through one of said sections, thus causing said devices to be operated in succession.

4. In combination, a transmission network having a plurality of sections directly connected in series, each section comprising inductive and capacitive elements, a plurality of electronic devices each having a control electrode connected to different sections respectively of said network, a source of electromotive force connected to said network for simultaneously similarly biasing said control electrodes, and means for varying said electromotive force to cause a change in the biasing of said control electrodes in succession.

5. In combination, a transmission network having a plurality of sections directly connected in series, each section comprising inductive and capacitive elements, a plurality of electronic devices each having a control electrode connected to different sections respectively of said network, a source of electromotive force connected to said network for simultaneously similarly biasing said control electrodes, and means for periodically changing said electromotive force to periodically change the biasing of said control electrodes in succession.

6. A bank of light emitting elements for producing television images each within the period of persistence of vision, there being one element for each elemental area of the field of view an image of which is to be produced, a source of image current, a plurality of said light emitting

elements being simultaneously directly associated with said source of image current, electronic means directly associated with said light emitting elements for causing them to emit light in succession in accordance with the variations of said image current, and means for controlling said electronic means comprising a delay network, and means for causing recurrent impulses to be propagated along said network.

7. In combination, a plurality of signal producing devices each having two terminals, a source of signaling current connected to a common terminal of said devices, a plurality of electronic devices each having an anode-cathode circuit connected to the other terminals of said devices respectively, each signal producing device being directly connected in series with one of said anode-cathode circuits and said source of signaling current, and means for controlling said electronic devices to cause current from said source to energize said signaling devices in succession.

8. In combination, a delay network comprising a plurality of similar sections directly connected in series, each section comprising inductive and capacitive elements, a plurality of electron discharge devices each having a control electrode, said control electrodes being directly connected to different sections respectively of said delay network, and means for periodically impressing an impulse of electromotive force upon said delay network.

9. In combination, a delay network comprising a plurality of similar sections directly connected in series, each section comprising inductive and capacitive elements, a plurality of electron discharge devices each having a control electrode, said control electrodes being directly connected to different sections respectively of said delay network, and means for periodically generating an impulse of electromotive force of such duration with respect to the wave-length constant of the delay network that said impulse is impressed successively upon said control electrodes one only at a time.

10. In a television system, image producing apparatus comprising light producing elements arranged in rows, mechanical means for selecting said rows in succession, a driving motor for said mechanical means, electronic means for selecting the light producing elements of each row in succession, a source of constant frequency current for controlling said driving motor and said electronic means for maintaining a desired time relationship between the selection of the rows and the selection of the light producing elements of each row, and means for simultaneously similarly changing the frequency or phase of the current from said source supplied to said motor and said electronic means.

11. In combination, two electric discharge devices each having a control electrode, an anode and a cathode, a source of direct current connected in each anode circuit, a source of alternating current connected to corresponding portions of said anode circuits, means for connecting the control electrodes of each device to the anode circuit of the other device so that current flowing in the anode circuit of one of said devices will prevent the flow of current in the other of said devices, a circuit including a variable condenser and a resistive element in shunt with a portion of the anode circuit of one of said devices to cause current to flow alternately in opposite directions in said condenser circuit, a third

electric discharge device the input circuit of which is connected to said condenser charging and discharging circuit, a source of biasing potential and a source of anode potential for said third electric discharge device, said potentials being adjusted to cause current to flow in said anode circuit of said third electric discharge device only when the current is flowing in a predetermined direction in said condenser circuit and when the amplitude of said current is substantially above zero, the current in said anode circuit reaching saturation before the current in said condenser circuit reaches a maximum amplitude.

12. In combination an electric discharge device, an input and an output circuit for said device, a source of varying current, means to be energized by current from said source connected to said output circuit, commutator means for connecting said source of varying current to said output circuit at intervals, a delay network connected to said input circuit, means for impressing an electric impulse upon said delay network to cause said first-mentioned means to be energized by current from said source of varying current at a predetermined interval after said electric impulse is impressed upon said delay network when said source of varying current is connected to said output circuit, and means for maintaining a predetermined phase relationship between the commutator means and the means for impressing an electric impulse upon said delay network.

13. In combination an electric discharge device, an input and an output circuit for said device, a series circuit comprising a source of signaling current, signal producing means to be energized by current from said source, said output circuit and commutating means for connecting said source to said output circuit at intervals, a delay network connected to said input circuit, means for impressing an electric impulse upon said delay network at substantially the same time that said source of signaling current is connected to said output circuit to cause said signal producing means to be energized by current from said source of signaling current at a predetermined interval after said electric impulse is impressed upon said delay network.

14. In combination a delay network comprising a plurality of sections directly connected and having a delay characteristic which is substantially the same for all frequencies over a wide frequency range, means for impressing electric wave energy upon said network, and a plurality of means responsive to said electric wave energy connected to different sections, respectively, of said network.

15. In combination a delay network comprising a plurality of sections, alternate sections of which have different phase characteristics, respectively, such that the phase distortion introduced by one type of section is compensated for by the phase distortion introduced by the other type of section to obtain a substantially zero phase distortion characteristic for any pair of connected sections, means for impressing electric wave energy upon said network and a plurality of means responsive to said electric wave energy connected to different sections, respectively, of said network, each of said sections comprising an inductive element and a capacitive element, said inductive elements being directly connected in series.

16. In combination a delay network comprising a plurality of sections directly connected,

one section of which has a delay characteristic different from that of another section to give an over-all desired delay characteristic, means for impressing electric wave energy upon said network, and a plurality of means responsive to said electric wave energy connected to different sections, respectively, of said network.

17. In combination, an electrical transmission circuit comprising a plurality of delay network sections directly connected in series each having inductive and capacitive elements, means for generating and impressing upon said transmission circuit an electric impulse having a duration less than .001 second, a plurality of devices responsive to said electric impulse electrically connected to said transmission circuit at positions following different delay sections respectively along the direction of transmission of said impulse.

18. In an apparatus for producing images of a field of view, an electrical transmission circuit comprising a plurality of delay network sections directly connected each having inductive and capacitive elements, means for generating and impressing upon said transmission circuit an electric impulse having a duration of the order of the product of the reciprocal of the number of elemental areas in the field of view and the period of persistence of vision, and a plurality of devices responsive to said electric impulse electrically connected to said transmission circuit at positions following different delay sections, respectively along the direction of transmission of said impulse.

19. In apparatus for producing images of a field of view, a combination in accordance with claim 18 in which the delay period of each delay section of the transmission circuit is of the order of the duration of said electric impulse.

20. In combination, an electrical transmission circuit comprising a plurality of delay network sections directly connected in series each having inductive and capacitive elements and a plurality of electric discharge devices having control electrodes connected to different delay sections, respectively, means for normally negatively biasing said control electrodes to reduce the currents flowing in the anode circuits of said electric discharge devices, and means for similarly changing the potential of said control electrodes in succession to permit current of increased amplitude to flow in said anode circuits, said means comprising means for impressing an electric impulse upon said transmission circuit.

21. In combination, a bank of light-emitting elements for producing television images, there being one light emitting element for each elemental area of the field of view, an image of which is to be produced, and means for causing said light emitting elements to be energized periodically in succession, all within the period of persistence of vision, each in accordance with the tone value of an elemental area, said means comprising a source of image current, means for connecting said source to groups of said light emitting elements in succession, an electrical transmission circuit having a plurality of delay network sections directly connected made up of inductive and capacitive elements, means for causing an electric impulse to be periodically transmitted along said transmission circuit, and means responsive to said impulse to cause the light emitting elements of a group to be energized in succession by energy from said source.

22. A television image producing system comprising a source of television image current, a plurality of light producing devices one for each of a plurality of elemental areas of a field of view, an electric discharge device for each of said light producing devices, each discharge device having an input and an output circuit, means for connecting said light producing devices directly in series with said output circuits, respectively, means for connecting said source of television image current across all of said series circuits simultaneously, and means for impressing an impulse of electromotive force upon the input circuits of said electric discharge devices in succession to cause current from said source of television image current to energize said light producing devices in succession said last-mentioned means comprising a continuous delay network along which electric impulses may be propagated, means for connecting said input circuits to different portions of said network respectively along the line of propagation, and means for impressing upon said network impulses the duration of which is less than the propagation time along said network from one input circuit to the following input circuit along the line of propagation and the interval between successive impulses being substantially equal to the time of propagation from the first input circuit to the last input circuit along the line of propagation.

WILLIAM A. KNOOP.