

June 11, 1940.

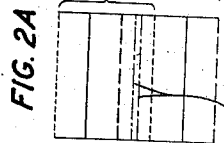
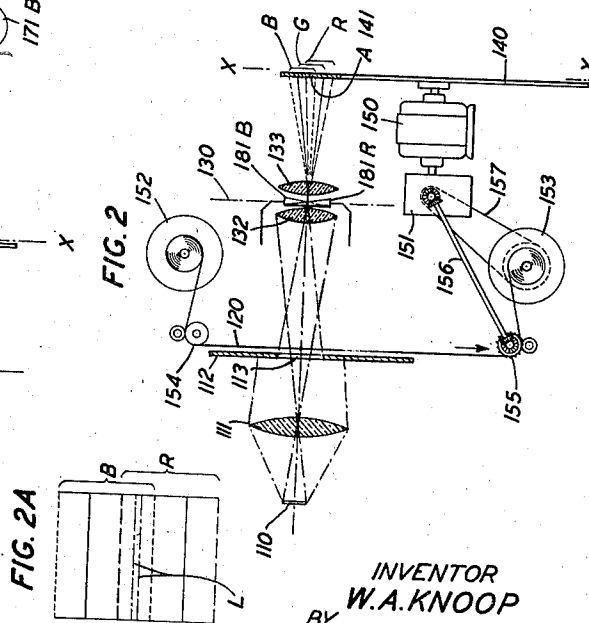
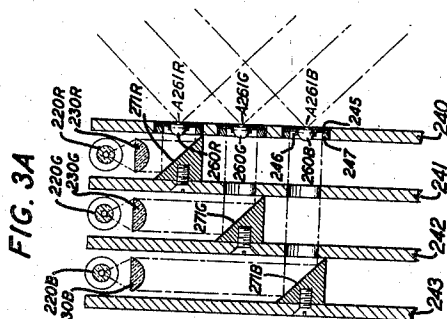
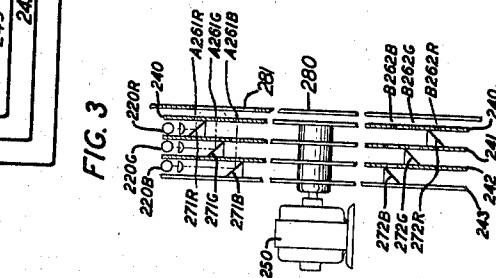
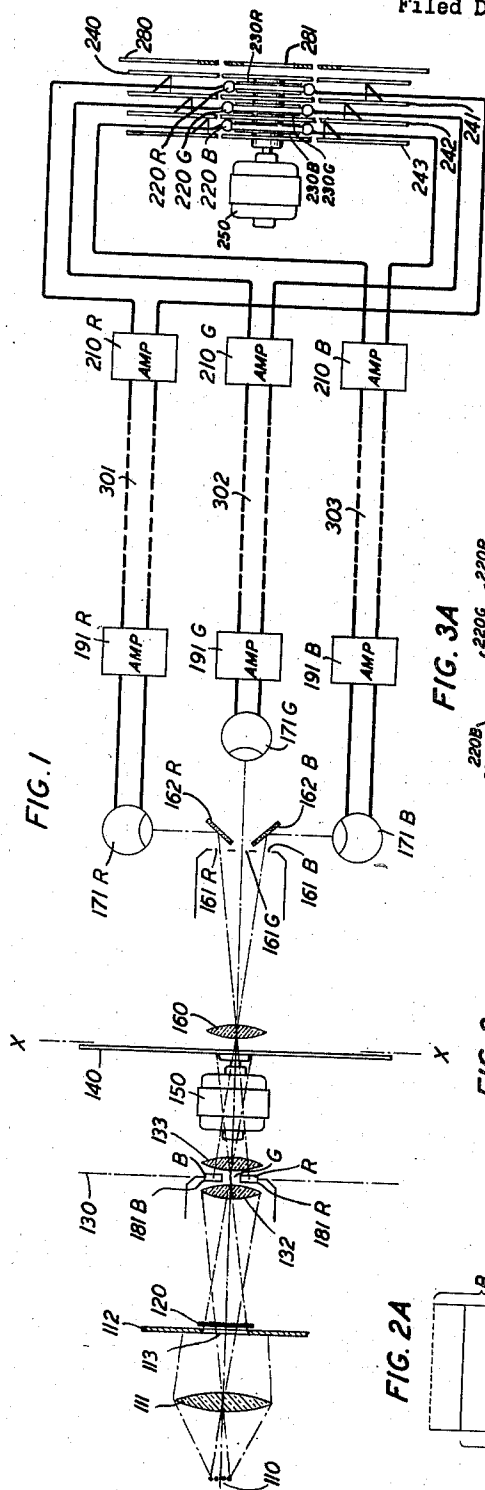
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2,203,870

MULTIPLE CHANNEL ELECTRO-OPTICAL SYSTEM

Filed Dec. 24, 1936

2 Sheets-Sheet 1



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MULTIPLE CHANNEL ELECTRO-OPTICAL SYSTEM

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2 Sheets-Sheet 2

FIG. 4

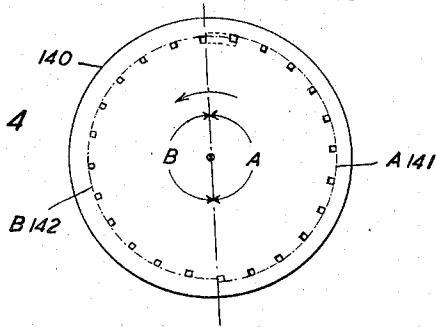


FIG. 5

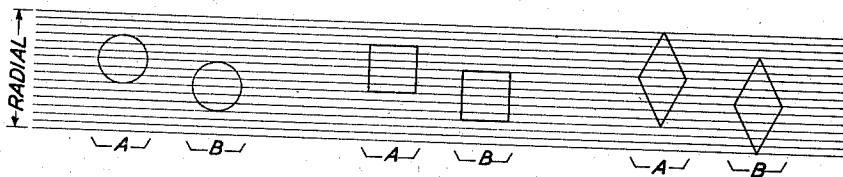


FIG. 6

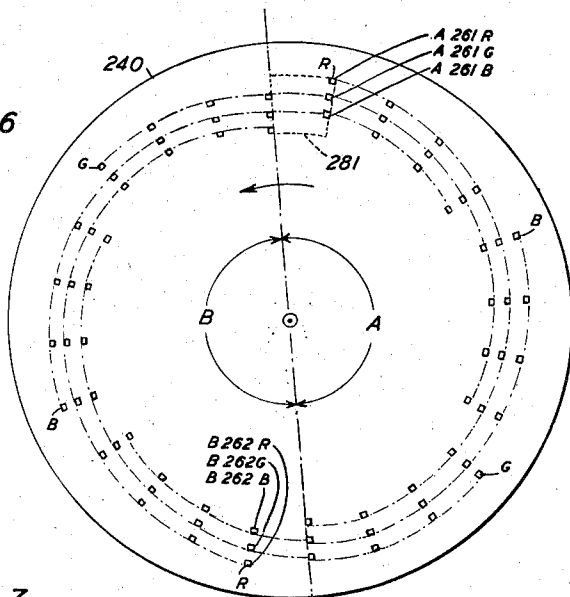
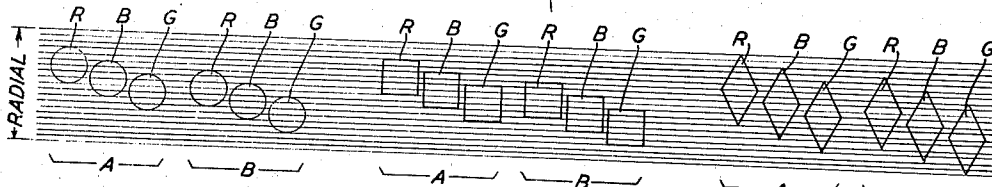


FIG. 7



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2,203,870

MULTIPLE CHANNEL ELECTRO-OPTICAL
SYSTEM

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8 Claims. (Cl. 178—5.2)

This invention relates to electro-optical systems for the transmission and production of images preferably in their natural colors and more particularly to a method and means for reducing extraneous patterns in the image field due to scanning strip-by-strip.

An object of this invention is to provide an improved television image producing system employing overlapping lines.

Another object is to increase the flicker frequency of the formed image above that annoying to the observer without increasing the picture or image frequency.

Another object is to increase at the receiver the number of lines across the field of view over that of the definition or fundamental number of scanning lines by a multiplier equal to the number of primary colors, by optically superimposing the primary color image fields with the respective scanning lines of each proportionately displaced and overlapping a fraction of the width of a scanning line, in combination with the staggering of the scanning lines of alternate scanning cycles.

A further object of this invention is the provision of means for scanning "Kodacolor" film so that the resultant color component signals, employed at the receiver to produce an image in color, have a substantial reduction in transmission band width as compared to that for the usual monochrome pictures of the same fineness of structure.

A feature of this invention is the simultaneous production of a plurality of photoelectric signal currents for the respective images of each primary color component of the object or picture whose image is to be transmitted by means of a single scanning aperture operating at each instant in the scanning plane and causing a multiple production of signal currents which may be readily adapted at the receiver to simultaneously superimpose a corresponding plurality of images with the respective scanning lines concurrently produced displaced by a desired amount, particularly by an amount to cause a separation of the lines simultaneously being scanned substantially equal to the height of the field of view divided by the number of images being simultaneously formed and plus or minus a fraction of the width of a scanning line to cause an overlapping of the lines. The scanning for each color component is preferably such that the scanning covers the entire image field.

Electro-optically produced images formed by scanning juxtapositioned lines of a field of view may be given an improved appearance either by

increasing the resolution by the simple method of increasing the number of fundamental scanning lines; or by increasing the picture flicker frequency up to a point where the persistence of vision holds the image in the eye with practically no fading, without increasing the resolution by the first-mentioned method. Flicker frequencies of the order of 35 flashes per second with moderate intensity of illumination, and 48 flashes per second with higher values of illumination, are sufficient and going higher is of no avail as the eye does not consciously detect flicker beyond this range. The latter plan while theoretically perhaps not as desirable as the former has the practical advantage of requiring a lower total frequency band for transmission, since the signal frequency increases as the square of the number of scanning lines in the former plan and at approximately one-half to two-thirds this rate in the latter plan where the fundamental number of scanning lines is kept relatively low and the appearance of the produced image is equally good in both cases. This invention is directed to the latter arrangement.

In the specific system of three-color television herein disclosed by way of example the three color components of a 48 line field are each optically superimposed with a relative displacement of a proportionate fraction of a scanning line to produce 144 lines and by stagger scanning this is doubled to 288 lines. And further, by displacing the image fields of the three color components substantially 120 degrees the flicker frequency is trebled, which with a picture frame scanning rate of 16 frames per second will cause a flicker frequency of 48 flashes per second, which is ordinarily practically unobservable to the eye. Forty-eight flashes per second is the frequency of good commercial projection of motion pictures wherein 24 picture frames are projected per second and each is exposed two times per frame by the operation of the shutter.

In electro-optical transmission, the transmission frequency band width in the above example of 48 fundamental picture lines for the three color components, each scanned at the rate of 16 per second and with a flicker frequency of 48 flashes per second, the total transmission frequency band equals

$$\frac{48^2 \times 16 \times 3}{2}$$

or 55,296 cycles per second. With ordinary monochrome scanning, this rate of 16 frames per second is too low because the flicker becomes objec-

tionable. Even taking the motion picture rate of 24 frames per second, scanned two times per exposure by the ordinary scanning arrangement, the flicker frequency is 24×2 or 48 flashes per second and the total transmission frequency is

$$\frac{48^2 \times 24 \times 2}{2}$$

or 55,296 cycles per second, but although the flicker frequency is maintained the same, the quality of the produced image becomes greatly impaired by reducing the apparent line structure to 48 lines, or at most to 96 if stagger scanning is employed, as compared to 288 lines. However, a flicker frequency of 48 is appreciably higher than needed and if the fundamental picture scanning rate is reduced to 12 frames per second the flicker frequency is 36 flashes per second and the total transmission frequency band is reduced to

$$\frac{48^2 \times 12 \times 3}{2}$$

or 41,472 cycles per second, and still the produced image is found to be of good quality. Thus, this invention is economical in its transmission frequency band width requirements especially as it provides images in color.

In accordance with a preferred embodiment of the invention, scanning means for generating the photoelectric signal currents for each of the primary color components are provided comprising a scanning member such as a disc having two sets of similarly arranged apertures, each set successively operating through a complete scanning cycle, and with the respective apertures of the two sets radially displaced by one-half the width of a scanning line and each set successively angularly positioned 180 degrees around the scanning disc. The two sets of apertures thus arranged shift the fundamental scanning lines of alternate scanning cycles by one-half the width of a line and thus double the apparent number of scanning lines with a consequent reduction of the appearance of line structure. The preferred arrangement is such that the disc scans moving images produced from a continuously moving Kodacolor film, one frame of the film passing the field of view as each set of apertures passes through its scanning cycle. With continuous uniform movement of the film, the scanning apertures are circularly arranged. While the scanning lines for a single frame are not staggered by the apertures in the scanning disc, the scanning lines of alternate frames are staggered with respect to each other by one-half a line width. A further shifting or staggering of the scanning lines as heretofore mentioned is brought about by the optical system. This second relative shifting is between the different respective primary color component images and is in addition to the first.

The respective color component images formed at the transmitter in the scanning plane from the Kodacolor film, comprise the color components preferably of the three primary color images, respectively. The scanning path is transverse to the lenticular structure and to the longitudinal movement of the film. The lenticular structure of the Kodacolor film directs the light from the color records to respective portions of the projection lens corresponding to the three primary color components. It is, therefore, possible to optically separately channelize the light rays which form the color component images, and cause the concurrent energization

of three separate photoelectric cells, each arranged or positioned to pick up the light of a single color component channel. With the arrangement so far described, the staggering or shifting of the scanning lines is effected entirely by the physical position or relative displacement of the two sets of scanning apertures in the transmitter scanning disc. The second or optically produced stagger is brought about by optically relatively shifting by a proportionate fraction of a scanning line or multiple thereof the three images formed from the respective primary color components. This is accomplished by positioning two optical deviating elements such as prisms in the light path, in the position of the usual color filters, between the Kodacolor film and the scanning disc in two of the color component channels or paths. The third color component light path need not be deviated. One prism causes a shift, say, of the blue light image components one-third the length of a projected picture frame less one-third the width of a scanning line in the direction of the movement of the image of the Kodacolor film in the scanning plane while the other prism causes a shift, say, of the red light image components, one-third the length of a projected picture frame plus two-thirds the width of a scanning line in the direction opposite to the movement of the image of the Kodacolor film, while the green light image components are not shifted. This results in causing a relative displacement of the red, green, and blue images formed upon the scanning field of the scanning disc by approximately one-third the longitudinal length of the projected picture frame and makes the total projected area of the several images longitudinally occupy approximately one and two-thirds the longitudinal length of a projected frame with the center third of the projected area superimposed by approximately one-third of each frame. It is, of course, this center third that the scanning apertures successively pass in scanning so that the effective scanning aperture at any instant passes color components for each of the primary colors simultaneously. This displacing of the three respective primary color images by approximately one-third the frame length causes an image scanning phase displacement of approximately 120 degrees. Other relative image displacements would cause scanning phase displacements of different amounts, for example, a displacement of one-sixth the length of a frame would cause a scanning phase displacement of 60 degrees. The amount of the displacement desired in forming the superimposed component images at the receiver. If two color component transmission were employed, the simplest proportional displacement would be of the order of approximately half the longitudinal length of a frame and the components would have a phase displacement of approximately 180 degrees. This arrangement makes the transmitting scanning system extremely simple and the use of Kodacolor film for the electro-optical transmission of pictures or images in natural color even more simple than the usual color processes of generating the several color component signal currents by the use of plain film or even the direct viewing of an object whose image is to be electro-optically produced in natural colors.

The receiver may employ a scanning disc having three spirals of apertures extending 360 degrees which are angularly displaced with respect

to each other approximately 120 degrees and have the radial position of the respective apertures of each set so positioned that the scanning lines of each set proportionately overlap, each set scanning the entire field of view for the color components of one of the respective primary colors. The scanning lines are shifted, as already stated, in alternate scanning cycles by one-half the width of the scanning lines so as to further reduce the appearance of line structure in the formed image. The shifting may be brought about by optical means such as a refracting element positioned in the scanning path which is moved at the end of each revolution of the scanning disc in a manner to cause alternate back and forth shifts of the scanning beam by half the width of a scanning line. This alternate shift between scanning cycles causing a stagger of the scanning lines may also be very simply achieved by arranging two groups of spirally positioned apertures in opposite halves of a scanning disc so that the apertures in one half of the disc cause three complete scanings of the field of view comprising one scanning for each of the three primary color components during one-half a revolution of the scanning disc, and during the other half revolution of the scanning disc the apertures in the second half of the disc also causes one complete scanning for each of the three primary color components, but with the scanning lines of the alternate scanning cycles relatively staggered to cause a 50 per cent overlap of the scanning lines. The corresponding apertures in the two halves of the scanning disc have a relative radial displacement equal to one-half the width of a scanning line, but may have similar respective angular positions. In each scanning disc arrangement whether with the first mentioned arrangement where the disc makes one revolution per scanning cycle and employs the optical means for causing the stagger of the scanning lines of alternate scanning cycles, or in the second arrangement where the stagger is produced by the mechanical positioning of the two groups of apertures in the scanning disc, the resulting scanning is the same. The latter arrangement is illustrated in the drawing and subsequently described more in detail. While the disc in the preferred arrangement is twice the diameter of the disc having one group of three spirals, it is rotated at one-half the angular speed of the smaller disc.

Three different primary color component light sources are associated with the scanning disc at the receiver, one with each plurality of scanning apertures representative of the different respective primary colors. The three color component light sources may be either stationary and have their light directed by optical means to their respective scanning apertures or, the different primary color light sources may be attached to the scanning disc directly in alignment with the proper apertures. The reduction of line structure in the production of the formed image, as already pointed out, is an important feature of this invention and the fact that the field of view at the receiver is scanned simultaneously for three overlapping lines representative of each of the primary color components in each scanning cycle and that these lines are relatively shifted in each alternate scanning cycle produces an unusually fine line structure in the formed image. In comparison with an ordinary monochrome image without any line stagger, it is obvious

from the foregoing that this arrangement has a line structure six times as fine due to the fact that each scanning path is made up of proportionately overlapping components of the three primary colors and they are shifted between alternate scanning cycles by one-half their width. The scanning arrangement at the receiver must, of course, match that at the transmitter. For example, with each of the three color components comprising forty-eight overlapping lines, the apparent structure is three times 48 or 144 for a single scanning cycle and with the alternate shift, two times 144 or 288 as heretofore stated in the general description of the scanning arrangement.

A softening of the scanning line structure by chromatic dispersion may be substituted for the slight shifting of the three lines of the three color components. This may be effected by a prism positioned with its base parallel to the direction of scanning in front of the field of view.

A more detailed description of an embodiment chosen for illustrating this invention follows:

Fig. 1 is a schematic plan view, partly in cross-section, of the transmitting scanning arrangement comprising a source of light, a Kodacolor film, a scanning disc, light sensitive cells and an optical system employed therewith, for simultaneously generating a plurality of photoelectric currents; and the receiving scanning arrangement comprising a plurality of sources of light which vary in intensity in accordance with received signal currents, a scanning disc member and an optical system employed therewith, for producing images.

Fig. 2 is a side elevation view, partly in cross-section, of that portion of the transmitting apparatus of Fig. 1 at the left of plane $x-x$, showing more particularly the film moving arrangement and the refracting elements or prisms in the optical system for effecting image displacement in a vertical direction.

Fig. 2A is a diagram showing the relative positions of the red, green and blue images as projected in the scanning plane at the transmitter.

Fig. 3 is a side elevation view with parts broken away of the receiving apparatus of Fig. 1 showing more particularly the optical arrangement.

Fig. 3A is a vertical cross-section of a portion of the scanning disc assembly and the associated optical elements of the receiving apparatus.

Fig. 4 is a face view of a transmitting scanning disc for use with continuously moving film showing the relative arrangement of two groups of circularly arranged scanning apertures.

Fig. 5 is a diagram showing the overlapping scanning paths of the two groups of scanning apertures in the transmitting scanning disc particularly illustrating the positioning of different shaped apertures such as round, square, and diamond-shaped apertures.

Fig. 6 is a face view of a receiving scanning disc showing the relative arrangement of two groups of spirally arranged scanning apertures as used for producing images.

Fig. 7 is a diagram showing the overlapping scanning paths of different apertures in the receiving scanning disc, particularly illustrating the positioning of different shaped apertures such as round, square, and diamond-shaped apertures.

Similar reference characters on the different drawing figures refer to similar parts.

Fig. 1 shows a schematic plan view, partly in cross-section, of the transmitting scanning arrangement comprising a source of light, a Kodacolor film, a scanning disc, light sensitive cells,

and an optical system employed therewith for simultaneously generating a plurality of photoelectric currents, and the receiving scanning arrangement comprising a plurality of sources of light which vary in intensity in accordance with received signal currents, a scanning disc member, and an optical system employed therewith for producing images. At the transmitter a finished motion picture film of the object whose image is to be transmitted, which may be produced by the Kodacolor process or a film of similar type, namely, a film provided on one surface with a continuous series of longitudinal lenticular element, and, on its other surface with a photographic emulsion which has been exposed through a suitable lens system having associated therewith a three-color filter and afterwards developed in accordance with established methods. The image on the film appears as black and white but comprises a triple linear mosaic produced by the lenticular ridges on the film. A source of light has its rays directed by the condenser lens system to the Kodacolor film which moves at a uniform rate past the aperture in the opaque plate. This aperture subtends one picture frame of the film and the opaque plate shields the film from superfluous light. The illuminating light after passing through the Kodacolor film comprises three parts corresponding to the respective colors of the filter through which the record on the film was made. The light next passes through the lens system and to the scanning disc. The film record of the three component images is accurately focussed in the plane of the scanning disc by this lens system. These images are formed in black and white. The lens system beyond the scanning disc produces in the apertures the image of the zones B, G and R in plane. The light passing through these zones in plane contains respectively the color components of the blue, green and red of the images on the film. By thus imaging them the color components are again separated after scanning. The lens system acts as a lens in the regular projector and the light after passing through the three apertures is directed into the respective photoelectric cells by the assistance in two of the channels of the mirrors and. The light sensitive cells are all similar and obviously no color filters are employed at the transmitter. Color is used only at the receiver where the respective signal currents are used for producing images of the original object or scene in natural colors. Even color might be omitted at the receiver and the image produced in black and white tones. As the film preferably moves continuously at a uniform rate, the scanning apertures in the scanning disc are circularly positioned as shown in detail in Fig. 4. As already explained preferably two groups of apertures A and B are employed each occupying successive circular angular spaces of 180 degrees and the two groups A and B are offset radially by one-half the width of scanning line in order to produce a stagger of the scanning lines in alternate scanning cycles. In the arrangement here shown the scanning disc and the film are spaced some distance from each other as this is preferable both optically and mechanically and more particularly when Kodacolor film is used as it affords space for properly positioning the elements and for optical focussing. A modified and alternative arrangement may be employed in which the film and scanning disc are adjacent

to one another but this is undesirable mechanically, particularly since it would be necessary for them to be practically in contact. The preferred optical arrangement shown is similar to that used in regular projectors for Kodacolor film wherein the set of red, green and blue filters are positioned in front of the lens and the image screen is positioned beyond at a suitable distance. In this scanning system at the transmitter both the filters and the screen are omitted and in their place are positioned two prisms in the zones of the red and blue components in the "filter plane" in front of the lens, and the scanning disc takes the place of the screen. In a color projecting system the green filter would ordinarily be positioned in the zones between the red and the blue filters. In this arrangement the prism is shown positioned to deflect or refract the red color components of the image downwardly and the prism to deflect or refract the blue components upwardly while the green components are allowed to pass directly without change of direction between these two prisms. With this arrangement the color components of the red, green and blue images are relatively displaced vertically on the scanning disc. This displacement is preferably equal to approximately one-third the longitudinal dimension of a picture, the exact displacement in the illustrated embodiment being such that the blue image B is displaced upwardly from the green image G one-third the longitudinal dimension of a picture less one-third of a line while the red image R is displaced downwardly from the green image G one-third the longitudinal dimension of a picture plus two-thirds of a line. The scanning discs Figs. 4 and 6, which will be described later, are shown for scanning a twelve line picture since for a small number of lines the scanning arrangement may be more clearly illustrated in the drawings. In a twelve line picture the blue image B is displaced upwardly with respect to the undeviated green image G by three and two-third lines and the red image R is depressed four and two-third lines. These fractions result from the design of the receiving disc, and other arrangement of the receiving spirals will result in a different arrangement at the transmitter. A large number of combinations are possible all within the scope of this invention. In this way one scanning aperture at each instant is caused to scan three different parts of the picture simultaneously. If, at a particular instant, the disc is scanning in the center third of the screen image, it is also scanning in the top third of the red image and in the bottom third of the blue image. The respective photoelectric currents are strictly proportional to the intensity of light reaching their respective photoelectric cells. The three image currents corresponding to a given white portion of the image will be identical in form and amplitude but will be displaced in time by substantially one-third of a picture frame due to the optical displacement of the respective images in the scanning field. In fact, the signal current corresponding to the green image of a particular point lags behind the signal current corresponding to the blue image of the same point substantially 120 degrees or one-third of a picture frame or cycle. Similarly, the signal current corresponding to the red image lags behind that of the green image current by substantially 120 degrees or one-third of a picture cycle. The scanning of a picture frame during its longitudinal movement across the

scanning field is here considered as a full picture cycle of 360 degrees and it follows that one-third of a picture frame or cycle comprises 120 degrees of the picture cycle. The relative displacement longitudinally of the several images may be made any desired amount by adjusting the amount of refraction caused by the two prisms 181R and 181B. However, a substantially proportionate relative displacement is preferable but this displacement must correspond to the system employed at the receiver for producing the formed image. Three photoelectric cells 171R, 171G and 171B activated by the red, green and blue light image components respectively generate three image currents which, after amplification in amplifiers 191R, 191G and 191B, are transmitted over separate channels, 301, 302 and 303 to a receiving station. The transmission channels may be physical circuits or carrier or radio channels.

The receiving scanning arrangement comprising a plurality of sources of light which are varied in intensity in accordance with the respective received signal currents, and a scanning disc member employed therewith for producing images is schematically shown in a plan view in the right portion of Fig. 1. The several signal currents received over channels 301, 302 and 303 are regulated and amplified in amplifiers 210R, 210G and 210B, respectively, and impressed upon light sources 220R, 220G and 220B, emitting light of the proper mixing proportions of the three primary colors, respectively. Suitable color filters may be employed with the light sources. These light sources are associated with a scanning disc member 240 comprising a number of discs, the details of which will be described later, so arranged with apertures and light baffle plates that each light source at any instant is illuminating only one respective elemental area on the field of view and causing a scanning of the field in accordance with the sequence heretofore described. This scanning disc member is driven by the motor 250 operated in synchronism and in phase with the scanning disc at the transmitter by any well known means, the details of which are not here shown. An opaque apertured plate 280 having an aperture 281 defining the field of view or image area is positioned in front of the scanning disc member to prevent any light other than that passing through the active scanning apertures from being seen by observers. The arrangement and relationship of the several light sources with the scanning disc member is such that each light source preferably scans successive lines until the entire area of the field has been scanned. The scanning lines produced by the respective light sources at each instant are approximately 120 degrees apart and consequently scanning is occurring at each instant in three separated regions of the image, the respective scanings occurring in different thirds of the image field in a three channel system. Means for accomplishing this will be described more in detail in connection with Figs. 3, 3A, 6 and 7.

Fig. 2 shows a side elevation view, partly in cross-section, of that portion of the transmitting apparatus of Fig. 1 at the left of plane x—x showing more particularly the film moving arrangement and refracting elements or prisms in the optical system for effecting image displacement in a vertical or longitudinal direction. The description of Fig. 1 relating particularly to the optical system is applicable here. The motor 150 which drives the scanning disc 140

also drives the film through a film driving gear unit 151. The film 120 is carried on reels 152 and 153 and passes downwardly over rollers 154 and 155 arranged to assist in guiding and driving it at a uniform rate across the field of view. The lower roller 155 equipped with drive sprockets is connected by suitable gearing and the shaft 156 with the film driving unit 151 while the film receiving reel 153 is also connected by pulleys and a slidable belt 157 to the driving unit for winding the used film upon the receiving reel all in accordance with well-known practice. Fig. 2 particularly shows the optical action of the refracting elements or prisms 181R and 181B in relatively displacing the continuously moving image components by directing, for example, the red image light components R downwardly and the blue image light components B upwardly with respect to the green image light components G so as to cause the relative displacement of the three sets of image components on the scanning disc as already described. These refracting prisms are preferably achromatic to avoid color fringes on the deviated images although for simplicity they are shown as simple prisms in the drawings. A scanning aperture A141 is scanning an elemental area of each of the superimposed portions of the three primary color component images.

Fig. 2A shows diagrammatically the relative displacement and overlapping positions of the red, green and blue image components of a picture frame as projected on the scanning field at the scanning disc 140 at the moment when one of the images, namely, the green image, is positioned with its center in the center of the scanning field. As stated above, the relative displacement is caused by prisms 181R and 181B, and the red, green and blue image components R, G and B, are shown longitudinally or vertically positioned so that for a given picture frame the portions superimposed are approximately the top third of the red image components, the middle third of the green image components and the bottom third of the blue image components. The exact relative displacement is such that the blue image components are displaced with respect to those of the green image one-third the length of a projected picture frame less one-third the width of scanning line in the direction of the movement of the image of the Kodacolor film while the red image components are displaced with respect to those of the green image one-third the length of a projected picture frame plus two-thirds the width of a scanning line in the direction opposite to the movement of the image of the Kodacolor film. At each instant one elemental area of the image field is scanned within the zone where a portion of the three images are superimposed upon one another such as along the path or line L.

The film 120 used at the transmitter for forming images to be scanned for generating the photoelectric currents may be stationary while being scanned and intermittently advanced between scanning cycles. In such an arrangement the film driving mechanism may be modified by the use of intermittent gearing to provide the proper film movement. The optical system is also so arranged that the images formed from the film frames are projected and stationarily superimposed on the image scanning field with the proper proportionate relative displacement during the scanning cycles. The groups of scanning apertures in the scanning disc 140 are posi-

tioned in spiral arrangement in accordance with the usual practice in scanning a fixed two-dimensional image field.

Fig. 3 shows a side elevation view with parts broken away of the receiving apparatus of which a plan view is shown in Fig. 1, and more particularly shows the relationship of the light sources with the scanning disc member and means for directing the light from each light source at any instant through a respective aperture of the scanning disc passing the field of view. The scanning disc member comprises a scanning disc 240 having two groups of spirally arranged scanning apertures. Each group angularly extends 180 degrees in the preferred arrangement. The relative positioning of the several spirals is shown in Fig. 6 which is subsequently described in detail. The apertures in the disc are accurately positioned and control the movement of the scanning beams from each of the three light sources 220R, 220G and 220B, respectively. Light from the several sources is simultaneously directed in mutually exclusive channels formed in the spaces between successive pairs of discs 240, 241, 242 and 243 to prisms or mirrors 271R, 271G and 271B which change their directions approximately 90 degrees and then through the proper apertures in the scanning disc 240. The light direction changing reflectors are mounted between the several discs and rotate therewith, one such deflector being employed for each scanning aperture. The apertures A261R, A261G and A261B have associated therewith light direction changing deflecting elements 271R, 271G and 271B, respectively, while apertures B262B, B262G and B262R have associated therewith deflectors 272B, 272G and 272R, respectively. In the drawings, for clarity, only two such deflectors are shown on each of the three supporting discs. The light sources should be of sufficient length to adequately span the angular or transverse width of the field of view, but their radial dimension may be small and as here shown, they are linear light sources. The light rays are shielded and directed as shown in their proper channels by any suitable means and the image field of view is defined by the opening 281 in the stationary opaque plate 280. The light sources as here shown are stationary, but any other suitable arrangement for channelizing the light from the several sources into mutually exclusive scanning beams may be used such as are shown in the patent issued to Blackwell and Herman, No. 2,101,976, dated Dec. 14, 1937, the chief difference in this arrangement being the employment of color component sets of spirally shaped lamps in association with the proper spanning apertures in the scanning disc 240.

Fig. 3A is a vertical cross-section of a portion of the scanning disc assembly and the associated optical elements in the receiving apparatus showing more in detail the optical arrangement for directing the scanning light from the linear light sources through the scanning apertures in divergent beams so that the beams subtend in passing the field of view sufficiently wide angles to permit a number of persons to simultaneously view the produced image. This divergence of the scanning beams is obtained by associating with each aperture of the scanning disc 240 a lens which is quite large in comparison with the size of the aperture and of comparatively short focal length. The image is viewed directly at the plane of the scanning disc by positioning the

eyes of the observers within the field common to all of the cones of light passed through the scanning disc apertures within the area of the scanning field. The cross-section shown in Fig. 3A is normal to the face of and coincides with the radius of the scanning disc passing through apertures A261R, A261G, and A261B. Light controlled by the signal currents in the several channels is produced in the stationary linear light sources 220R, 220G, and 220B. These light sources are of small cross-section and of sufficient length to permit light from them to be directed through each scanning aperture as it passes across the scanning field. Stationary collimating cylindrical lenses 230R, 230G, and 230B, associated respectively with each of the stationary light sources, direct the light therefrom in substantially parallel beams onto direction changing elements 271R, 271G and 271B, respectively, which change the direction of the beams approximately 90 degrees and causes them to impinge upon lenses 260R, 260G and 260B, respectively, as their associated apertures in the scanning disc 240 pass the scanning field. The direction changing elements 271R, 271G and 271B are mounted on discs 241, 242 and 243, respectively, and rotate with the scanning disc 240. One such light direction changing element is aligned with each aperture in the scanning disc. Certain openings about the size of the lenses associated with the scanning disc apertures are formed in alignment therewith in the baffle discs 241 and 242 for the passage of light from light sources 220G and 220B to the scanning apertures in the scanning disc 240. In the forward baffle disc 241 two rows of openings are required as light from both light sources 220G and 220B must pass through it to reach the aperture in the scanning disc; while in the second baffle disc 242 only one row of such openings is required as light from only one light source 220B must pass through it. In the scanning disc the opaque material surrounding the apertures is thin so that the aperture orifices are of relatively short length. The scanning disc 240 is preferably formed with comparatively large holes at the aperture positions and an apertured member and lens assembly is placed in each hole and firmly held therein. As shown for aperture 261B this assembly consists of a cup-shaped member 245 of thin opaque material which is pressed into the above-mentioned large hole at the position of aperture 261B and accurately drilled or punched to form the aperture, and lens 260B with its holding frame 246 is inserted in cup-shaped member 245 and held by the tight-fitting holding ring 247. The ring 247 may be either pressed into place, or after being shrunk by cooling to a low temperature put in place and allowed to expand to a tight fit upon rising to normal temperature. The assemblies of apertured members and lenses are identical for each of the apertures.

Fig. 4 which is a face view of the transmitting scanning disc 140 arranged for generating photoelectric currents by scanning continuously moving film records has been described hereinbefore in detail in connection with the description relating to Fig. 1.

Fig. 5 shows diagrammatically the arrangement of the two groups A and B of scanning apertures in the transmitting scanning disc showing particularly the positioning of different shaped apertures such as round, square and diamond-shaped apertures for half-line stagger

scanning. The two groups A and B are positioned so that a relative shift of half a line, the amount stated in describing the arrangement of the apertures in the transmitting scanning disc shown in Fig. 4. The round apertures are shown as having a diameter equal to the width of a scanning line and the square apertures as having their sides also equal to the width of a scanning line. The round and square apertures are positioned so that those in the A group are radially displaced as positioned in the scanning disc with respect to those in the B group one-half the width of their scanning path, and the projected images of the film are advanced as an aperture passes across the scanning field an amount equal to the width of a scanning line. The diamond-shaped apertures may have the same area as the square apertures and are here so shown, as their longitudinal diagonal parallel with the scanning direction is equal to the length of a side of the square apertures while their radial or transverse diagonal is twice the length of a side of the square aperture. The two groups of diamond-shaped apertures are relatively displaced the same amount as the square apertures and they not only have a fifty per cent area overlap as between the A and B groups, but also the apertures of each group overlap in the scanning of their image fields. This particular dimension of the diamond-shaped apertures corresponds to that used at the receiver and will be described more in detail in describing the arrangement used at the receiver.

Fig. 6 is a face view of the receiving scanning disc 240 showing particularly the relative angular and radial positions of the scanning apertures spirally arranged in two groups A and B as used in producing images, the size of the scanning apertures being greatly exaggerated in the drawings. The scanning process as carried on at the receiver has already been described in detail. The two groups A and B of spirally positioned apertures are located in opposite halves of the scanning disc and are so positioned that the apertures in each half of the disc cause three complete scanings of the field of view, comprising one scanning for each of the three primary color components respectively during each half revolution of the scanning disc. The apertures in opposite halves of the disc cause similar scanings of the field of view but the scanning lines of the alternate scanning cycles are relatively staggered to cause a fifty per cent overlapping of the scanning lines in the alternate scanning cycles. This stagger of the scanning lines is produced by positioning the corresponding apertures in the two halves of the scanning disc with a relative radial displacement equal to one-half the width of the scanning line. This fifty per cent overlap of the scanning lines of the apertures in the two groups A and B causes a relative stagger of the scanning lines in alternate scanning cycles corresponding to the stagger of the apertures in the two groups A and B in the transmitting scanning disc 140 as shown in Fig. 4.

The layout of the apertures on the disc of Fig. 6, may be arrived at from the following considerations. First, assume that there are six identical spirals of apertures each scanning juxtapositioned lines and each beginning at the same radial distance from the center of the disc, but circumferentially displaced by 60 degrees, each spiral extending 180 degrees or half way around the disc. Assume that these spirals are numbered 1 to 6, inclusive, in a clockwise direction.

Next assume that each of the apertures of spirals 2 and 5 are moved toward the center of the disc one-third of the radial distance between adjacent apertures in any one spiral, or in other words one-third the width of a scanning line, and that each of the apertures in spirals 3 and 6 are moved toward the center of the disc two-thirds of such distance. Finally, assume that all of the apertures on that half of the disc occupied by spiral 4 are moved toward the center of the disc one-half of the radial distance between adjacent apertures in any one of the original spirals. The location of the apertures according to this final assumption is the location of the apertures shown in Fig. 6. Each group A and B may consist of one complete 180 degree spiral, namely, spirals 1 and 4, respectively, and one section of each of four other spirals which are broken as is clearly shown in Fig. 6. The portions of the four broken spirals are the equivalent of two 180 degree spirals, so that the group of apertures in each half of the disc comprises the equivalent of three complete spirals and completely scans the image field three times during each half revolution of the scanning disc. There are as many different overlapping scanning paths at the receiver as there are apertures in a full spiral multiplied by the number of such spirals; for example, taking 48 apertures in each of the six equivalent full spirals, they produce an image, in effect, scanned by 288 overlapping scanning lines for each revolution of the scanning disc. In the scanning disc 240, the A group may be considered as commencing with apertures designated A261R, A261G and A261B, which apertures are shown entering the area of the field of view 281, and the B group may be considered as commencing with apertures designated B262R, B262G and B262B. The aperture designated A261R is the first aperture in a red component spiral, the apertures designated A261G is the first aperture in the middle third of a green component spiral, and the aperture designated A261B is the first aperture in the last third of a blue component spiral of the A group of apertures. The apertures designated B262R, B262G and B262B occupy corresponding positions in the B group of apertures.

Fig. 7 diagrammatically shows the overlapping scanning paths of the different spirals of apertures in the receiving scanning disc particularly showing the positioning of the different shaped or types of apertures such as round, square and diamond-shaped. In this diagram, one corresponding aperture, R, B and G, for example the first apertures of each spiral starting in each of the A and B groups for the respective red, blue and green color components is shown for each type of aperture. As heretofore stated corresponding apertures in the different respective color component spirals in both the A and B groups are radially displaced with respect to each other in any one group one-third the width of a scanning line; and the radial distances of corresponding apertures in the two groups A and B have a difference equaling one-half the width of a scanning line. This all results in a successive overlapping of the scanning paths such that the width of a fundamental scanning path of one aperture is, in effect, divided into six proportionate paths, in each revolution of the scanning disc causing, in effect, six times as many scanning lines as there are apertures in one full spiral and thus, while employing a comparatively coarse fundamental scanning structure, the appear-

ance is that of a fine structure with a resolution or fineness of line structure equalling one-sixth that of the fundamental line scanning. The general arrangement of the apertures in the several spirals is the same whether round, square, diamond-shaped or other type of apertures are used, as will be obvious from the diagram of Fig. 7.

With the diamond-shaped apertures having the same area as the square apertures, the same amount of light passes through each. When perfectly juxtapositioned square apertures scan an illuminated field of uniform tone, no line structure can be seen but if a television picture is being received, a series of "steps" will define the edges of oblique lines. The diamond-shaped aperture has the advantage of softening these steps.

Throughout this specification, where it is stated that spirals of apertures completely scan the image field, it is to be understood, of course, that the language does not apply strictly to the edges of the field which are parallel to the scanning lines. This is obvious from Figs. 5 and 7, where the overlapping of scanning paths is illustrated.

The use of such language is justifiable, however, since it departs from strict accuracy only with respect to a negligible portion of the image field.

The electro-optical system as herein described will transmit not only from the usual Kodacolor film and produce images in color at the receiving station but it will also transmit, without change in the apparatus, Kodacolor film which has been taken without color filters in the camera and images thereof will be produced at the receiver as black and white images. The system will also transmit from ordinary film which has no lenticular ruling on the film and produce at the receiver black and white images. In each case the regular primary color light sources may be used at the receiver and where black and white images are produced the colors normally mix to produce white light of the proper tones. This property resulting from the use of ordinary plain film may be used for testing the equipment to ascertain whether the several color channels are balanced. If they are properly balanced, the produced images appear in black and white tones and, if out of balance, color distortion shows. When this test shows a proper balance of the several channels the equipment is in such adjustment that images produced in color faithfully represent the natural colors of the object whose image is produced.

In projecting Kodacolor film the lenticular structure directs the light passing through the three zones on each lenticular semi-cylinder to corresponding zones across the projection lens. These three zones correspond to the red, green and blue portions of the picture that would otherwise be gathered into a composite whole for that element or strip of picture. The components which represent these colors are registered in black and white tones in the film and if there is no lenticular structure the portions of the picture in this and any other element is projected directly through the filter plane but in this system it is there divided up into three parts. One part affects the red channel, another part the green channel and a third part the blue channel. When a black and white film is projected, it is possible to screen off by an opaque screen, any two of the areas covered by the deflecting prisms and a complete picture will appear at the scanning disc although reduced in brilliancy. When the color factor alone is eliminated and the image is

produced in black and white, this system affords all of the other advantages such as reducing the appearance of line structure and flicker while employing a relatively coarse fundamental scanning at the transmitter. However, when the color factor is included as heretofore pointed out while the structure and the flicker period are the same in either case, the addition of color causes a greater blending of the elements and a more pleasing appearance in the produced image.

What is claimed is:

1. The method of reducing in an electro-optically produced image the extraneous pattern superimposed upon the image field by the process of constructing the image strip by strip, which consists in transmitting primary color signal components of the object whose image is transmitted and producing an image thereof strip by strip, proportionately overlapping the respective color component scanning strips in each scanning cycle, and staggering the scanning strips a fraction of the width of the scanning strips in alternate scanning cycles.

2. In an electro-optical system, means for producing concurrently a plurality of complete images of the same field of view in a common plane said complete images being displaced so as to partially overlap one another, means for scanning an elemental strip across the overlapping portions of said displaced images to produce a beam of light composed of rays emanating at any one instant from an elemental area of said overlapping portions, and means for utilizing groups of rays of said beam which groups corresponding to said respective images for separately producing image currents individual to each image.

3. In combination in an electro-optical system, a Kodacolor film having transversely displaced image components formed on said film, means for illuminating said film, means for projecting images corresponding to said image components by light controlled by said film on a scanning plane, means for longitudinally relatively displacing the different images, means for simultaneously scanning different elemental areas of said images, and means for simultaneously generating photoelectric currents representative of the tone values of each of said scanings.

4. In an electro-optical system for color transmission, a source of light, an optical system for converging light from said source on a moving picture lenticular film having the color components of primary colors of images of objects or scenes, a lens system for directing the light from said film upon a scanning plane, light deflecting means positioned between said lens system and said scanning plane for shifting the light components of one of the primary color images longitudinally in one direction and the components of another primary color image longitudinally in the opposite direction with respect to said film by substantially one-third the length of the image on said film, a scanning member positioned in the scanning plane and rapidly scanning successive line areas of the said images, optical means positioned in the path of the scanning beam directing said beam in a given general direction, and separate photoelectric cells positioned in the paths or channels of the scanning beams of the three primary color components of said images formed by the said lenticular film.

5. In an electro-optical system for simultaneously producing a plurality of photoelectric signal currents representative of the color compo-

nents of the primary colors of an image, means for scanning at any instant a single elemental area of an image field said scanning being limited to a single line series of elemental areas of said field, means for simultaneously producing on said field a plurality of continuously moving primary color images on said field including means for relatively displacing said images by such an amount as to cause a separation of the lines simultaneously being scanned in the several images by an amount substantially equal to the longitudinal dimension of the field of view divided by the number of lines being simultaneously scanned plus or minus a fraction of the width of a scanning line, means for deviating the respective primary color light tone components of the image modulated scanning light into respective paths, and light sensitive elements positioned in the said respective paths for generating photoelectric signal currents of the different respective primary color tone components.

6. In an electro-optical system, means for simultaneously producing on a scanning field images comprising the respective primary color components of an object or picture, means for laterally displacing into segregated positions the said respective primary color components, means for producing a scanning phase displacement as between the light tone components of the different primary color images comprising longitudinally relatively displacing said images a given amount, an apertured scanning member scanning with a single aperture at any instant an elemental area of each primary color image projected on said field, means for continuously moving said images across the field of view in a direction transverse to the motion of the said scanning aperture, and light sensitive means positioned in the scanning paths of each of the primary color components for generating respective photoelectric signal currents thereof.

7. A television transmitter comprising an opaque plate having an aperture therein which subtends one frame of a motion picture film carrying a colored picture record formed by cylindrical lenticulation extending lengthwise of the film, a uniformly continuously moving driving mechanism moving such a film lengthwise past said aperture, a scanning disc having a half circle of apertures on one-half of said discs and another half circle of apertures on the other half of said discs, the apertures of said second half circle being located one-half the radial dimension of an aperture nearer to the center of rotation of said disc than the apertures of said first half circle, driving mechanism rotating said disc in a plane parallel to said opaque plate and film at a speed of one-half revolution during the time that one frame of said film moves past a given point of said aperture in said opaque plate, a projection

lens located between said opaque plate and said scanning disc having its conjugate foci at said film and said disc respectively and forming an image of said film on said disc, the line structure of said image due to the lenticulations on said film being at right angles to the paths of the scanning apertures across said image, a source of light, a condensing lens directing light from said source through said film to said projection lens substantially uniformly illuminating that portion of the film which is opposite the aperture in said opaque plate, a first prism deviating the light rays passing through one transverse zone of said projection lens to move the image formed by said rays on the scanning disc approximately one-third the dimension of the image on the disc from the position where it would have been formed if the rays had not been deviated and in a direction parallel to the axes of the cylindrical lenticulations on said film, a second prism deviating light rays passing through another transverse zone of said projection lens to move the image formed by said rays on the scanning disc approximately one-third the dimension of the image on the disc from the position where it would have been formed if the rays had not been deviated but in a direction opposite to the movement of the image by the first prism, a second opaque plate having three apertures corresponding respectively to the two zones mentioned in connection with said first and second prisms and a third zone of said projection lens, the rays of which are undeviated, a second projection lens adjacent said scanning discs on the side opposite from said first projection lens which gathers the light rays passing through the apertures in said scanning discs from all the zones of said first projection lens and has its conjugate foci at said prisms and second opaque plate respectively forming images of said three zones at said respective apertures in said second opaque plate, three light sensitive electric devices energized by the light passing through said three apertures respectively in said second opaque plate, and three image current transmission circuits associated with said light sensitive electric devices respectively.

8. The method of reducing in an electro-optically produced image the extraneous pattern superimposed upon the image field by the process of constructing the image strip by strip, which consists in transmitting primary color signal components of the object whose image is transmitted and producing an image thereof strip by strip, proportionately overlapping the respective color component scanning strips in each scanning cycle, and staggering the scanning strips in each scanning cycle a fraction of the width of a strip with respect to the scanning strips of the preceding cycle.

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