Nov. 13, 1928. **1,691,324**

V. K. ZWORYKIN

TELEVISION SYSTEM

Filed July 13, 1925 2 Sheets-Sheet 1

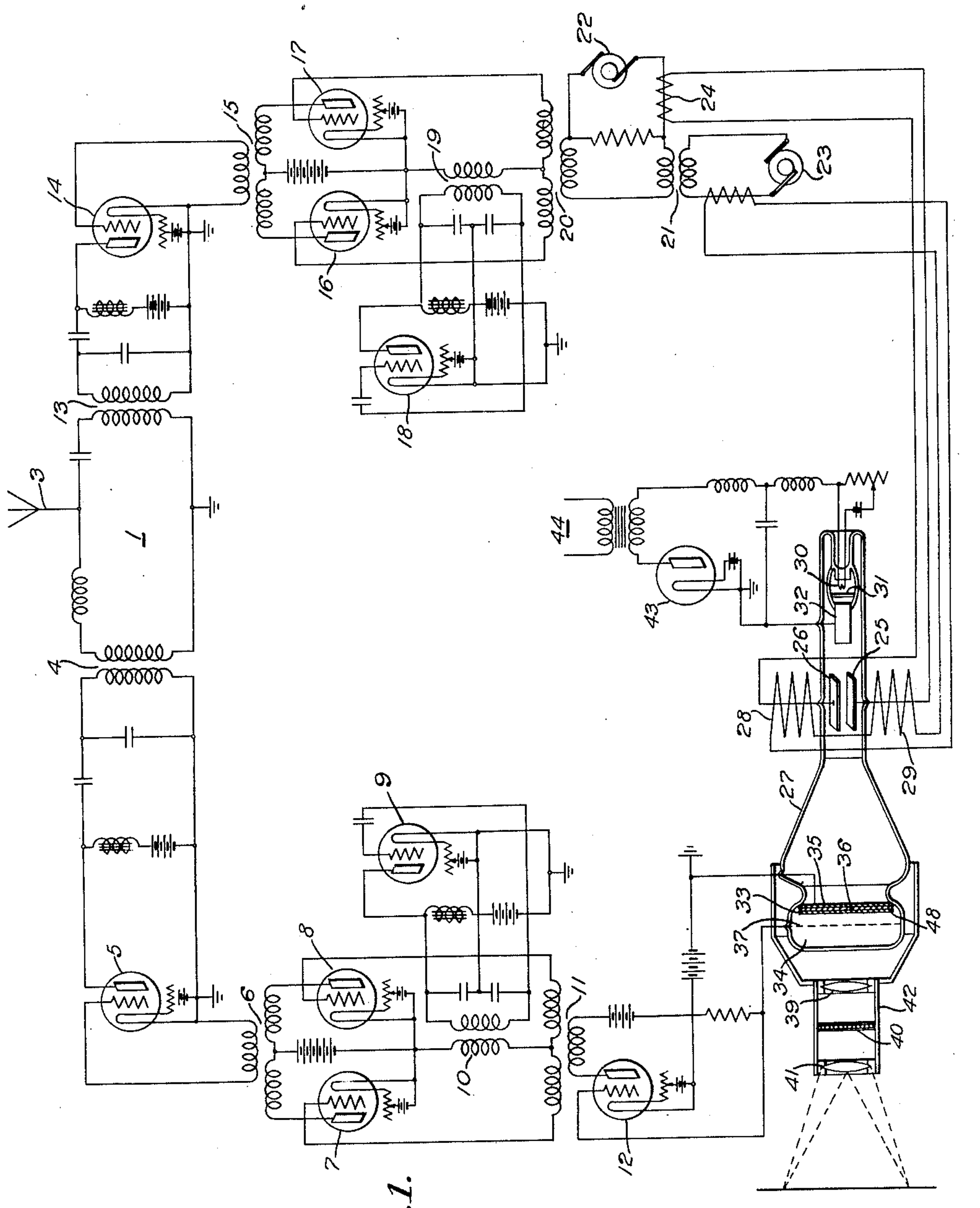

Fig. 1.

WITNESSES:

G. S. Neilson

J. E. Gardner.

INVENTOR

Vladimir K. Zworykin.

BY

Wesley G. Carr

ATTORNEY

Nov. 13, 1928. 1,691,324

V. K. ZWORYKIN

TELEVISION SYSTEM

Filed July 13, 1925 2 Sheets-Sheet 2

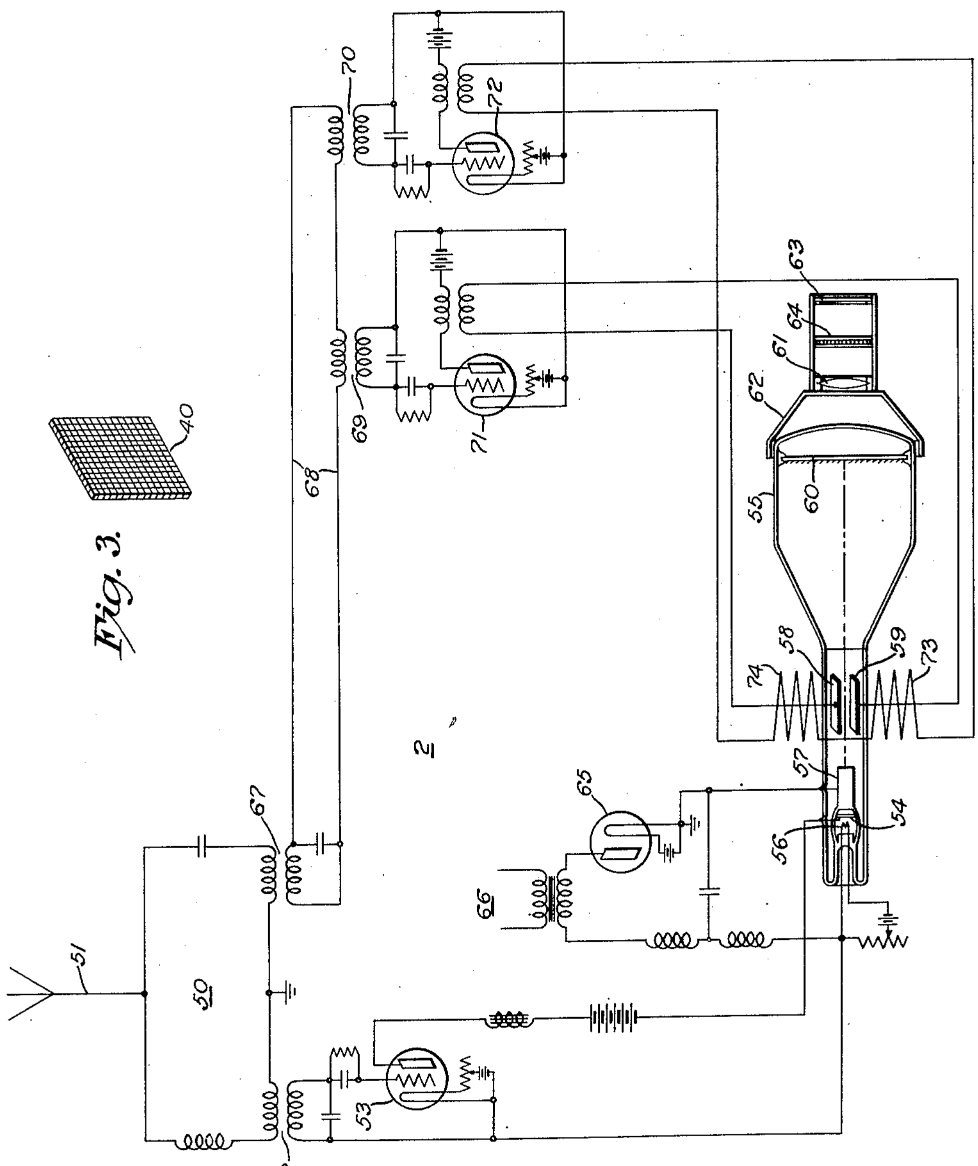

Fig. 3.

Fig. 2.

WITNESSES:

G. S. Neilson

J. E. Gardner.

INVENTOR

Vladimir K. Zworykin.

BY

Wesley G. Carr

ATTORNEY

Patented Nov. 13, 1928. 1,691,324

UNITED STATES PATENT OFFICE.

VLADIMIR K. ZWORYKIN, OF SWISSVALE, PENNSYLVANIA, ASSIGNOR TO WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY, A CORPORATION OF PENNSYLVANIA.

TELEVISION SYSTEM.

Application filed July 13, 1925. Serial No. 43,219.

My invention relates, in general, to television systems.

One of the objects of my invention is to provide an improved means for reproducing, at the receiving station, the image of the desired object in its natural colors.

Another object of my invention is to provide improved means for indicating any change in color of the object or any change in position at the receiving station.

A still further object of my invention is to provide means for securing color television with very small change from the apparatus that may be used to produce television without colors.

There are other objects of the invention which, together with the foregoing, will be described in the detailed specification that is to follow.

Referring now to the drawings, Figure 1 is a diagrammatic view of a station for broadcasting visual indications and movements of any object and may be considered the television transmitter.

Fig. 2 is a diagram of a receiving station for receiving the electrical energy from the transmitting station and translating it to reproduce an image of the desired object in its natural colors.

Fig. 3 is a view in perspective of a color screen.

The apparatus and circuits in both these stations are shown by means of the usual conventional diagrams and serve to disclose my invention in such manner that it may be readily explained and understood.

Any visual indications may be broadcasted by the transmitting set 1 consisting of apparatus and circuits and be received by the receiving set 2 consisting of circuits.

The apparatus of the transmitting set 1 comprises an antenna system 3 which is so tuned that it may oscillate at two separate and distinct frequencies. The oscillating circuit including the antenna 3 is connected on one side by means of a transformer 4 to the plate circuit of an amplifier triode 5. The grid of the amplifier 5 is connected through a transformer 6 to the plate circuits of modulator triodes 7 and 8. An oscillator triode 9 is connected through a transformer 10 to the grid circuit of the modulator triodes 7 and 8.

By means of a transformer 11, the plate circuit of an amplifier 12 is also connected to the grid circuits of the modulator triodes 7 and 8.

The oscillating circuit comprising the antenna 3 is also connected, by means of a transformer 13, to the plate circuit of an amplifier triode 14. The grid circuit of the amplifier 14 is connected, by means of a transformer 15, to the plate circuits of the modulator triodes 16 and 17. An oscillator triode 18 is connected, by means of a transformer 19, to the grid circuits of the modulator triodes 16 and 17. By means of transformers 20 and 21, alternating-current generators 22 and 23 are also connected to the grid circuits of the modulator triodes 16 and 17.

The generator 22 is so constructed as to generate alternating current of a frequency of about 1000 cycles, while the alternating-current generator 23 is adapted to generate an alternating current of a frequency at about 16 cycles.

It is, of course, obvious that triodes connected in oscillating circuits may be used in place of the alternating-current generators 22 and 23.

The plates 25 and 26 in a cathode-ray tube 27 are connected in the circuit through a series transformer 24. Coils 28 and 29 are associated with the cathode-ray tube 27 in such position that the magnetic field which may be produced by said coils is parallel to the electrostatic field which may be generated by the plates 25 and 26, and these coils are connected in circuit with the alternating-current generator 23. The cathode-ray tube 27 is similar in some respects to the ordinary Braun tube or cathode-ray oscillograph, and has a hot cathode 30, a diaphragm 31 and a tubular anode 32. The beam of the electrons passes through the hole of the diaphragm 31 and canal of the anode 32 to a plate 33 in the tube.

In place of the ordinary fluorescent screen is substituted a composite plate 33 having layers of different material. The plate 33 is placed in the glass container of the cathode-ray tube in such manner that there is a portion 34 at the end of the tube which is separated from the remaining portion. The plate 33 is constructed of a screen 35 which may be about 300 mesh, upon which is placed a thin layer of some insulating material 36, such as aluminum or magnesium oxide. Upon this is placed a layer of alkali metal 48 which may be potassium hydride, or other photoelectric material. The photoelectric material, such as potassium hydride, is evaporated on the aluminum oxide, or other insulating medium, and treated so as to form a colloidal deposit of potassium hydride consisting of minute globules. Each globule is very active photoelectrically and constitutes, to all intents and purposes, a minute individual photoelectric cell.

The cathode-ray tube 27 is filled with argon, or other inert gas, at low pressure for a purpose that will appear hereinafter.

Lenses 39 and 41 are secured in place by means of a frame 42 disposed at the end of the cathode-ray tube. A color screen 40 is placed between the lenses 41 and 39. This color screen may be of any usual type employed in photography. In the present case a three-color screen of the Paget type is employed. That is, the screen is made up of small squares of three different colors; namely, red, blue and green. This screen is shown in detail in Fig. 3. The lenses 41 and 39 serve to focus the image of the object upon the photoelectric material 48, the light passing from the color screen 40 in order that it may be analyzed, as will be described.

A grid 37 is placed at some distance in front of the composite plate 33 in the cathode-ray tube 27 and is connected to the grid of the amplifier triode 12. A high potential is applied to the anode 32 by a rectifier 43 which is supplied with current from an alternating-current source 44.

In the receiving device 2, an oscillating circuit 50, including an antenna 51, is adapted to be resonant to current of two distinct frequencies, these frequencies being the frequencies generated by the oscillating circuits that include the triodes 9 and 18 of the transmitting set. A detector triode 53 is connected to the oscillating circuit 50 directly or through the amplifier. The plate circuit of the detector triode 53 is connected to a grid 54 in a cathode-ray tube 55.

The cathode-ray tube 55 is constructed in a manner similar to the ordinary Braun tube or cathode-ray oscillograph and comprises a hot cathode 56, the grid 54, a tubular anode 57, plates 58 and 59 that are used to set up an electrostatic field and a fluorescent screen 60, and is filled with argon at low pressure for a purpose that will be hereinafter described. A lens or system of lenses 61 is placed in front of the fluorescent screen 60 and is held in position by the framework 62. At the end of the framework 62 is placed a ground glass screen 63. A color screen 64, of the same type as the color screen 40, is disposed in the frame 62 between the lens 61 and the ground glass screen 63. The lens or system of lenses 61 is adapted to focus the image of the fluorescent screen 60 upon the ground glass screen 63. The anode 57 of the cathode-ray tube 55 is supplied with high voltage by the operation of a rectifier 65, that rectifies the alternating current supplied by a source of alternating current 66.

The oscillating circuit 50 is also connected by means of a transformer 67 with a circuit 68. The circuit 68 is, in turn, connected by means of transformers 69 and 70 with the grid circuit of detector triodes 71 and 72. The plate circuit of the detector triode 71 is connected with the plates 58 and 59 of the cathode-ray tube 55, while the circuit of the detector triode 72 is connected to the coils 73 and 74 that are associated with the cathode-ray tube 55 and so disposed with respect thereto that the magnetic fields generated by the coils are parallel to the electrostatic field generated by the plates 58 and 59.

The transformer 69 is so constructed that it acts as a wave trap for the particular high frequency that is modulated by the current from the generator 22 at the transmitting station so as to eliminate this modulated frequency current from the circuit 68. In a like manner, the transformer 70 acts as a wave trap for the particular modulated current that is modulated by current of the frequency generated by the generator 23 of the transmitting station.

Having briefly described the apparatus shown in the drawings, I will now explain its detailed operation. For this purpose, it will be assumed that it is desired to broadcast the image of some object which is in front of the lens 41 associated with the transmitting cathode-ray tube 27.

Ordinarily, the oscillations generated by the oscillator 9 are not radiated by the antenna 3. This is because of the fact that these oscillations are neutralized by the action of the modulator triodes 7 and 8, and, consequently, there is no transfer of energy into the secondary of the transformer 6. The only manner in which the antenna can be set in oscillation by the operation of the triode 9 is by a change in condition in the primary of the transformer 11 which is connected to the grid 37 and to the screen 35 of the composite plate 33.

The light from the object placed before the lens 41 is so varied that, upon the focusing of this light upon the photoelectric material 48 of the composite plate 33, electron emission of varying intensity from the minute globules of photoelectric material takes place in accordance with the reflected light from the object placed before the lens 41.

However, inasmuch as the light, before reaching the photoelectric material 48, passes through the color screen 40, it is analyzed. That is, if a particular point of the object is a certain color—for example, red—only the red light will be transmitted through any of the squares of the color screen and this will be through the red square or squares in the color screen, depending upon the size of the red part of the object. All the other wave lengths or colors of the light will be absorbed. The action of the color screen is the same for blue and green lights, and other colors are analyzed and light transmitted through the various squares in accordance with primary colors combining to form the remaining colors. This follows as all the colors may be obtained by varying the combination of these three colors, and all the colors of the object will be analyzed in an obvious manner. Consequently, the image appearing upon the photoelectric material 48 is broken up into a mosaic pattern, there being light spots on the photoelectric material 48 corresponding to each square of the color screen 40 through which light is transmitted. This, as before described, is controlled by the color of the object.

Therefore, the electron emission from each minute globule of the photoelectric material 48, in addition to being controlled by the relative lights and shadows of the object, is controlled by the colors. To explain more fully, if a red spot appears on the object, light is transmitted to certain minute globules of the photoelectric material that correspond or are relatively in the same position with respect to the remaining photoelectric material as the red squares in the color screen through which light is transmitted. The same is true of any other spot on the picture.

This electron emission may be considered a species of conduction between the globules of photoelectric material 48 and the grid 37. This phenomena is intensified by the argon that fills the container 27 as a result of the ionization of the gas brought about by the electron impacts.

In view of the fact that the oxide plate 36 is an insulator, there is no conduction between the grid 37 and the screen 35, even though the photoelectric globules emit electrons. The cathode beam impinges on the composite plate 33 as soon as the filament 30 is energized. This cathode beam ionizes the argon gas through which it passes. The ionized gas then acts to confine or concentrate the cathode beam in a well known manner.

When the cathode beam strikes a particular point upon the screen, it ionizes the argon covered by the beam and this bridges the spaces between the screen and certain of its globules. As a result of this operation, through the particular point that is covered by the cathode beam, there is conduction between the aluminum plate 35 and the grid 37, the small globules of photoelectric material acting as individual photoelectric cells. The current flowing in the circuit, from the grid 37 to the plate 35, is amplified by means of the amplifier triode 12. The output of the amplifier 12 now causes the modulator triodes 7 and 8 to transmit, through the transformer 6, the high-frequency oscillations, generated by the oscillator triode 9, modulated in accordance with the current in the amplifier triode 12 which, in turn, is governed by the intensity and color of the light focused upon the particular spot at which the cathode ray is located. The intensity of this electron stream is, of course, governed by the intensity and color of the light reflected from the object.

The intensity of the light from the object is, in turn, governed on any particular point by the color of the light reflected from the object. That is, if red rays of a certain intensity dominate, there will be an electron flow at this point proportional to the amount of red rays. In the event that the beam is covering a portion of the cathode-ray stream corresponding to one of the other small squares of the screen—for example, a blue one—the intensity of the electron emission is governed by the amount of blue light transmitted by the color screen which is controlled by the amount of blue light reflected from the corresponding surface of the object.

As previously mentioned, the alternating-current generators 22 and 23 are producing alternating current of a high and low frequency, respectively. By the operation of the modulator triodes 16 and 17, the oscillations produced by the oscillator triode 18 are modulated in accordance with both the frequency of the alternating-current generated by the generator 22 and the alternating current generated by the generator 23. This modulated high-frequency current is amplified by the amplifier triode 14 and radiated by the antenna 3.

As the output of the alternating-current generator 22 is also connected to the plates 25 and 26 in the cathode-ray tube 27, an electrostatic field is set up by these plates which varies in accordance with the frequency of the current generated by the generator 22. As this electrostatic field varies, the electrostatic action upon the electron beam causes it to be swung from one side of the composite plate 33 to the other.

A portion of the alternating current generated by the generator 23 also traverses the coils 28 and 29 which, as before mentioned, are so positioned with respect to the cathode-ray tube 27 that the magnetic field generated by these coils is parallel to the electrostatic field generated by plates 25 and 26. The varying magnetic field set up by these coils tends to cause the cathode-ray beam to traverse the plate 33 in a direction at right angles to that before described.

The resultant action between the magnetic fields and the electrostatic fields upon the cathode beam is such that the beam covers every point in the whole area of the composite plate 33 in $\frac{1}{32}$ of a second, that is, in $\frac{1}{2}$ cycle of the frequency generated by the alternating-current generator 23. Thus, in $\frac{1}{16}$

of a second, the cathode beam traverses the surface of the composite plate twice.

As the cathode beam traverses the surface of the composite plate 33 point by point in a definite sequence, there is a current flowing from the grid 37 and the aluminum foil 35 at each particular point, and this current is directly proportional to the intensity of light of a particular frequency from the object to be observed. Thus, the oscillatory current generated by the oscillator triode 9 is modulated in accordance with the intensity and color of light from each portion of the image.

At the receiving station, the modulated oscillatory currents generated by the oscillator 9 of the transmitter are received by the antenna 51 and transferred to the detector triode 53 through the transformer 52. The detector triode 53 then operates to detect the modulations and then these are transferred through its plate circuit to the grid 54 of the cathode-ray tube 55.

By means of the transformer 67, associated with the oscillatory circuit 50, the modulated radio-frequency current generated by oscillator 18 is received and transferred by transformers 69 and 70 to the detector triodes 71 and 72. By the operation of the transformer 69, only the radio frequency that is modulated by the frequency of the current generated by the generator 22, is detected. In a like manner, by the operation of the transformer 70, only the radio frequency modulated by the frequency of the current generated by the generator 23 is received by the detector triode 72.

As the plate circuit of the detector triode 71 is connected to the plates 58 and 59 in the cathode-ray oscillograph 55, an electrostatic field is set up by these plates which varies in identically the same manner as the electrostatic field generated by the plates 25 and 26 in the transmitting cathode-ray tube. Likewise, the plate circuit of the triode 72 is connected to the coils 73 and 74 which generate a magnetic field parallel to the electrostatic field generated by the plates 58 and 59 and that varies in exactly the same manner as the magnetic field set up by the coils 28 and 29 at the transmitting station. Thus, when the cathode-ray beam passes through the gird 54 and the anode 57 to the fluorescent screen 60, it is caused to traverse a path in accordance with the resultant magnetic and electrostatic fields set up. Therefore, the cathode-ray beam traverses the whole area of the fluorescent screen once in $\frac{1}{32}$ of a second, or twice in $\frac{1}{16}$ of a second, in the same manner as the cathode beam in the cathode-ray tube 27 at the transmitting station. This cathode beam is focused quite sharply by the action of the ionized argon gas in a manner similar to that before described.

When the cathode beam in the cathode-ray tube of the transmitter is in a certain particular position, the oscillatory current generated by the oscillator 9 is modulated in accordance with the intensity of the light of a definite color falling upon that particular point. This modulated current is radiated by the antenna 3 and received by the antenna 51 at the receiving station. At this particular point, the cathode beam in the cathode-ray tube 55 will be in the same relative position as the cathode beam at the sending station. By the action of the grid 54, the intensity of the cathode ray reaching the fluorescent screen at this particular point is varied in accordance with the intensity and color of the light reflected from the object at the transmitting station.

Thus, for every particular point on the image, the carrier current radiated by the antenna 3 is modulated whereby the potential on the grid 54 of the receiving cathode-ray tube 55 is varied, as is, also, the intensity of the fluorescence of the particular point upon the fluorescent screen 50.

As the color screen 64 is placed in front of the fluorescent screen 60, the varying intensities of the light given off by the fluorescent screen from any particular point will pass through the color screen at a definite point. If the color of the particular square in the color screen is the same color as the square of the color screen 40 that is controlling the intensity of the light modulation of the carrier wave, the same color will be produced in the same relative position upon the ground glass screen 63. The color screen at the receiving station 64 may be placed in the proper position by throwing a beam of monochromatic light, such as red, upon the lens 41 at the transmitting station.

When the red light is analyzed by the color screen 40, there will be light transmitted only to those crystals constituting portions of the photoelectric material 48 that correspond to the red squares comprising the color screen. Consequently, only these photoelectric cells, considering each crystal as a cell, will be active to emit electrons. The fluorescent screen 60 in the cathode-ray tube 55 in the receiving station corresponding to the illuminated spots of the photoelectric material at the transmitting station will only be illuminated. Consequently, it is only necessary to adjust the color screen 64 so that red light only appears upon the ground glass screen 63. When this adjustment is made, the color screen 64 is in the proper position to reproduce the various colors of any object that it is desired to place before the transmitter at the sending station.

Returning now to the operation of the system that was being described, as the whole area of the composite plate 33 at the transmitting station and the fluorescent screen 60 at the receiving station is covered by the cathode beams in $\frac{1}{32}$ of a second, the colored image of the object will be displayed on the ground glass screen 63 during $\frac{1}{32}$ of a second. However, as the frequency of the oscillation of the generator 23 is 16 cycles per second, the picture will be transmitted twice and will remain on the screen 60 during $\frac{1}{16}$ of a second. Thus, due to the persistency of vision phenomena, any movement or change in color of the object before the lens 41 will be properly transmitted and recorded upon the fluorescent screen 60 and will appear thereupon as a moving image.

It will be obvious, of course, that it is necessary to have the fluorescent screen 60 composed of fluorescent material that will give off white light or, at least, light comprising the three primary colors red, blue and green. There are certain zinc sulphides, that, when subject to bombardment by the cathode ray, give off white light. If the screen is made up of a combination of several elements, a mixture of the three primary colors may be obtained. For example, cæsium, when subjected to cathode rays, gives off a red fluorescence, barium a blue fluorescence and zinc sulphide gives off a green fluorescence. Consequently, by composing the screen 60 of these materials, color television may be secured.

Of course, in place of transmitting the image of actual objects, it is entirely possible to send moving pictures, as all that is necessary is to pass the pictures before the lens 41 at the required rate of speed and a replica of them will appear on the screen 60. In order to place these pictures before a large audience, it is, of course, possible to intensify and focus them upon an ordinary screen by means of any well-known optical system.

My invention is not limited to the particular arrangement of the apparatus described, but may be variously modified without departing from the spirit and scope of my invention.

I claim as my invention:

1. In a television system, comprising a television transmitter, a television receiver and an object at the transmitter, means including said transmitter and receiver for reproducing an image of the object, a light filter associated with both the transmitter and receiver, means controlled by the filters for causing the reproduced image to appear in the colors of the object, a source of monochromatic light of a definite color, and means including the light for enabling the light filter at the receiving station to be properly adjusted to control the reproduction of the image in the desired colors.

2. In a television system, the combination with a transmitting station including a cathode-ray oscillograph in which the position of the cathode-ray at any moment determined the point of the view to be transmitted at that moment, a receiving station including a cathode-ray oscillograph in which the position of the cathode-ray at any moment determines the point of the reproduction of the view to be received at that moment, means for imparting to each point of the reproduction a color corresponding to the color of the corresponding point of the view to be transmitted, said means including corresponding color screens correspondingly located at the respective oscillographs and operatively associated therewith.

3. In a television system, the combination with a transmitting and a receiving station, of a cathode-ray oscillograph at said transmitting station, a cathode-ray oscillograph at said receiving station, two sources of high-frequency current at said transmitting station, detecting devices at said receiving station, an object at said transmitting station, means for modulating said second source of high-frequency current at two different frequencies, means controlled by said current of two frequencies for moving said cathode ray at said transmitting station, means including said detecting device at said receiving station for moving the cathode ray thereat, means controlled by the cathode ray at said transmitting station for modulating said first high-frequency current in accordance with the intensity and color of light at various portions of the object, and means at the receiving station for causing said cathode ray to reproduce an image of said object in its original colors.

4. In a television system, the combination with a transmitting and a receiving station, of a cathode-ray generator at each of said stations, means at each station for forming the cathode rays generated into a beam, two generators of high-frequency alternating current at said transmitting station, means including the current from one of said generators for causing said beams to move synchronously over said screens, and means located partly at one station and partly at the other and co-operating with the current from the other of said generators for causing one of said beams to impress upon said current a representation of the color and intensity of the light from that portion of the object corresponding to the position of the beams and causing the other of said beams to reproduce an image of said object in original colors.

5. In a television system, the combination with a transmitting and a receiving station, of a cathode-ray generator at each of said stations, means at each station for forming said cathode rays generated into a beam, a screen at each station, an object at the transmitting station, means for moving said beams over the surfaces of said screens synchronously, means for focusing an image of said object on said screen at said transmitting station, and means

cooperating with said cathode beams for obtaining by the agency of the beam at the transmitting station an energy representation of the brightness and color of that portion of the object corresponding to the position of the beams and for reproducing by the agency of the other beam the various points of the image of the object on said transmission screen within such time as to make the various points form an image on the eye in the original colors of the object.

In testimony whereof, I have hereunto subscribed my name this first day of July, 1925.

VLADIMIR K. ZWORYKIN.