Jan. 20, 1931. S. FEINGOLD 1,789,521

TELEVISION SYSTEM

Filed April 10, 1928 7 Sheets-Sheet 1

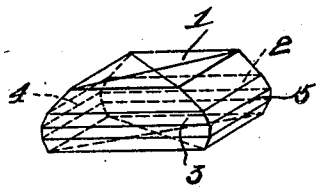


Fig. 1

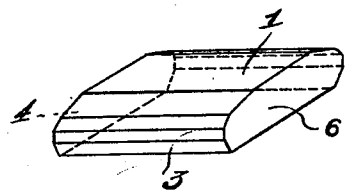


Fig. 2

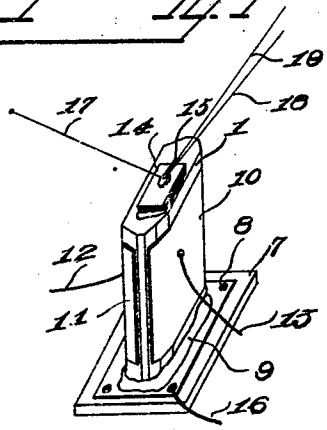


Fig. 3

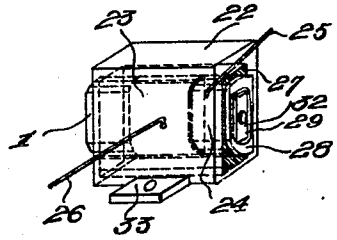
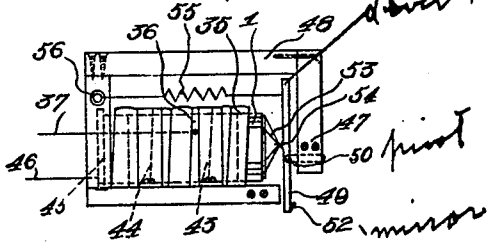


Fig. 4

spring drive system



print

mirror

Fig. 5

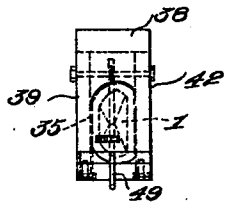


Fig. 6

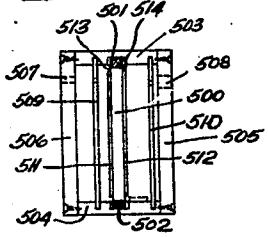


Fig. 7.

INVENTOR.
Samuel Feingold
BY William A. Strauch
ATTORNEY

Jan. 20, 1931. S. FEINGOLD 1,789,521

TELEVISION SYSTEM

Filed April 10, 1928 7 Sheets-Sheet 2

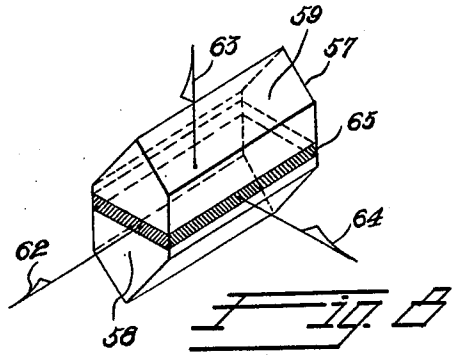


Fig. 8

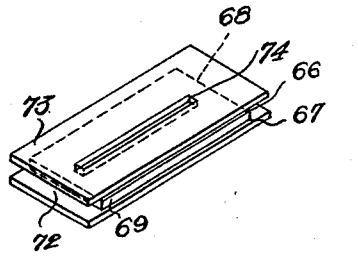


Fig. 9

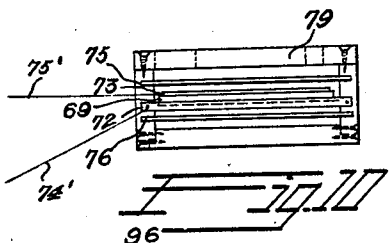


Fig. 10

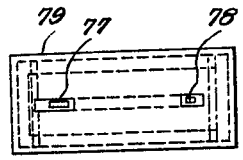


Fig. 11

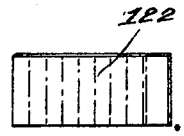


Fig. 18

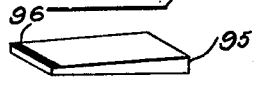


Fig. 13



Fig. 14

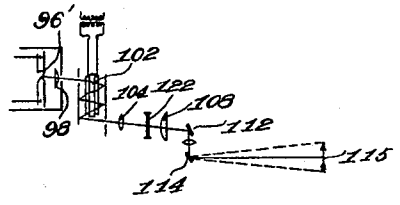


Fig. 15

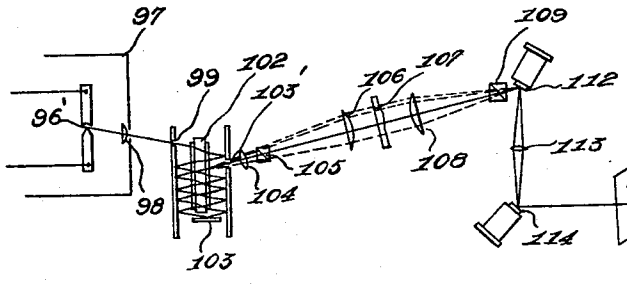


Fig. 16

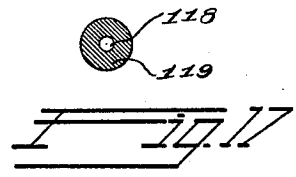


Fig. 17

INVENTOR.
Samuel Feingold
BY William A. Strauch
ATTORNEY

Jan. 20, 1931. S. FEINGOLD 1,789,521

TELEVISION SYSTEM

Filed April 10, 1928 7 Sheets-Sheet 3

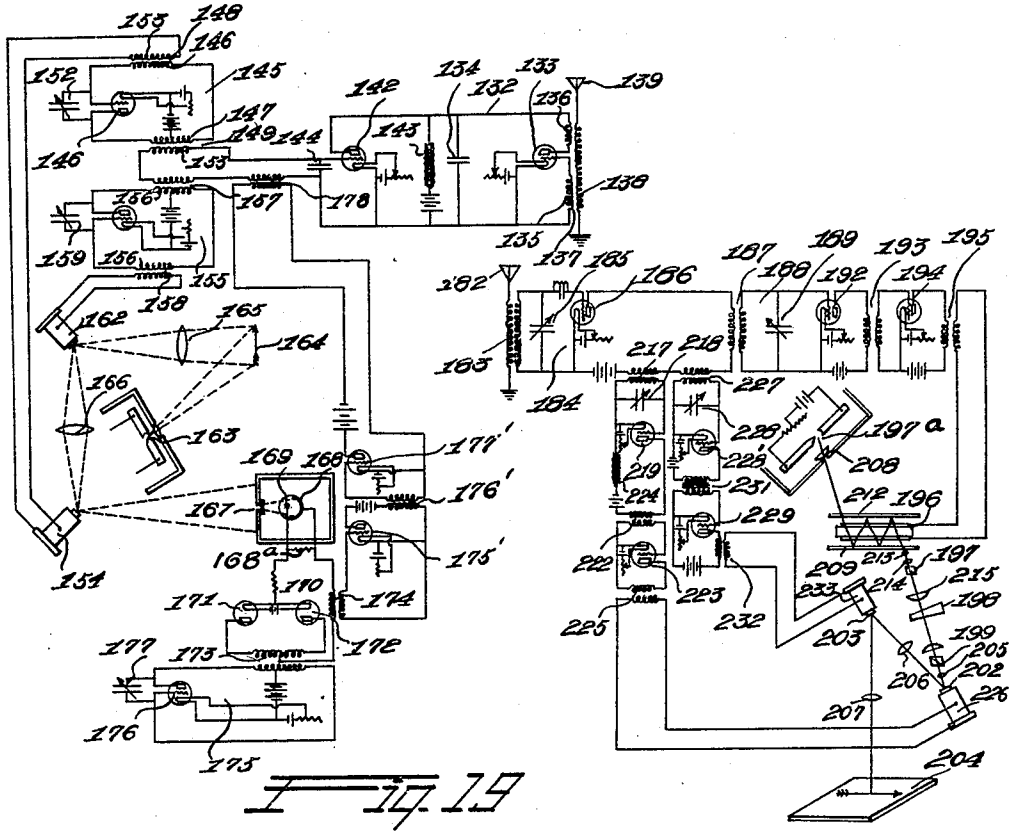


Fig. 19

Fig. 20

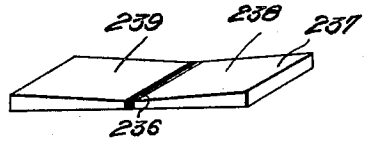


Fig. 21

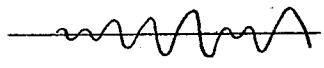


Fig. 22

INVENTOR.
Samuel Feingold
BY William A. Strauch
ATTORNEY.

Jan. 20, 1931. S. FEINGOLD 1,789,521

TELEVISION SYSTEM

Filed April 10, 1928 7 Sheets-Sheet 4

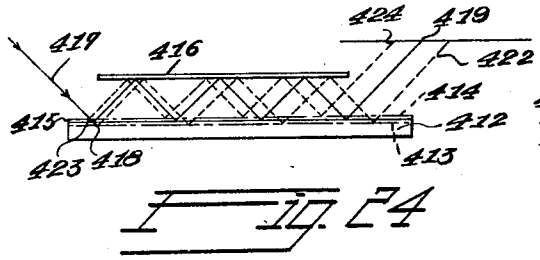


Fig. 24

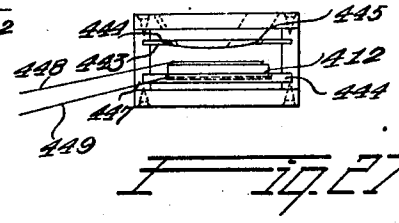


Fig. 27

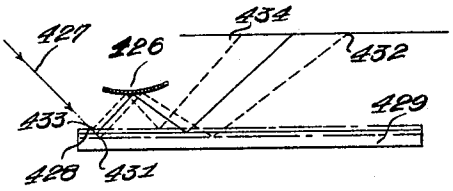


Fig. 25

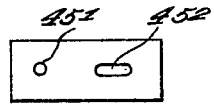


Fig. 28

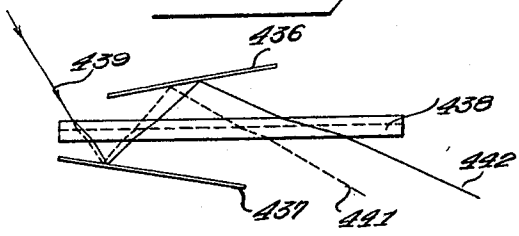


Fig. 26

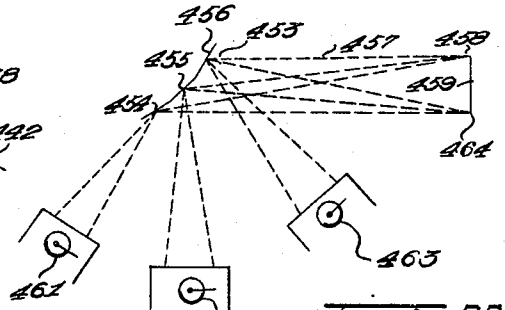


Fig. 29

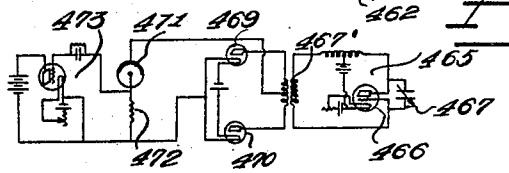


Fig. 30

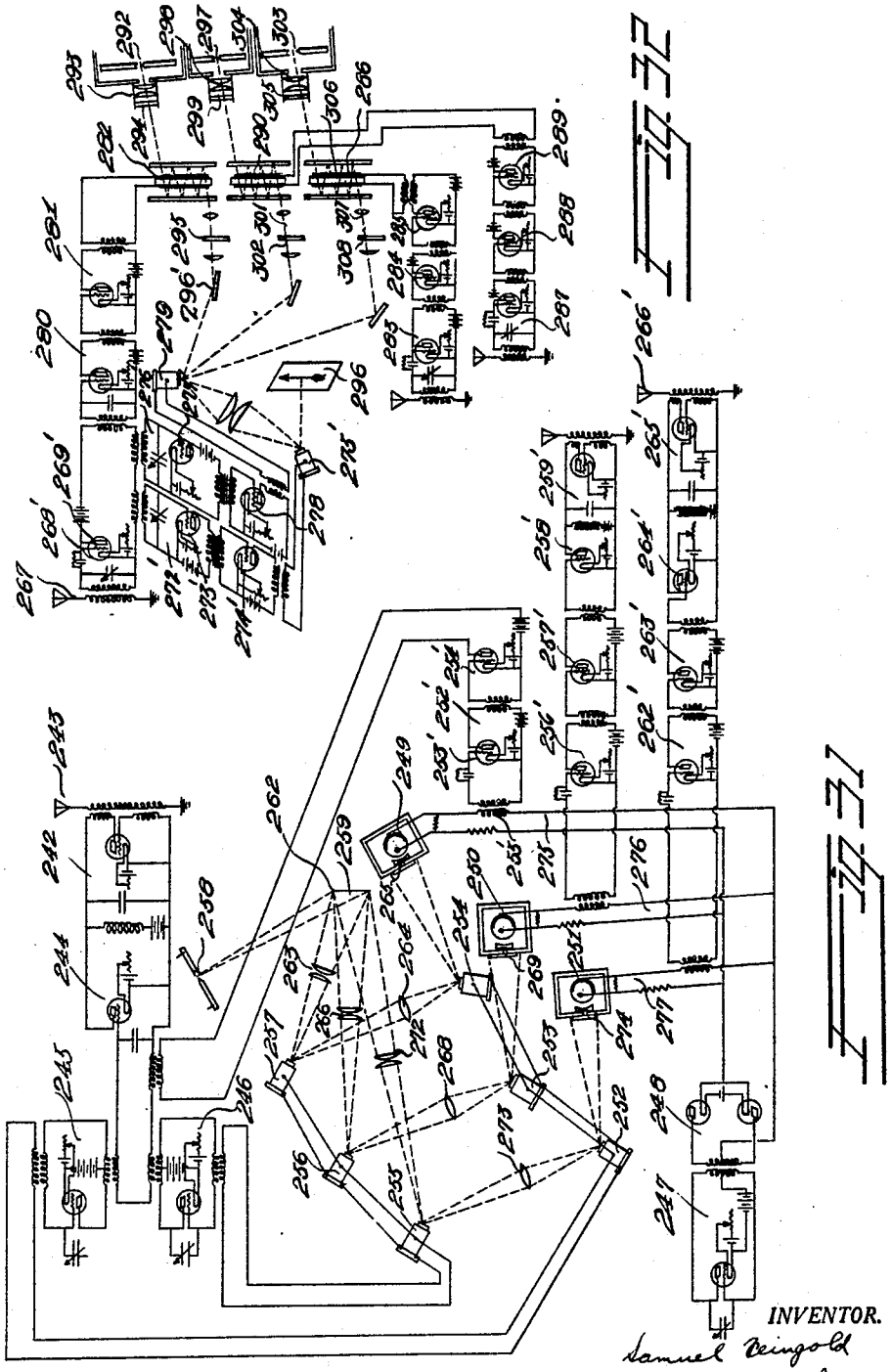
Fig. 12

INVENTOR.
Samuel Feingold
BY
William A. Strauch
ATTORNEY

Jan. 20, 1931. S. FEINGOLD 1,789,521

TELEVISION SYSTEM

Filed April 10, 1928 7 Sheets-Sheet 5



INVENTOR.
Samuel Feingold
BY
William A. Strauch
ATTORNEY

OPTICS,

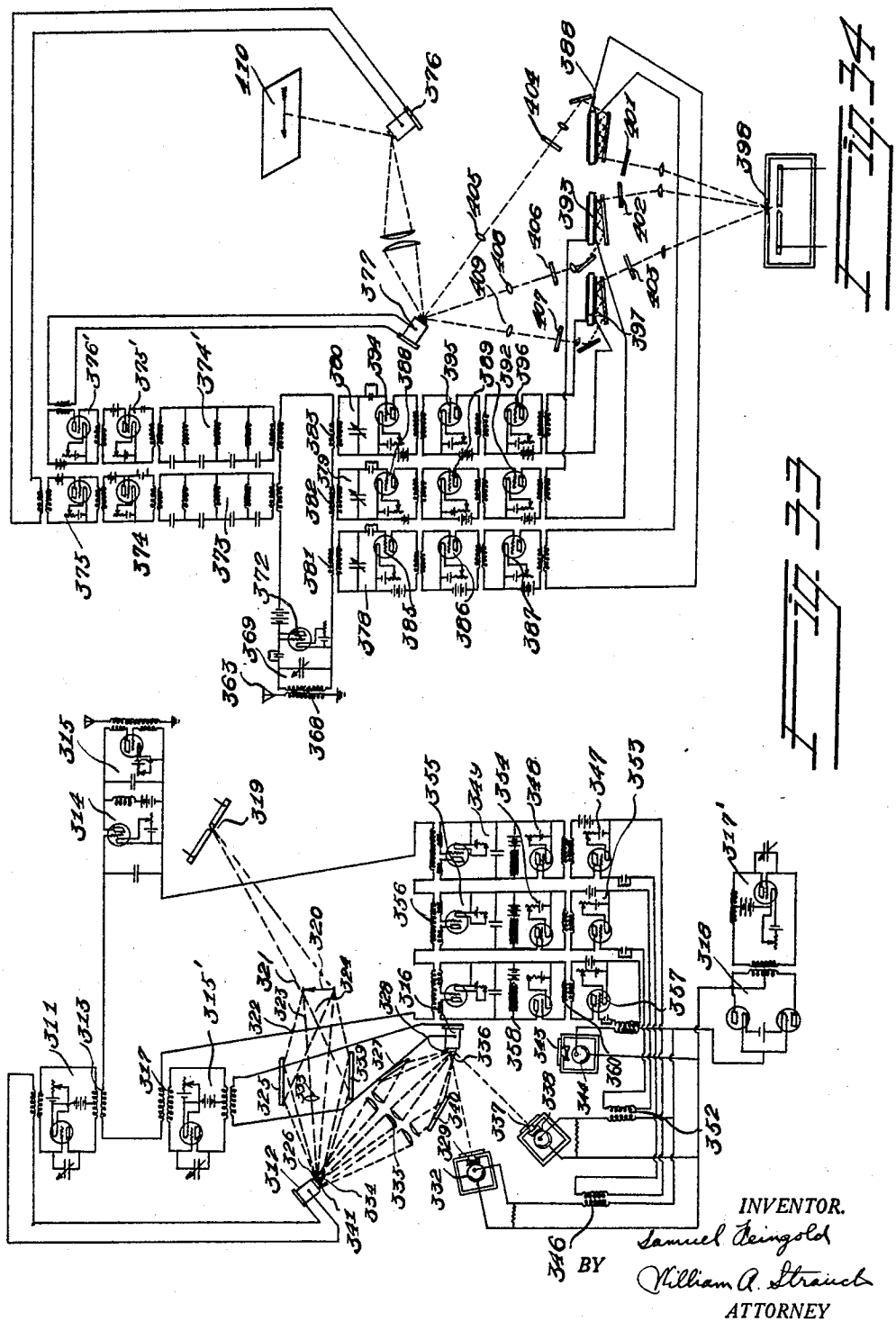
Cross Reference

Examiner

Jan. 20, 1931. S. FEINGOLD 1,789,521

TELEVISION SYSTEM

Filed April 10, 1928 7 Sheets-Sheet 6



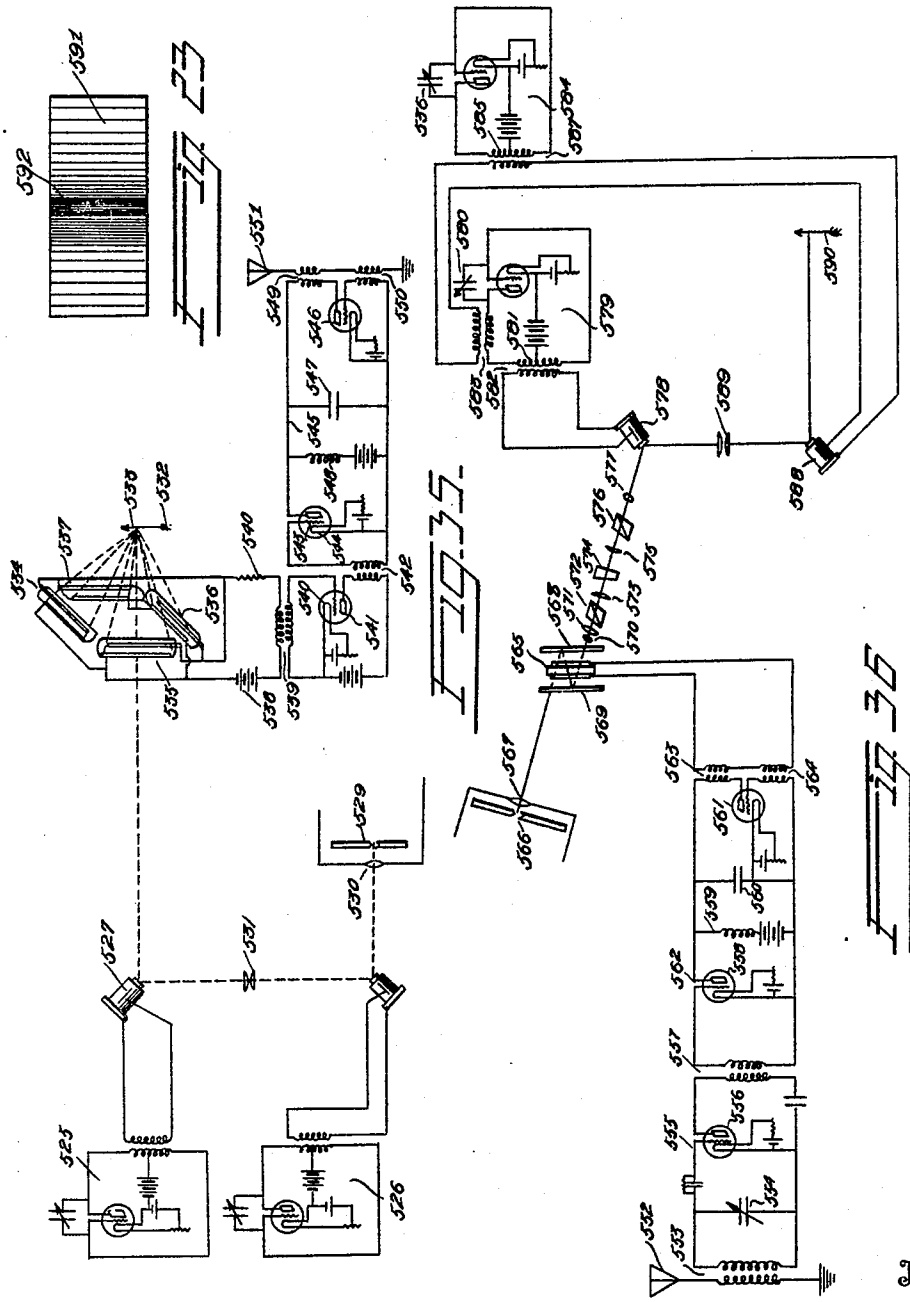
INVENTOR.
Samuel Feingold
BY
William A. Strauch
ATTORNEY

Examiner

Jan. 20, 1931. S. FEINGOLD 1,789,521

TELEVISION SYSTEM

Filed April 10, 1928 7 Sheets-Sheet 7



Inventor
Samuel Feingold

By William A. Strauch

Attorney

Patented Jan. 20, 1931 1,789,521

UNITED STATES PATENT OFFICE

SAMUEL FEINGOLD, OF BROOKLYN, NEW YORK

TELEVISION SYSTEM

Application filed April 10, 1928. Serial No. 268,912.

My invention relates to signalling systems, and more particularly to television systems in which a succession of complete images are transmitted by electrical means to a remote point at such a rate as to give the impression of a continuous image movement such as obtained in motion pictures.

Although successful picture transmitting systems have been invented and put in operation in which a single image with some detail is transmitted within a reasonably short interval of time, no success has been obtained heretofore in the development of a television system because of the failure to solve the problems encountered because of the high speed operation necessary.

As is well understood in television, a series of complete images are transmitted successively at a rate equal to that at which successive images are projected upon a motion picture screen which produces upon the observer the impression of a continuous moving event. This impression of a continuous event is made possible by the phenomena known as "persistency of vision". When light from an image is impressed upon the retina of the eye, the retina will continue to be affected thereby for about one seventeenth of a second after the light is cut off due to "light inertia" of the retina. If, therefore, in projecting a series of images on a screen, the successive images are projecting within one seventeenth of a second, after the preceding one is cut off, the observer will receive the impression of a continuous picture and not of two separate ones. This principle of motion pictures is also applicable to picture transmission so that by transmitting images in succession at a rate of about seventeen images per second, an observer will receive the impression of a continuous event.

For transmitting a picture, it is considered as composed of a large number of minute unit areas, each of which is of some component shade or color and the whole blending together to make a picture, each component shade or color being assigned a predetermined current value. At the transmitting station the shade or color of each successive unit area is translated into predetermined current values and transmitted to a receiving station. At the receiving station, the currents are translated back into light or color in accordance with the value assigned thereto and this light is projected on corresponding positions of the reproduced image. This is known as scanning and is accomplished by scanners which move across the unit areas. It will be evident from the above that in order to scan equivalent units of the two images, the scanners must be maintained in synchronism and in proper phase relation.

The dimensions of these units are, of course, variable, depending upon the degree of picture detail desired. For an average image, however, this area is 1/100 of an inch square. A picture therefore one inch by one inch will be considered as divided into 10,000 areas, there being 100 horizontal divisions and 100 vertical divisions. Employing the two co-ordinate scanning elements in which one scanning element scans in a vertical direction and the other in a horizontal, it is evident that while the first scanning element moves across the picture once, the vertical scanning element must move across the picture one hundred times in order to scan every unit area of the picture. Since, as explained above, the entire pictures must be scanned at least seventeen times per second, the vertical scanner makes 1700 oscillations during one second or 850 cycles.

Numerous attempts have been made to produce mechanically moving parts which could be oscillated at the desired frequency or rotating members which could be rotated at the proper speed for scanning 1700 lines per second. But in all of these attempts, difficulties have been experienced with the moving element due to the difficulties experienced in maintaining synchronism and proper phase relation. At the high speeds at which they must naturally operate as explained above, there is increased likelihood of these elements falling out of step.

Attempts have been made to correct this mechanical difficulty of rotating members by substituting non-moving members, one particular arrangement including the cathode

ray tube in which either electromagnetic or electro-static fields placed at right angles to each other function to move a cathode beam over a fluorescent screen. While theoretically this appears to solve the problem, actually the arrangement was found to be entirely impractical and to create new and more serious problems.

The cathode ray itself is of very low signal light intensity. It will be recalled that it was pointed out in the above that for a picture one inch by one inch about 10,000 points must be scanned. Since, however, the pictures must be scanned at least seventeen times per second, there are 170,000 unit areas to be scanned per second. This means that light is impinged on one unit area of a picture for 1/170,000 of one second. It becomes evident at once that unless an extremely intense point source of light is available, the lumens in 1/170,000 of one second is inconsiderable and a dim image if any at all will result. Exactly this difficulty is experienced in the case of the cathode ray, the intensity of which is limited to a comparatively weak beam. In actual practice it has been found as would be anticipated from the discussion above, that the intensity of the image projected on the fluorescent screen is so weak as to be practically invisible. This has been in a degree overcome by increasing the voltage impressed upon the grid of the cathode ray, but this voltage also has a practical limit within the range of which the light admitted from the cathode is still found to be considerably insufficient to distinctly illuminate the fluorescent screen. A further difficulty is experienced with the fluorescent screen in the cathode ray tube, the light inertia of which tends to maintain the effect of an image beam impinged thereon. If, as usually happens, the image remains effective while the succeeding image is being received, the picture will obviously blur, rendering the already dim image still less visible.

To these difficulties is added the fact that it is a practical impossibility to apply the principle of the cathode ray tube at the transmitting end so that moving parts are still necessary thereat and since the system which is limited in its operation by the weakest point in the system, which in this case is the transmitting end, any advantage which might have been gained by the non-moving parts of the cathode ray tube at the receiving end is lost by reason of the fact that rotating members are necessary at the transmitting end. Although attempts have been made to provide a cathode ray at the transmitting end, none of these have proved to be successful.

Other efforts toward eliminating mechanical scanners in a television system are illustrated by the arrangement shown in the German patents to Skaupy, Serial Nos. 352,581 and 355,891. In these patents a chemical solution is used having a different angle of refraction for the ordinary and extraordinary ray employed. This solution is responsive to variations in the potential of condenser plates between which it is placed to vary the angle of refraction of the ordinary ray of light, thereby changing the angle of path of the beam of light.

This arrangement, however, is only of theoretical interest inasmuch as the angle through which the light beam can be shifted by the voltage wave is so slight as to be negligible. In actual practice the shift of the angle is so slight as to have little practical value. No attempt has been made to put it on a commercial basis and the arrangement, therefore as pointed out above, is entirely of theoretical interest and not of practical value.

Although for a number of years considerable interest has been expressed in television systems and skilled engineers in the art have been, and are actively engaged in providing an operative and practical system, the general tendency has been to attempt to accomplish this not by any such theoretical and impracticable arrangements as that shown in the cathode ray, but in the more practical rotating members but these, as pointed out above, have certain inherent difficulties which make their use undesirable.

Not only have difficulties been experienced with the scanning at both the transmitting and receiving ends, but problems have been met in translating the received current into light of the proper comparative intensity. While the transmitter itself has been worked out fairly satisfactorily and the photo electric cell has been developed to a point where it is extremely sensitive to light and will respond accurately to light variations occuring at the rate of 170,000 per second, the same accuracy has not been obtained at the receiving end. This component of the system has also been the subject of considerable but unsuccessful development. One commonly proposed device at the receiving end to overcome this difficulty is the neon tube, the characteristic light of which is pink. Besides numerous other drawbacks, however, the intensity of the beam of light in the neon tube is limited to a comparatively low value and is, therefore, impracticable.

In order to provide the maximum intensity of light necessary at the receiving end, it has been proposed to employ a local source of light of any intensity desired and operating a shutter in front of the light in accordance with the picture current variations so as to permit a varying amount of light to pass through to a light sensitive device or screen. This, however, has limitations because of mechanical difficulties simi-

lar to those experienced in connection with scanning to a greater degree. Since the picture current variations are received at a rate of about 170,000 per second it is obvious that difficulties will be experienced with the shutter which must operate at this speed. Such operation is practically impossible to obtain. Other receiving devices of a similar character all have been tried, none of which, however, have proved effective.

It is accordingly an object of my invention to provide a television system in which scanning is accomplished without the use of rotating members, the scanning element being maintained in synchronism and in phase automatically by the inherent characteristics of the scanning element itself to reproduce a picture at the receiving station which is distinct and easily visible, and to provide an inertialess member for varyng a local source of light which may be of any intensity in accordance with received picture currents.

More specifically it is a further object of my invention to employ the piezo electric qualities of certain crystals in a television system for scanning and operating a receiver in accordance with current variations.

A further object of my invention is to provide scanning elements which have natural frequencies inherent in themselves equal to that at which they are to scan the pictures and receiving elements which have natural inherent frequencies equal to the rate at which the currents are transmitted.

In systems heretofore, neon tubes have been employed at the receiving stations to vary light in accordance with current variations. Other arrangements have been used including disks of varying thickness, that is, varying from pure transparency to opacity, so that different intensities of light are permitted to travel therethrough. In the case of the Nicol's prism, light is polarized and the intensity of the light passing through is proportional to the effect on the analyzer of the picture currents. In all of these systems, however, only a varying shade of light is transmitted and no colors.

It is a further object of my invention to provide a system in which colors as well as varying shades of white, such as from black to white, may be transmitted.

Another object of my invention is to employ the principles of expansion and contraction of crystals or what is known as piezo electric qualities for transmitting pictures in color.

There are other objects of my invention which together with the foregoing will appear in the specification which follows.

It is well known that if a crystal of Rochelle salt, made and cut in a predetermined manner described in the art is subjected to pressure on certain sides or along certain axes, the crystal will contract along these axes and expand along axes at the right angles and will as a result produce an electromotive force, and conversely, if an electromotive force is impressed along certain axes or upon certain sides of the crystal the crystal will either expand or contract depending upon the natural reaction of the crystal to the polarity of the electro-motive force. Similarly, if an alternating current is impressed on certain sides or along a certain axis of the crystal the crystal will expand and contract in accordance therewith at a frequency depending upon the frequency of the alternating electro-motive force.

Not only, however, does the crystal showing piezo electric effects vibrate when subjected to varying electro-motive forces but it has also been found that the Rochelle piezo crystal and quartz piezo crystal have a natural or resonant period of vibration and that if, the crystal is subjected to a frequency of alternating current, which is within the limits of this natural frequency of the crystal, the crystal will contract or expand at its greatest amplitude and if subjected to frequencies other than this natural frequency will expand and contract at a considerably less amplitude, but that always the crystal will vibrate at its natural frequencies when subjected to an alternating current, the amplitude thereof merely changing in accordance with the variation in frequency impressed thereon. This important fact, namely that the crystal has a natural frequency at which it vibrates together with the relation it shows in connection with alternating current, has been taken advantage of in my proposed system, not only in the scanning but also in translating light into electricity, the transmission of the current over the line, and the translation of the electric current into light.

Referring to the drawings,—

Figure 1 shows a natural crystal of Rochelle salts, in perspective.

Figure 2 is a similar view of the same crystal cut and ready for mounting.

Figure 3 is a perspective view disclosing the crystal mounted as a scanning element.

Figure 4 is a similar view disclosing the same element mounted in a manner to permit freedom of oscillation so as to provide a maximum amplitude of movement unaffected by its own weight.

Figure 5 is a side view showing a special mounting of the reflecting mirror on the piezo crystal.

Figure 6 is an end view of the apparatus shown in Figure 5 showing the crystal of quartz.

Figure 7 is a form of housing for a quartz crystal.

Figure 8 is a perspective view disclosing the natural crystal of quartz.

Figure 9 is a similar view disclosing the

manner of mounting the crystal shown in Figure 8.

Figure 10 is a side view disclosing the arrangement of mounting mirrors in relation to the crystal.

Figure 11 is the top view of Figure 10 showing the slots for the admission and departure of the ray of light.

Figure 12 is a diagrammatic showing of the crystal arranged to respond to received picture currents.

Figures 13 and 14 are perspective views showing wedges of quartz cut perpendicular to their axes.

Figure 15 is a diagrammatic view disclosing a system for receiving a picture either in black and white or in color.

Figure 16 similarly discloses a receiving system for the projection of color images in accordance with the colors transmitted.

Figure 17 is a sectional view showing the manner of mounting the mirror on the scanner.

Figure 18 is a top plan view of any well known form of color spectrum.

Figures 19 and 20 are diagrammatic views of the circuits and apparatus employed in one embodiment of my invention.

Figure 21 is a perspective view of the quartz slab for varying the light ray at the receiving station.

Figure 22 is an oscillograph showing of a complicated picture current wave.

Figure 23 is a view of a light gradient.

Figures 24 to 28 inclusive are views of various modifications of piezo electric crystal arranged to respond to picture currents.

Figure 29 is a diagrammatic view of a modified scanner for transmitting pictures in colors.

Figure 30 is a diagrammatic showing of a modulator and oscillator for picture currents.

Figures 31 and 32 are diagrammatic showings of the circuits and apparatus in a system for transmitting pictures in colors.

Figures 33 and 34 are showings of modified circuits and apparatus for transmitting pictures in colors.

Figures 35 and 36 are diagrammatic showings of a modified system for transmitting pictures in color.

In Figure 1, 1 is a natural crystal of Rochelle salt, comprising sides 2 and 3, and sides 4 and 5. If an electro-motive force is impressed across sides 2 and 5, the crystal will either expand or contract depending upon the polarity at either side. If an electro-motive force is impressed across sides 3 and 4 in such a direction that the potential at side 3 with respect to side 2, the crystal will react thereto in the same manner, that is, either expand or contract depending upon the polarity. If the crystal expands with potential in one direction, it will contract with potential in the opposite direction. From this, it is apparent that by impressing an alternating current across either sides 3 and 4 or 2 and 5, the crystal will expand and contract with the reversals of the alternating current.

Not only do these crystals oscillate when an alternating current is applied thereto, but they have been found to have a natural period of oscillation or frequency. The crystal will, therefore, oscillate at its maximum amplitude when an alternating current of the frequency to which the crystal is resonant is impressed thereacross.

This phenomena of quartz crystal is well known and has been applied to radio to maintain the carrier frequency thereof substantially constant.

In Figure 2 the crystal 1 is shown cut and ready for mounting. It will be assumed that the side 6 has been found by experiment to be one point of a polarity. As has already been explained in detail above, if an electro-motive force is applied to this crystal, it will expand and contract as the polarity of the electro-motive force is reversed remaining at all times in step with the reversals of the alternating current.

In Figure 3 the crystal 1 is shown mounted on a base 7, which may be made of wood, rubber or any other suitable substance, the characteristic of which is such as to permit the greatest amount of freedom of the crystal in its vibration. The crystal is secured to the base 7 by a metallic plate 8 to which it is soldered although it will be understood that any convenient method of fastening may be employed.

Coatings 10 and 11 are soldered or cemented to the sides of the crystal 1 for providing the necessary connections for the leads 12 and 13 connected to the source of electro-motive force which is impressed across the crystal. These coatings 10 and 11 are the electrodes to which the electro-motive force is applied. Cemented to the end facing of the crystal 1 is a metal mounting 14 for supporting a mirror 15. Mounting 14 is soldered to the crystal by means of Wood's metal as shown in the drawing although in this case also any type of soldering may be used. Although as shown, the vibrations due to the electro-motive force impressed across faces 10 and 11 is such as to impart that motion to mirror 15, it will be understood that vibrations could be obtained at other faces by impressing the electro-motive forces at other faces as, for example, at terminal 16. In any event motion to face 14 could be brought about by connections to 12, 13 or 16.

In the arrangement shown, a beam of light 17 impinged from any light source will be reflected along the line 18. When, however, the crystal has expanded, the mirror moves forward and reflects the beam 17 at an advanced position, thus shifting or displacing the beam to 19 as shown. By arranging the angle of

Cross Reference

the beam 17 with respect to the mirror 15 any extent of displacement of beam desired can be obtained.

In Figure 4 the crystal 1 is shown mounted in a housing 22 comprising wood, hard rubber, or any other suitable material. A tin foil coating 23 and 24 is cemented to the crystal 1 and to which in turn are soldered the leads 25 and 26. The housing 22 is filled with wax 27, in which the crystal 1 is securely imbedded. To the facing 28 of the crystal 1 is mounted a mirror holder 29 to which is soldered the mirror 32. A mounting lug 33 is provided to facilitate mounting of the crystal. In this arrangement, it is obvious that as the crystal is held so to speak suspended in the wax, it is free to move in this elastic medium and its amplitude is accordingly greater than could ordinarily be obtained in the mounting shown in Figure 3.

It will be seen that in Figures 3 and 4 a simple arrangement is provided for shifting or displacing a beam of light in accordance with the vibrations of the crystal. It is, however, possible as is well known in the leverage principles, to obtain a considerably greater movement of the mirrors and accordingly greater displacement of the beam of light for the same small movement of the crystal. To this end I have shown the arrangement in Figures 5 and 6. The crystal 1 is here shown encased by a rubber tape 35 wrapped thereabout. Connections to the crystal are made as shown in Figures 3 and 4 with a girdle of tin foil 36 at the center of which is soldered the lead 37. As shown in Figure 6, the crystal 1 is placed in a receptacle or housing 38 and rigidly held so that it fits snugly between the walls 39 and 42. Metal straps 43 and 44, Figure 5, hold the crystal 1 rigidly in position against the base. The crystal 1 is also urged into rigid connection against the metallic plate 45 to which is attached the lead 46. Metal plate 45 and the tin foil 36 around the girdle are the electrodes of the crystal and are so chosen that the crystal will expand or contract in the direction of its length. Secured to the extension 47 of housing 38, mounted upon the side 48 is a metal rod 49 pivoted at 50 carrying a mirror 52. At the end of the crystal 1 is mounted a hard rubber cap 53 which bears against the rod 49 through the bearing member 54. A spring 55, the tension of which can be adjusted by turning the thumb screw 56 urges the lever 49 to maintain engagement with pivot 54.

As will be clearly seen, when the crystal vibrates, the lever arm 49 is moved on its pivot 50 and in turn oscillates the mirror 52. Because of the leverage obtained, the movement of the mirror and accordingly the beam displaced thereby, will be considerably greater than in the case where the mirror is directly attached to the crystal.

This same principle can be applied to two crystals arranged adjacent to each other, the one arranged to expand at the instant the second contracts, the arm 49 being pivotally mounted on both crystals resulting in a movement thereof which is the function of the sum of the contraction of one crystal and the expansion of the other.

The crystal 1 with a mirror 15, 32 or 52 secured thereto is adapted for scanning at both the transmitting and receiving stations. When so employed, a crystal having a natural period equivalent to 2,000 cycles and another having a natural period equivalent to 20 cycles have connected across their electrodes currents of 2,000 and 20 cycle frequency. The mirrors secured to the crystals are then positioned relative to each other in such a manner that a beam of light playing on one of them from a fixed source is reflected to the other and moved along one co-ordinate as the first crystal oscillates, the beam being reflected by the second mirror and moved along a path at right angles to the movement by the first mirror. As a result of these two component movements an entire image is scanned once while for example the first mirror moves the beam up and down 100 times and the second mirror moves the beam across once. It will be understood, however, that the figures assumed in the above, that is the 2,000 and 20 cycle crystals are arbitrary and any values may be chosen depending upon the accuracy and detail of picture desired. It must be borne in mind that a complete cycle applied to a crystal will cause expansion in a certain direction, then a contraction to zero and a further contraction in the opposite direction, then back to zero. In other words, a single linear displacement will result.

It is one of the features of this invention not only to take advantage of this expansion and contraction characteristic of quartz when subjected to an alternating electro-motive force for varying a beam of light at the receiving station in accordance with the received picture currents. As is well known, quartz is a triagonal trapezohedral crystal with double refracting uni-axial positive characteristics. The refractive index for the extraordinary ray is 1.5533 while for the ordinary ray it is 1.5442 and it is evident, therefore, that the degree of separation between the ordinary and extraordinary ray is negligibly small.

Such a crystal in its natural state is disclosed in Figure 8. In its normal state, the ends 57 and 58 of the crystal 59 are in the form of a six sided pyramid, although for purposes of illustration, flat end portions are here shown.

The crystal 59 comprises an optical axis 62 and electric axis 63 and axis 64. The optical axis 62, it will be noted, coincides in this case with the crystallographic axis. From a crystal of this character in its nat-

ural state, a slab is cut including the cross hatched portion 65. This rectangular slab portion 65 is so cut that its edges are perpendicular to each other and the top and bottom faces 66 and 67, Figure 9, are made parallel as are the end and side faces 68 and 69. This is the shape of the crystal as ordinarily employed for maintaining constant frequencies in radio telegraphy. If to a crystal of this character, an electro-motive force is applied along the electric axis 63, the crystal will expand and contract in the direction of this axis. Here again the expansion or contraction depends upon the polarity at any one electrode. When the crystal is in a state of contraction along the axis 63 it is in a state of expansion along the axis 64 and vice versa. It will be noted that under these conditions no changes take place along the axis 62. If now an alternating current is applied along the electric axis 63, the crystal will expand and contract along this axis with the alternations of the current.

The crystal 59 is mounted upon a metal plate 72, Figure 9, which serves as one electrode. Suspended a minute distance above the crystal 59 in order that the electrostatic field may be as large as possible, is another plate 73. A slot 74 is cut in a plate 73 in order to admit a beam of light for the purpose to be described in detail hereinafter. A similar slot is cut in the plate 72 for the same purpose.

In Figure 10, it will be noted that mirrors 75 and 76 are located above and below the crystal slab 69. Electrical circuit connections are made to the plate 72 and 73 by conductors 74′ and 75′ respectively. In Figure 11, I have disclosed a top view illustrating the slots 77 and 78 cut in the container 79.

Referring to Figure 12, the path taken by a beam light as it passes through a quartz crystal and is reflected by the mirror is disclosed in accordance with received picture currents. A beam of light 80 from any source is admitted through a slot and impinges on the quartz slab at 81 when the quartz is in its normal state, that is, neither expanded nor contracted. This beam is refracted due to the change in velocity of the light in the quartz slab as shown by the full line 82 and after passing through the quartz slab, passes through the air medium until it is reflected by the mirror at 83. The reflected beam 80 now again is impinged on the quartz slab at 84 and is again reflected by the mirror at 85. In this manner, it is seen that a series of refractions and reflections take place until the beam 80 ultimately emerges through an opening and is impinged on the screen at 86. This condition, as pointed out above, exists with the crystal in its normal state. Assuming now that the crystal is under the influence of an electro-motive force, which is varying in accordance with the variations of picture currents being received due to an instantaneous current value received, the crystal is contracted as shown by the dotted line 87. The same ray of light 80 now impinges on the crystal at 88 before being refracted by the crystal and is accordingly displaced a distance equal to the perpendicular distance from the point 88 to the first described path of the beam before contraction of the crystal took place. Thereafter, as will be noted, the beam follows a path parallel to the original path maintaining, however, a displacement equal to the distance noted above until the beam emerges from the crystal at point 89. At this point, refraction ceases for this second beam although the original beam at an equivalent position, continues to be refracted and the second beam is therefore displaced still further from the first beam so that when now the second beam is again reflected by the mirror at 90, the displacement is greater than that of the distance at point 88. It will now be evident that each time the beam is reflected and refracted, through the crystal the distance of displacement of the second beam with respect to the first when the crystal is contracted or expanded increases until at the point of emergence from the crystal the second beam is at a distance 91 from the original beam. This distance for any fixed length of crystal will, it is obvious, be proportional to the extent of expansion and contraction of the crystal, which can be made greater or smaller for any fixed expansion or contraction of the crystal by varying the length of the crystal and accordingly the number of reflections and refractions which occur before the beam emerges therefrom.

It will now be understood that the vibrations of the crystal or its expansions and contractions have had the effect of moving the ray of light from 86 to 92 and the distance that the beam of light will undergo between the entrance and exit points is dependent upon the distance of the mirrors.

It will also be obvious from the above description, that a quartz crystal can be employed to vary a beam of light in accordance with the picture currents received. Since the quartz slab can be made to vibrate at high frequencies, it will follow substantially all variations of the picture currents irrespective of the rate at which they are received.

It is an important object of my invention to provide an arrangement for transmitting pictures in color and, I have accordingly shown the apparatus and arrangement for such a system in Figures 13 to 17.

Referring to Figure 13, a wedge of quartz 95 is shown cut perpendicular to its axis and designed to vary in thickness uniformly. The quartz slab is also provided with opaque portions 96 which as will be described here-

inafter corresponds to small current values from a photo electric cell and represents a dark spot on the picture being transmitted. As shown in Figure 16, a quartz slab is positioned in the path of a beam of light from a source of intense white light 96′ located in a housing 97. The beam passes through a lens 98 and through a slot 99 to the receiver crystal 102. The crystal 102 is similar to that disclosed and described in connection with Figures 12 and 10 with the addition of a mirror 103 which, it will be observed, reflects the beam to start it back over a continued path thus doubling the number of reflections and refractions for the same length of quartz slab. An electro-motive force varying in accordance with picture currents is impressed across the quartz slab 102 which is therefore vibrated in accordance with the received picture currents. The beam of light passes through the slot 103′ after having been shifted or displaced from its normal path by the contraction or expansion of the crystal in accordance with the received picture currents and then passes through the lens 104 to the polarizing Nicol's prism 105 thence through lens 106, quartz slab 107, lens 108, to the analyzing prism 109 and is thereafter focused on the scanner 112. The beam is reflected from the scanner 112 through lens 113 and focused on the scanner 114 from where it is reflected to the screen 115.

It is now well known that quartz has in addition to the property of expansion and contraction described above, the characteristic of producing rotary polarization of light. This property may be described as follows:

Assuming that a ray of homogeneous light is polarized and the analyzer say of a Nicol's prism is turned until the light does not pass therethrough, if a thin section of a quartz crystal cut at right angles to the axes is placed between the polarizer and analyzer with its plane at right angles to the ray, it will be found that light will now again pass through the analyzer. If now the analyzer is turned, it will be found that the light passing through the analyzer is plane polarized but in a plane inclined to a certain angle to the plane of primitive polarization. If the beam of light which passes through the slab is red and the slab is one millimeter thick this angle is about 17 degrees. Investigation of the above phenomena has disclosed the fact that for a given color the angle through which the plane of polarization is turned is proportional to the thickness of the quartz, the rotation for a fixed thickness of quartz being different for different colors.

It will be evident from the above that with a plate of a fixed thickness, a beam of red light will be rotated a fixed angle and a beam of voilet light rotated a different angle while all other beams of light intermediate these two will be rotated at angles intermediate the limits set by the red and violet beams. Accordingly, with a beam of white light, for any one position of an analyzing Nicol's prism, a greater or smaller quantity of each color will be passed through, depending upon the direction of rotation of the Nicol's prism. Conversely if a quartz slab of varying thickness is employed and a beam of light passed therethrough the analyzing prism in one position will permit varying colors to pass through depending upon the thickness of the plate and the points through which the beam passes.

It will now be evident from the above description that the receiving arrangement disclosed in Figure 16 will operate in accordance with varying light. The beam from the source 96′ normally passes through the quartz 102 and the Nicol's prism 105 and analyzer 109 to the scanning elements 112 and 114, the two scanners oscillating under control of alternating currents impressed thereacross at different frequencies in the manner described above for scanning the entire picture. The scanner 112 may shift the beam in a horizontal line while 114 moves the beam vertically and the resultant as is well known in the television art is to cover the entire picture at the screen 115. Although in this particualr modification the form of scanning disclosed in Figure 3 is shown for purposes of convenience, it will be evident that a scanner such as disclosed in Figure 5 may more preferably be employed as providing a greater deviation of the beam of light and accordingly permitting a greater area to be scanned. In this system it will be assumed that the photo electric cell varies in sensitivity in accordance with the beam of light impinged thereon from the image to be transmitted. Accordingly the picture current of the beam will be in accordance with the color of the image being transmitted and the quartz slab 102 will contract or expand in accordance with the received currents to displace the beam of light from the source 96′. Current due to a white point on the image so affects the quartz that the beam from source 96′ follows. This beam, it will be noted, passes around the Nicol's prism 105 and passes through the end portion of the quartz disk 107 so that white light is transmitted without being polarized through the analyzer 109 to the scanning elements 112 and 114 and is thence projected upon the screen 115. If, however, a colored picture is received, a current in accordance with a colored point of a picture is received, the quartz slab 102 is expanded or contracted, as the case may be to such an extent that the beam passes through the Nicol's prism 105. The extent of the expansion or contraction of the slab 102 which itself is controlled by the picture current will determine through which portion of the quartz slab 107 the beam passes and since as shown in Figure 13 the slab is

of varying thickness, the beam will pass through a more or less thick portion thereof and will accordingly be rotated a varying amount. As pointed out above, the extent of rotation of the polarized beam is dependent upon the color, a greater rotation producing a greater color. Accordingly, the beam which reaches the scanners will be of a color similar to that of the point on the image to the light of which the photo electric cell at that instant responded.

It will be evident, of course, that the eye may take the place of the screen 115 and will receive the impression of an image, similar to that which would have been projected upon the screen 115.

In Figure 14, I have shown a modified form of quartz slab which may be employed, the shape of which is determined by the characteristics of the photo electric cell. The photo electric cell to be employed in connection with the quartz wedge shown in Figure 13 has the characteristic of uniformly varying sensitivity throughout the entire spectrum. In Figure 14, on the other hand, the extended portion 116, the light passing through which will not strike the first Nicol's prism as described in connection with Figure 13, is made of varying thickness and will, therefore, give white light of varying intensity in accordance with the intensity of the picture being transmitted. One end 117 is opaque as illustrated, to correspond to small picture currents due to a dark spot on the image.

Figure 17 shows the mounting for a scanning mirror 118 on member 119. It will be noted that the mirror 118 is made small, due to the fact that since the beam of light is brought to a focus on the mirror it need not be very large, although of course, it will be understood that any size mirror may be employed.

In Figure 15, I disclose a modification of the receiving apparatus for operation in accordance with the colors transmitted and also black and white images.

In the case of transmission of black and white, the slab 122 is graduated from clear transparency at one end to opacity at the other end. Inasmuch as the intensity of light leaving the slab will depend upon the portion thereof through which the light passes and the displacement of the light rays is a function of the picture current, the intensity of light thrown on the screen 115 will be proportional to the picture currents. The graduated slab 122 shown in Figure 18 is graduated in the different colors of the spectrum starting with black for an area of no light and ending with violet for an area of violet light and thereafter continuing with diffused and pure white. The slab 122 may be made of glass and dyed the proper color although it will be understood that any spectrum arrangement may be employed. Preferably, the spectrum is arranged so that the colors will start from deep red and go to light red, then deep orange to light orange, deep yellow to light yellow and so on, rather than uniformly dyed although it will be understood that such an arrangement may be employed. The slab 122 is placed in the path of the ray in the system shown in Figure 15 comprising the same source of light and receiving apparatus as shown in Figure 16. In this system, as described in detail hereinabove, the displacement of the beam is a function of the amplitude of the received picture current which in turn is proportional to the color of the point image being transmitted. It is evident that the beam of light which passes through the focusing lens 108 to the scanning elements 112 and 114 will be of a color depending upon the portion of slab 122 through which the light passes which in turn is proportional to the expansion or contraction of the picture current responsive crystal 102. From the arrangements thus far described, it should be clear now that a simple arrangement for transmitting pictures in color is disclosed.

Referring now to Figures 19 and 20, the circuit arrangements and apparatus at both the transmitting and receiving ends of one embodiment of my invention is disclosed. The transmitting apparatus is shown in Figure 19 and the receiving apparatus in Figure 20. The circuit arrangements are such that a single carrier current generated at the transmitting end is modulated by an oscillating current which is composed of the frequencies of the currents which operate the scanning elements at the transmitting end and the frequencies of the picture currents from the photo electric cell. This modulated carrier current in turn operates the associated scanners at the receiving station in synchronism and proper phase with the scanner at the transmitting end since by this arrangement the same frequency operates the scanners at the transmitter and receiving stations. The equivalent scanners at each station are operated by piezo crystals having substantially the same natural frequencies.

Similarly, the carrier current generated at the transmitting end is modulated by picture currents which are arranged to operate a receiver piezo crystal. A single carrier is thus employed for the scanning and picture currents. The oscillating circuit 132, Figure 19, comprises a three element tube 133 of the standard well known type comprising a plate grid and filament connected in a tuned radio frequency circuit including the condenser 134 and the primary windings 135 and 136 of the transformer 137, the secondary winding 138 of which is connected to the antennæ 139 for radiation of the carrier current generated in the oscillating circuit 132. The three element

Cross Reference Examiner

tube 142 with impedance 143 and a condenser 144 with the oscillator described above comprise a modulator and oscillator of the Heising type or of the absorption type. Although for purposes of illustration a specific form of modulator is disclosed, it will be understood that any one of the numerous well known types of oscillators may be employed in practicing my invention.

The oscillator 145 comprises a three element tube 146 connected in the oscillating circuit including the primary windings 146' and 147 of transformers 148 and 149 respectively. A variable condenser 152, the capacity of which may be changed, alters the constants of the circuit until it is tuned to oscillate at a frequency for example of 20 cycles per second. The secondary 153 of the transformer 149 is connected to the input of the modulator 142 through which it modulates the oscillations of the radio frequency generator 132. The same oscillations generated in the circuit 145 are transmitted through the secondary winding 153' of the transformer 148 to the scanner 154 which is vibrated at 20 cycles per second. The scanning element 154 here disclosed is of the Rochelle salt type described in connection with Figures 1 to 5. Although the scanner is here shown as that disclosed in the modified form of Figure 3, it will be understood that this is merely for purposes of illustration as the arrangement shown in Figure 5 is more preferably employed because of the greater amplitude which can be obtained although for certain specific purposes the arrangement shown in Figure 3 may be preferable. A similar oscillating circuit 155 comprises a three element tube, primary windings 156 of the transformers 157 and 158 and a variable condenser 159, the adjustment of which is such that the circuit is tuned to oscillate at 2,000 cycles and accordingly generates oscillations of 2,000 cycles per second. The secondary winding of the transformer 156 is connected to the input of the modulator 142 and thence to the oscillating circuit 132. The same oscillations are transmitted through the secondary of the transformer 158 to the second scanning element 162 which is accordingly oscillated at a frequency of 2,000 cycles per second. The scanning element 162 as in the case of the scanning element 154 is of the type shown in the Figures 1 to 5, although it will be understood that any of the modified forms illustrated in the specification heretofore may be employed.

A source of light 163 is projected upon the image 164 from which it is reflected through the focusing lens 165 upon the scanning element 162. This scanner as it oscillates, picks up light rays from successive points along one co-ordinate of the image and reflects the rays therethrough focusing lens 166 upon the scanning element 154 and thence through the slot 167 and diverging lens 168 to the photo electric cell 169. As the scanner 154 makes one oscillation, the scanner 162 will have completed 100 oscillations and will have, therefore, scanned the entire image. This will be repeated for each oscillation of the second scanner 154. The photo electric cell 169 is thereby successively subjected to the succession of points comprising the image 164. Photo electric cell 169, as it is well understood, comprises a light sensitive substance such as potassium hydride or any other well known element of similar characteristics, and a second electrode 170 is connected in circuit with the two rectifier units 171 and 172 each comprising the standard two elements well understood by those skilled in the art. The plate circuits of rectifier units 171 and 172 are connected to the secondary winding of the transformer 173, the mid-terminal of which is connected to the primary winding of the transformer 174, and thence to one electrode of the photo electric cell.

An oscillating circuit 175 comprises a standard three element tube 176 and the primary winding of the transformer 173 and the variable adjustable condenser 177. By proper adjustment of condenser 177, the circuit 175 is tuned to oscillate at 100,000 cycles. The circuit including tubes 171 and 172 acts as a full wave rectifier for the oscillation produced in circuit 175 which flows in the secondary of transformer 173 through the primary thereof. The amplitude of this rectified current is then varied in accordance with the variations of light intensity impinged on photo electric cell 169 from the image 164.

In order to operate the crystal at the receiving station properly in accordance with the picture currents, it is essential that a current of a single frequency, the amplitude of which varies, be transmitted in order that the crystal in the receiving station should operate at its resonant frequency. It is evident, however, that if a dark spot of a picture is being scanned, the cell will be of such resistance that no current will flow in the circuit. Accordingly there would be a momentary change in the frequency of the picture current, which would not conform with the resonant frequency of the receiving crystal. To overcome this difficulty a resistance 168*a* is connected across the photo electric cell to insure a minimum flow of current through the circuit at all times. With this arrangement, when a dark spot on the image is reached, a flow of current of very small magnitude will result and the current variations will increase in accordance with the intensity of light to which the photo electric cell is subjected, although at no time of zero value. The character of the transmitted picture frequency is thus kept constant, the amplitude being the sole varying factor.

The picture currents in the output of the

photo electric cell flow through the primary winding of the transformer 174 and are impressed across the input of the amplifying tube 175′ of the standard three element type, the output of which is connected through the transformer 176′ to a second stage amplifier tube 177′. The output of the amplifier tube 177′ in turn is connected to the transformer 178, the secondary of which is connected in circuit with the modulator and oscillator 132. By this circuit arrangement the carrier oscillator current 132 is modulated in accordance with the two synchronizing or scanning frequency and the picture currents. A single carrier current modulated in accordance with variations of three different frequencies is radiated over the antennæ 139, or impressed upon a line which is not shown in the drawings.

At the receiving station, Figure 20, the signals are received over the antennæ 182 and are transmitted through the radio frequency transformer 183 to the tuned circuit 184. The tuned circuit 184 in addition to the secondary of the transformer 183, comprise a variable condenser 185 and vacuum tube 186. By proper adjustment of the capacity of condenser 185 this circuit can be tuned to the carrier current frequency for maximum reception. The received carrier current is then impressed across the detector and amplifier tube 186. Although no radio frequency amplifying stages are shown, it will be understood that radio frequency amplification employing any well known circuit therefor properly neutralized may be employed.

The amplified and detected wave is then transmitted through transformer 187 to the tuned circuit 188. The capacity of a variable condenser 189 connected in the tuned circuit is varied until the circuit is tuned to a frequency of the received picture currents. The picture currents are thus selected from the detected modulated carrier current in the output circuit of tube 186. These picture currents are now transmitted through amplifying and detecting tube 192, transformer 193, the second stage amplifier 194, transformer 195, and impressed across the electrodes of the crystal 196.

The ray of light emanating from the source of intense white light 197*a* and made parallel by the lens 208 passes through the crystal 196 to be refracted and reflected from mirrors 209 and 212 as described in detail hereinabove. The ray is then passed through a slot to lenses 213 and 214 which will amplify the distance that the beam transverses through the Nicol's prism 197. Nicol's prism 197 plane polarizes the light which has been elliptically polarized by the receiver crystal 196. If a Nicol's prism is rotated in the path of a ray of light which is elliptically polarized, no part of the ray is cut off although its intensity is varied. Since the phenomenon of color, due to double rotation depends upon a ray of plane polarized light the Nicol's prism 197 must polarize the ray of light at its maximum intensity. This beam then passes through lens 215 to the quartz wedge 198 so adjusted that when the crystal 196 is oscillating at its maximum amplitude for an elementary area of no color, i. e. black, the ray of light falls in the black ledge of the slot. The ray then passes through converging lenses 199 and 205, and through the analyzing Nicol's prism 205′ upon the mirror 202 of the scanner 226. From thence it is reflected through the converging lens 206 upon the mirror 203 of the scanner 233. Thence through the converging lens 207 upon the screen 204. As has been described in detail hereinabove, the wedge slot in conjunction with the Nicol's prisms now passes through light of varying color in accordance with the extent of displacement of the beam of light and focuses it upon the screen 204.

A second circuit for the detected and amplified received modulated carrier current in the output of the tube 187 is completed through the transformer 217, the secondary winding of which together with the variable condenser 218 are of such values that the circuit is tuned to a frequency of the 20 cycles. Accordingly this circuit will select from the received modulated carrier wave the 20 cycles impressed thereon by the oscillating circuit 145 at the transmitting station. This selected frequency will be amplified by the three element tube 219 and transmitted through the transformer 222 to the second stage amplifying tube 223. Before this stage, however, an impedance coil 224 is connected in the circuit for choking or keeping out any higher frequencies than the 20 cycle wave current. From tube 223 current which is transmitted through transformer 225 to the scanning element 226 which comprises a Rochelle salt piezo electric crystal having a natural frequency equal to 20 cycles and accordingly it will be oscillated in synchronism therewith.

A similar tuned circuit including the secondary of transformer 227 and the condenser 228 is resonant to 2,000 cycles generated at the transmitting station by the tuned circuit 155′. These currents are therefore selected from the received modulated carrier current and are amplified through the tubes 228′ and 229 over circuits including transformers 231 and 232 to the second scanning element 233 which has a natural period of 2,000 cycles and will, therefore, vibrate in synchronism with these currents.

From the above description the operation will now be evident. Two oscillating circuits, one at 20 cycles and one at 2,000 cycles are provided at the transmitting station which are impressed across two scanning elements having natural periods of 20 and 2,000 cycles respectively. These currents also

modulate a carrier current. Simultaneously picture currents obtained as a result of subjecting a photo electric cell to light from successive points on an image modulate the carrier current and accordingly a single carrier is radiated, modulated in accordance with the two scanning frequencies and the picture current. At the receiving station a tuned circuit tuned to the frequency of the picture currents picks out these currents from the carrier and impresses them across a quartz receiver device in a manner described in detail above. A second and third circuit each tuned to a particular scanning frequency select them from the oscillating circuit and impress them across piezo crystals having natural periods equal to the particular frequency impressed thereacross.

It will be evident that by using crystals at the transmitting and receiving stations having a natural period equal to the scanning frequency and impressing currents of the same frequency thereacross that the crystals will oscillate at maximum amplitudes and in synchronism. These crystals are known to be substantially inertialess and therefore provide no mechanical problem even at the high rate of operation to which they are subjected. Similarly, the receiving quartz crystal will respond to any frequency of picture currents without distortion, inasmuch as it also is substantially inertialess. Since no limitation beyond practical difficulties is placed upon the intensity of light at each station, a maximum intensity of light can be obtained to provide the necessary lumens of light for operation at the high speed and short light period available in television.

Although it will be evident from this description that only the simplest forms of circuit are disclosed, any form of improved radio system may be applied to my invention. The particular circuits shown are of the simplest type, inasmuch as this does not form a part of my invention. Although tubed circuits are used for separating the various frequencies, it will be evident that similar results can be obtained by means of electrical filters in which the various frequencies are filtered out rather than by employing tuned circuits.

Summarizing, the system employs a quartz crystal having a natural period of 2,000 cycles, a scanner oscillating at 20 cycles and a second scanner oscillating at 2,000 cycles. The relation between the scanners at the transmitting stations and the scanners at the receiving stations are so adjusted that they are in phase and will maintain synchronism. This is easily done because of the natural characteristics of the crystal itself. As has been mentioned before, it will be like a polarized relay and merely by determining faces of different polarity it is possible to make a phase difference, between the scanners zero. Since the constants of the electrical circuits are so chosen that a value similar to the natural period of the crystals frequencies are transmitted, and since the crystals have a natural period they must keep in step and cannot vary even by a small amount. It is evident therefore that this properly takes care of the matter of synchronizing.

In Figure 22 I have shown a form of the wave which the picture current received may take. It will be noted from this form that the wave is complicated with values above and below zero, and accordingly a quartz slab cut as the quarts 198 would allow only one-half of the wave, either the upper half or the lower half to be utilized. The efficiency therefore of the type of wedge would be only fifty per cent. In order to obtain the maximum value a double wedge such as shown in Figure 21 may be employed. In this arrangement it will be noted that the dark portions 236 of the wedge 237 is at the center of the wedge to provide for proper operation at the receiver for an area of no color value, as for example black. The wedge consists of two crystals 238 and 239 which may be secured to each other. One of these crystals is a right handed quartz crystal and the other a left handed quartz crystal. The portion in the center may be a foreign substance to which is cemented the two quartz wedges. The width of this dark portion should of course, be sufficient to completely obliterate the light which would result from the transmission of a black area. In transmitting a complex wave such as shown in Figure 22, in which the upper and lower halves are not symmetrical, the first two cycles, the amplitude of which being symmetrical, would cause light to shine on the dark area. The upper half of the curve would cause light to be impinged on the right hand side of the double wedge while the lower half of the curve would cause light to be impinged on the left hand side of the double wedge. In this manner, it is at once seen that if the curve is not symmetrical, as it probably would not be, the correct color valuation could be obtained by means of this arrangement. The double wedge could be so cut as to give the exact color valuation if the curve were symmetrical: in other words, the amplitude of one half of the cycle of a wave would be exactly the same as the amplitude of the other half. It will be understood, however, that the present invention is not limited by any particular form of wedge as there are many similar modifications thereof which come within the scope of this invention.

The scanner shown in the above system, although shown as of the type disclosed in Figure 3, may be of any of the modified forms illustrated and it will be understood that the invention is not limited to any particular form of scanner employed.

In the systems thus far described, the pictures are transmitted in either black or white or in colors by a specific circuit arrangement. In the systems now to be described, colored pictures are transmitted by the three color system. The principle of the three color process as is well known is based upon the fact that any colors in the visible spectrum can be matched by the combination of three of the so-called primary colors, namely; orange-red, green and blue-violet, popularly called red, green, and blue. It is well known that if a red screen is placed in the path of white light to act as a filter, it will permit only red light to be passed through. Similarly, a blue screen will act as a filter permitting only blue light to be transmitted therethrough and green screens will act as a filter to permit only green light to pass through. In each case, all the other light will be prevented from passing through the filter. In cases where combinations of light colors are passed through a filter, these lights may be further filtered out from each other. Conversely, it is known that by combining the above mentioned primary lights in combinations and proportions, a resultant color comprising any part of the entire spectrum may be obtained.

It is manifest from the above that if a multicolored object be viewed through the three-colored filters, namely; red, green and blue, the complementary colors only will be seen. If the complementary colors are again recombined, the original color will again be transmitted. By the use of different amounts of these colors or by the use of colors of different intensity any color in its correct value can be reproduced. A system for transmitting a picture in colors by means of the three colors scheme is disclosed in Figures 31 and 32. Figure 31 discloses the transmitting apparatus and Figure 32 the receiving apparatus.

In Figure 31 an oscillating circuit 242 similar to that disclosed in Figure 19 generates a carrier current which is radiated over the antenna 243 or over a pair of wires, not shown. A modulator 244 similar to that shown in Figure 19 modulates the carrier current in accordance with the oscillations impressed thereon. An oscillator 245 which produces currents of 20 cycles frequency and oscillator 246 producing currents of 2,000 cycles frequency as described in Figure 19, operate through circuit 244 to modulate the carrier current generated in circuit 242. A circuit 247 producing oscillations of 100,000 cycles, is provided with a double wave rectifier 248 in circuit with which are connected photo electric cells 249, 250, and 251.

It will be noted that the oscillator 245 is connected in multiple to three scanning elements 252, 253 and 254. The oscillator 246 is similarly connected in multiple to three scanning elements 255, 256 and 257.

Light from source 258 is impinged on an image 259 which is to be reproduced at a remote station. Any one beam from a point, as for example 262, is reflected through a focusing lens 263 to the scanner 257. The same beam is then reflected through focusing lens 264 to the scanner 254 from where it is again reflected through a red filter 265 to photo electric cell 249. Photo electric cell 249 is, therefore, affected only by red light emanating from the image 259. From the same point 262 on an image a beam is reflected through lens 266, scanner 256, lens 268, scanner 253 and through the blue filter 269 and photo electric cell 250 will be affected only by the blue rays emitted from the image 259. A third beam from point 262 passes through focusing lens 272, scanner 255, lens 273, scanner 252 and through the green filter 274 to photo electric cell 251. Similarly, therefore, photo electric cell 251 will be affected only by green rays emitted from the image.

From the above description, it is now clear that the rays from image 259 can be divided into their component primary colors and a separate photo electric cell is affected by the intensity of these rays. There are, therefore, produced three separate picture currents, one in accordance with the intensity of the red light from the image, a second in accordance with the intensity of blue light from the image, and a third in accordance with the intensity of green light from the image.

The currents of 100,000 cycles from oscillator 247 are rectified by the double wave rectifier 248 and this rectified current is varied in amplitude in circuits 275, 276, and 277 in accordance with the variations of the light intensity playing on the photo electric cells 249 to 251 respectively. The picture current from the photo electric cell 249 is transmitted through the transformer 255′ to the repeating and amplifying circuit 252′ including tubes 253′ and 254′ to the transformer 244′ and thence to modulator 244 and oscillator 242 and radiated over the antennæ 243.

The picture currents generated by the photo electric cell 250 are transmitted through the amplifier tubes 256′ and 257′ to the modulator 258 and oscillator 259′ of a type similar to that disclosed at 244 and 242. It will be understood, of course, that the oscillations produced in oscillator 259′ are sufficiently separated in frequencies from that produced by the oscillator 242 to enable separation thereof at the receiving stations.

Similarly, the picture currents flowing from the photo electric cell 251 are transmitted through the repeating and amplifying tubes 262′ and 263′ to modulator 264′ and oscillator 265′ from thence they are radiated over the antennæ 266′. Oscillations

generated by the oscillator 265 are, of course, of sufficiently different frequency from that generated in the oscillators 259′ and 242 to permit proper separation at the receiving stations.

It will be evident from this description that three picture currents are now transmitted, the value of each being in accordance with the amount of red, blue, or green in an image. At the receiving station shown in Figure 32, the modulated carrier currents are received over the antennæ 267 and circuit 268″ tuned to the frequency of the carrier current generated by the oscillator 242. This current is then amplified and detected by the tube 269. A circuit 272′ tuned to the frequency of 20 cycles will separate the oscillations from generator 245 from the carrier and these currents are then transmitted through the amplifier tubes 273′ and 274′ to the scanner 275′. Similarly, a circuit 276′ tuned to 2,000 cycles selects currents of this frequency from the carrier. These currents flow through the repeaters and amplifier tubes 277 and 278 to the scanner 279. Accordingly the scanner 275′ will oscillate at 20 cycles and in synchronism and in proper phase relation with the scanners 252 to 254 while the scanner 279 will oscillate in synchronism and in proper phase relation with the scanners 255 to 257. A circuit 280 tuned to 200,000 cycles will select the received picture currents from the carrier and will transmit these currents through amplifier 281. These currents will then be impressed across the quartz crystal 282 which will vibrate in accordance with amplitude of these received currents in the manner hereinbefore described. Inasmuch as the picture currents which modulated the oscillator 242 were those generated by the photo electric cell 249 which is subjected to the red light in the image 259, the quartz crystal 282 will be operated in accordance with the intensity of the red light emitted from the particular point of picture at that time being scanned.

Similarly the circuit 283 is tuned to the frequency of the carrier current generated by cell 259. These currents will, therefore, flow in this circuit and through the detector and amplifier tubes 284 and 285 and will then be impressed across the quartz crystal receiver 286. It will be recalled that the currents generated by the oscillator 259′ were modulated by picture currents from the photo electric cell 250 which in turn was operated in response to the blue portions of the image and accordingly the crystal 286 operates in accordance with the intensity of the blue light emitted from the image the particular point thereof being scanned at that instant. Similarly, the oscillating circuit 287 is tuned to the frequency of the oscillator 265′ modulated by picture currents. These currents, will therefore, be picked up, amplified and detected by the tubes 288 and 289 and then impressed across the quartz crystal receiver 290 which in turn will operate in response to the green light emitted from that point of the picture at the instant being scanned due to the fact that the currents generated by the oscillating circuit 265′ are modulated by currents from the photo electric cell 251 responding to the green light rays of the picture.

A beam of light from a source 292 passes through the proper lens arrangement 293 and thence through a red filter 294 so that only red light is refracted by the quartz crystal receiver 282. The red light then passes through the lens in front and back of the light gradient 295, and impinges upon the mirror 296′ from whence it is reflected to the scanners 279 and 275′ from where they are impinged to produce an image upon the screen 296. Since the intensity of this light will depend upon the extent of displacement of the beam through gradient 295, it is evident that the amount of light which will be impinged upon the scanner 179 will be of the same intensity as the red light which is impinged upon the photo electric cell 249. Similarly, light from a source 297 passing through the proper lens arrangement 298 and thence through the green filter 299 is shifted in accordance with the expansion or contraction of the quartz crystal receiver 290, passes through the proper lens system 301 and light gradient 302 to the scanners 279 and 275′ and screen 296. Since the intensity of the green light thus emitted depends upon the operation of the quartz crystal 290 which in turn is operated in accordance with the amount of light impressed upon the photo electric cell 251 which in turn is a function of the green light emitted from the image 259, it will be evident that the amount of green light impinged upon the screen 296 is proportional in this instance to the amount of green light emitted from the image at the transmitting station. In a similar manner the beam from the source 303 passes through the lens arrangement 304, the blue filter 305, the crystal 306, the lens arrangement 307, light gradient 308 to the scanning elements 279 and 275′.

From the above, it will now be evident that at any instant the amount of light impinged upon the screen 296 at the receiving end comprises red, blue and green light in proportions equal to the amount of red, green and blue light in the image 259 being transmitted from the transmitting station, at that point and at that instant.

When at the receiving end, the proportions of red, green and blue are in proper amounts, the resultant picture produced will be of the same color as that emitted from the image at the transmitting station.

It will be noted from the above descrip-

tion, that while three sets of scanning elements are employed at the transmitting end, only two are employed at the receiving end for performing the same scanning operation.

The use of so large a number of scanning elements clearly complicates the system and I accordingly disclose in Figures 33 and 34 an embodiment of my invention for transmitting pictures in color with two scanning elements at the transmitting station and two scanning elements at the receiving station.

Oscillating circuit 311 generates a frequency of 20 cycles and operates a scanning element 312. Current from oscillator 311 is also transmitted through transformer 313 and impressed across a modulator 314 and carrier current oscillator 315. A second tuned circuit 315′ operates a scanner 316 and current therefrom at 2,000 cycles per second, is transmitted through 317 and impressed across the modulator 314 and oscillator 315. Alternating currents of about 100,000 cycles are generated in the oscillating circuit 317′ which operates through the double wave rectifier 318 producing pulsating currents of this frequency which are varied by picture currents in the manner to be described in detail hereinafter. It will be noted that the mirrors on the scanners 312 and 316 are three-sided for a purpose which will appear more clearly hereinafter.

All of this apparatus has been described in detail in connection with Figure 19, and need not, therefore, be repeated here. A source of white light 319 projects a beam of light upon an image 320. From point 321 on image 320, three rays 322, 323, and 324 emanate. Considering the first ray 322, passing through lens from mirror 325 to the first scanning element 312 at point 326. From this scanning element the beam is reflected to a second reflector 327 and then to the second scanning element 316 at 328 from where in passes through a red filter 329 to the photo electric cell 332. The second beam of light from the same point 321 on the image passes through the focusing lens 333 to point 334 on the scanner 312, and then passes through the focusing lens 335 to point 336 on the scanner 316. From the second scanner the beam passes through the blue filter 337 to the photo electric cell 338. The third beam from point 321 on the image 320 passes through lens and is reflected by the mirror 339 to the first scanning element at point 341, thence to the reflector 340 to the second scanner element 316 and thence through the green filter 343 to the photo electric cell 344.

It will be evident from the above description that the beam of light from the image separated into three component parts by means of the reflector mirrors 325, 327, 339 and 340 is impinged on three independent photo electric cells. In this manner three picture currents, one from each of the photo electric cells, are produced, one varying in accordance with the intensity of red light emitted from the image, a second in accordance with the intensity of blue light emitted from the image from that point, and the third in response to the intensity of green light emitted from that point of the image, the three cells being operated simultaneously. It will be evident, of course, that the same point of the picture need not necessarily be impressed on the three photo electric cells simultaneously, if an equivalent arrangement is provided at the receiving end so that, if for example the red light from the uppermost point of the picture is impressed on the photo electric cell 332, and the green light from the lowermost point is impressed upon the photo electric cell 344, if at the receiving end the blue, red and green lights are respectively impressed simultaneously on the upper, middle and lower portions of the screen simultaneously and all the points are scanned for each color, the result will be the same as though a single point were analyzed into its component light values simultaneously.

The 100,000 cycles generated in the oscillating circuits 317′ and translated into pulsating currents of 200,000 pulsations by the double wave rectifier 318 are repeated through the transformer 346 and impressed across the input of the three element tube 347. Tubes 348 and 349 together with choke coil and condensers shown, comprise an oscillator-modulator in which the tube 349 is the oscillator and the tube 348 the modulator. Tube 349 generates a high frequency alternating current. The currents from the tube 347 are impressed upon the modulating tube 348 which in turn modulates this high frequency current. This modulated high frequency current is impressed upon the modulated tube 314 of the oscillator 315. The modulated picture currents are thus produced in the output circuit of the oscillator of a frequency equal to that generated in the oscillating circuit 318. Similarly, currents from the photo electric cell 338 vary the amplitude of the current in the circuit 318 and these currents are repeated through the transformer 352 through the oscillator and amplifying tubes 353 to 355 and these picture currents are transmitted through transformer 356 and impressed across 314 and carrier current oscillator 315. The picture currents generated in photo electric cell 344 vary the amplitude of the currents in the circuit 318 and are impressed across the input of the tube 357. The amplified currents are transmitted through transformer 360 across the oscillator 358. These currents from the oscillator 258 are modulated by the picture currents from photo electric cell 344 and are impressed across the modulator 314 and oscillator 315. It will be understood, of course,

that the oscillators 349, 355, and 358 each generate currents of frequencies widely different from each other and different from the carrier current oscillator 315, so that they easily can be separated from each other.

At the receiving station, currents are received over the antennæ 363, are repeated through the radio frequency transformer 368, to the tuned radio frequency circuit 369, tuned to the frequency of the carrier current generated by the oscillator 315. These currents are then detected and amplified by the three element tube 372. A filter circuit 373 is designed to permit only currents of 20 cycles to pass therethrough and will accordingly select from the modulated carrier currents received those frequencies generated by the oscillator 311. These selected currents are then transmitted through the amplifying tubes 374 and 375 and are impressed across scanner 376. Scanner 376 is a crystal having a natural period of 20 cycles and will, therefore, oscillate in synchronism and phase with scanner 312. A second filter 374′ is designed to permit only currents of 2,000 cycles to pass therethrough and accordingly selects from the modulated carrier current receiving those generated by the oscillator 315′ at the transmitting station. These currents are amplified through the tubes 375′ and 376′ and are impressed across the second scanning element 377. Scanner 377 is a crystal having a natural period of 2,000 cycles and is accordingly maintained in oscillation at 2,000 cycles and will be maintained in synchronism and phase relation with the second scanning element 316 at the transmitting station.

For the reception of the picture current, tuned circuits 378, 379 and 380 connected to the receiving circuits through transformers 381, 382, and 383 are provided. The circuit 378 is tuned to the frequency of the alternating currents generated at 348 and will, therefore, select currents of these frequencies from the receiving currents. These are first detected by the tube 385 and then amplified by the tubes 386 and 387.

The output from the tube 387 is then impressed across the quartz slab 388 the expansion and contraction of which, therefore, is varied in accordance with the variations of picture currents which in turn are proportional to the intensity of a red light being at that instant impinged on the photo electric cell. Similarly, the transformer 382 connects the circuit 379 which is tuned to the alternating current generated at 354. These currents are, therefore, selected from the received waves and impressed across the detector tube 388. From the output of the tube 388, these currents are amplified through the tubes 389 and 392, and impressed across the receiving quartz slab 393, the expansion and contraction of which is accordingly varied as a function of the amplitude of blue light at the receiving station. In a similar manner the currents varying according to the intensity of green light, received currents are transmitted through the detector tube 394 and amplifier tubes 395 and 396 are impressed across the quartz crystal 397. A source of white light 398 impinges light on each of the three crystals, 388, 393 and 397 through light filters 401 to 403, filter 401 permitting only red light through, filter 402 permitting only blue light through the filter 403 permitting only green light through. The red light is refracted by crystal 388 and is displaced in a manner already described in detail, in accordance with the intensity of the red light at the transmitting station, emanating from the picture at that instant. This displaced light then passes through a light gradient 404 which varies the intensity of the light in accordance with the picture thereof, through which the light passes which in turn depends on the extent of displacement of the beam. The beam then passes through the focusing lens 405 and scanners 377 and 376 to screen 410. The intensity of red light impinged on the screen 410 is, therefore, proportional at all times to the component of red light in the image.

Similarly, the intensity of blue light is varied in accordance with its displacement by crystal 393 by the light gradient 406 and reflected to screen 410 by scanners 377 and 376 and the intensity of green light is varied by the light gradient 407 in accordance with its displacement, which in turn is a function of the green light in the image 320. In each instance focusing lens such as 408 and 409 are employed. Inasmuch as the intensity of the red, green and blue light are varied in accordance with the modulated ray, currents which are in turn functions of the light intensity of the respective colors in the image at the transmitting station, the resultant beam reflected by the first scanning element 377 will be a composite of these three in proportions equivalent to the image 320 and a beam will be impinged upon the screen 410 of a color substantially proportional to that which affected the photo electric cells at the transmitting station at that instant. This beam of varying color is moved over the entire screen 410 by the scanning elements 377 and 376 as the crystals vibrate thus producing a picture current equivalent to that at the transmitting station.

In the above, I have described a preferred embodiment of the crystal arranged to respond to received picture currents. It will be evident, however, that this may take other forms, such as reflections without any refractions.

Referring to Figure 24, the quartz slab 412 of the type already described in detail in the above, is arranged to expand and contract in accordance with the received picture as shown by the dash lines 413 and 414. A mirror 415

is secured to the crystal and a second mirror 416 placed opposite thereof. A beam of light 417 is impinged upon the crystal at 418 when the crystal is in its normal state. This beam then emerges at 419 after a number of reflections. It will be assumed that the quartz crystal 412 contracts, that is, its side 415 assumes a position along the dash line 413. The beam is then reflected as shown in the illustration and emerges at 422. If the quartz slab is expanded and assumes a position along the dash line 414, the ray of light will then be reflected at 423 and will emerge at 424. The distance between 422 and 424 is the displacement due to the expansion and contraction of one side of the quartz slab, as was explained in detail above.

In Figure 25, I have shown an arrangement for increasing this distance between the emerging beams to a considerable degree in order to obtain greater variations in the beam. This is accomplished by employing a convex mirror 426 as the stationary reflecting mirror. The ray of light 427 is impinged on the reflecting mirror 428 attached to the expanding and contracting quartz slab 429. This beam is reflected at 431 when the slab is in a contracted state, will follow the paths of the beam, and will emerge at 432. When the slab, however, is expanded the beam is reflected at 433 and emerges at 434. It is evident from this, that the same ray of light impressed upon the crystal at the same angle has a greater degree of displacement than in the arrangement shown in Figure 24, due to the fact that the mirror is convex instead of plain. All that is necessary, therefore, in order to obtain any desired degree of displacement is to substitute various combinations of mirrors.

In the above illustration, the quartz slab is used as a reflector. A further modified form in which both refraction and reflection take place is illustrated in Figure 26. Two plain mirrors 436 and 437 inclined at an angle to each other are positioned on opposite sides of a quartz crystal 438 and a beam of light 439 is impinged thereon. If the quartz crystal 438 is compressed, the beam of light 439 will after undergoing several reflections and refractions emerge at 441 as shown. When the crystal is in its natural slab, however, the beam will emerge at 442 due to the greater thickness of quartz through which the beam must pass and which, therefore, refracts the beam to a greater extent and also due to the varying angle the beam 439 makes with mirrors 436 and 437.

In Figure 27, the manner of mounting the crystal designed to be used in the deflecting method is disclosed in which a crystal 412 is set in a hard rubber base 444 which is so cut as to allow the crystal to move in any direction. A slightly convex mirror 443 with recesses 444 and 445 cut therethrough to allow the passage of rays of light is secured opposite the crystal. The crystal 412 together with the base 444 and the mirror are held in place in the container 447, as shown in the drawing. To the silver deposit on the crystal is soldered or cemented leads 448 and 449. If only one side is used, electrodes upon which the crystals rest, may be of tin foil. If both sides are used, both should have silver coatings. In Figure 28 the slots 451 and 452, in permitting the beam to enter the container, are shown.

It will be recalled that in Figures 33 and 34, an arrangement for employing a single scanner to transmit the three primary colors was shown. In Figure 29, I have shown a modification of this arrangement. A scanner 453 comprising three sections 454, 455 and 456 is arranged to reflect a single beam 457 from one point 458 on an image 459 to three photo electric cells 461, 462 and 463. It will be noted that similarly, a beam emitted from the point 464 impinges upon the scanner at 456 and is reflected to the photo electric cell 463. A beam from the same point 464 is impinged on the scanner at 455 and is reflected to the photo electric cell 462 and a third beam from the same point 464 impinged upon the scanner at 454 and is reflected on the photo electric cell 461. The scanning mirror 453, it will be noted, is made up of three distinct mirrors bent at different angles so as to deflect the image in the manner described above. This is a preferred arrangement of mirrors in accomplishing this result although it will be understood that any similar arrangement may be employed.

In Figure 30, I have shown in detail the circuits and apparatus employed in the oscillator for generating picture currents. The oscillator 465 comprises a three element vacuum tube 466, and a variable condenser 467. This tuned circuit generates currents of approximately 100,000 cycles. Currents from this oscillator are impressed through the transformer 467′ across the double wave rectifier comprising two rectifying tubes 469 and 470. The rectified wave is impressed across the photo electric cell 471 and resistance 472, and the amplitude varied in the manner well known in accordance with the intensity of light impinged on the photo electric cell. A resistance 472 is connected across the input of the three element amplifying tube 473 through which the picture currents are amplified.

In Figure 23, a light gradient 481 is shown which is used in conjunction with Figures 32 and 34. It consists of a slab of glass 591 which is opaque at 592 and varies in opacity in either direction to pure transparency. It is clear that the intensity of light which falls on the screen will vary in intensity depending upon the portion of the slab through which the beam passes. Since the displacement of the beam is a function of the picture

currents, it is clear that the light intensity will vary in accordance therewith.

In Figures 15 and 16, a quartz crystal is shown, in a vertical position whereas Figure 9 discloses a container for such a quartz crystal to accommodate the crystal in a horizontal position. Figure 7 is a showing of a container built to house a quartz crystal in a vertical position. As was described in detail in the above, the expansion and contraction of the quartz takes place along the electric axes but does not take place along the optic axes 62 in Figure 8. Accordingly, I have shown in Figure 7, a container built to house a quartz crystal in a vertical position. The quartz 500 in Figure 7 is mounted to rest on a side perpendicular to the optic axes and has wrapped about its end a rubber tape 501 and 502. The crystal 500 is then inserted in the channel holders 503 and 504 which are rigidly connected to the side 505 and 506. These sides have slots 507 and 508 through them to accommodate the passage of a beam of light for purposes described above. Plain or convex mirrors 509 and 510 are positioned on the opposite sides of the crystal for reflecting the beam of light in the manner described in detail above. Tin foil coatings 511 and 512, soldered to leads 513 and 514 are wrapped about the quartz crystal 500. As will now be clear, expansion takes place in a direction perpendicular to the optic axes but not parallel to the optic axes so that the crystal can be held firmly by sides 503 and 504. It will be evident from that, the crystal holder may be used for a crystal in any position whatsoever.

In Figure 35 a modified system for transmitting an image in color, making use of only a single carrier current and eliminating entirely the rectification arrangements for the photo electric cell is disclosed. As is well known in the art, photo electric cells are comparatively insensitive to light of low intensity. When, in addition to low intensity, the light is of short duration the amount of light lumens impinged on the cell is small and the problem of actuating the photo electric cell is one of paramount importance.

Heretofore, in the transmission of television images the required intensity of light has been obtained by illuminating the image with an intense beam of light. It is obvious, however, that crude arrangements is exceedingly uncomfortable to the subject and is furthermore inefficient inasmuch as only the light from that point on the image which is at the instant being scanned, is reflected to the photo electric cell.

Accordingly, a system is disclosed in Figure 35 in which a strong beam of light is first impinged upon the scanner and then brought to focus upon the image and the reflected light is gathered by large photo electric cells, three or four in number, connected in parallel. Since in such an arrangement all the light from the source is impinged on the photo electric cell each scanning position is sufficient to activate the photo electric cells and produce a comparatively large pulsating current of sufficient strength to be beyond the moise value of detecting and amplifying tubes.

An oscillator 525, as described before, is adjusted as to generate alternating currents of 2,000 cycles per second and oscillator 526 is adjusted to generate oscillations of 20 cycles per second. These oscillations are transmitted to scanners 527 and 528 which will scan the image at 2,000 and 20 cycles, respectively. An intense beam of light from the source 529 is focused upon the scanner 528 by the lens 530 from whence it is reflected and focused by the lens 531 on the scanner 527. From the scanner 527 the beam is impressed upon the image 532 at a point 533 depending upon the relative scanner positions. This light is reflected from point 533, to the four photo electric cells 534, 535, 536 and 537, connected in parallel.

A source of direct current 538, the intensity of which varies in accordance with the variations of light intensity reflected from the image is impressed upon these cells through the primary winding of transformer 539, and the resistance 540. These variable currents flowing in the primary winding of transformer 539 produce proportionately fluctuating voltages which are impressed across the grid 540 of the vacuum tube 541.

The primary winding of transformer 542 is placed in the plate circuit of the tube 541 in which the amplified picture currents flow and as a result amplified oscillations generated in the secondary are impressed upon the grid 543 of the modulating tube 544 of the oscillator modulator 545. The oscillating tube 546, together with condenser 547, the choke coil 548 and the transformers 549 and 550 will oscillate at a high carrier current frequency which is modulated by the picture currents in the output of modulator 545, and will radiate through the antenna 551.

This comprises the entire transmitting system. In one particular it differs from the other systems heretofore described in so far as no scanning current frequencies are transmitted. The only frequency transmitted is the picture current. Furthermore, all of the light from the source is at all times available for the photo electric cells. Picture currents are further amplified by utilizing a plurality of cells and operating them at their most efficient values.

Figure 36 is a receiving circuit which is used in conjunction with the transmitting circuit just described. Inasmuch as no scanning current frequencies are transmitted these must be produced at the receiving station. However, since the scanning current fre-

quencies are kept constant at the transmitting station, it is only necessary to supply the same frequencies at the receiving station, the differences in phase being taken care of by the adjustments on the condensers of the oscillators.

Another feature of this receiving system resides in the use made of the heterodyne principle in the scanning system. Since a quartz crystal operates at a constant frequency whose amplitude may be varied, it is impossible to cause it to respond to photo electric cell impulses, since these are not constant either in amplitude or in frequency. The crystal is, therefore, kept at a constant frequency whose amplitude is varied by the variations in the photo electric cell currents.

The receiving antennæ 552 is connected in circuit with the transformer 553. The transformer 553 and the condenser 554 comprise a tuned circuit, tuned to the frequency of the carrier wave emitted by the antenna 551. Oscillations radiated from antenna 551 are accordingly impressed upon the grid 555 of the vacuum tube 556 the function of which is to detect and amplify these oscillations so that a greater current flows through the primary of the transformer 557.

The tube 558 together with the choke coil 559, the condenser 560 and the vacuum tube 561 comprises a de-modulator-oscillator as described in previous drawings. The amplified oscillations in the output of tube 556 are, therefore, impressed upon the grid 562 of the modulating tube 558. These modulate the carrier current in the circuit of the tube 561 which flows through the transformers 563 and 564. The secondary windings of the transformers are connected to the quartz crystal 565. It is manifest, therefore, that the quartz crystal will vibrate at a constant frequency equal to that of the oscillator tube 561. This constant frequency will be modulated or its amplitude varied by the modulating tube 558, in which picture currents flow. In other words, the amplitude of the quartz crystal is modulated by the output of the photo electric cells.

A source of intense white light 566 which is brought to focus upon the quartz crystal 565 by the lens 567 is refracted and reflected by the mirrors 568 and 569 and made to pass through the lenses 570 and 571, the Nicol's prism 572, lens 573, quartz wedge 574, lens 575, Nicol's prism 576, lens 577 and brought to focus upon the scanner 578. This arrangement for receiving colored impulses has been described before, and need not be gone into detail here. It is manifest that some of the other systems which I have described will also accomplish the same results, this one being chosen simply by way of illustration.

The oscillator 579 is so adjusted by the condenser 580 and the transformer 581 that it will oscillate at a frequency of 2,000 cycles per second. By virtue of the transformer 582, these 2,000 cycles are impressed upon the scanner 578. If it is desired to alter the frequency to conform to the phase of the scanner in the transmitting set, all that is necessary is to adjust condenser 580.

The transformer 583 is placed in the plate circuit of this oscillator and will also have 2,000 cycles impressed upon its secondary. The oscillator 584 is so adjusted by the transformer 585 and the condenser 586 as to oscillate at 1,980 cycles per second and by virtue of the transformer 587, 1,980 cycles per second are impressed upon its secondary. As is well known, therefore, the resultant frequency in the secondaries of the transformers 583 and 587 will be 20 cycles per second which 20 cycles are impressed upon the scanner 588. The light from the scanner 578 is reflected through the lens 589 upon the scanner 588 and from thence to the image 590. It will be clear that it is not necessary that the two condensers be variable, as the same results can be obtained with one fixed and the other variable.

It will be clear from the above that a television system is disclosed in which no synchronizing currents are required. It is recognized that by using local sources of alternating currents a sufficient degree of synchronism for practical purposes can be obtained. By proper adjustments for phase relations, accurate synchronism can be obtained.

From the above descriptions, it will now be clear that systems are shown for transmitting pictures at a sufficiently high rate to produce an impression to an observer of a continuous moving scene, substantially as is produced by motion pictures. In carrying this out, I employ scanners which have substantially no mechanical inertia and which in their natural state have natural periods of vibration which they tend to maintain. By means of scanners of this character it now becomes a comparatively simple matter to scan images at high speeds and in synchronism which is substantially perfect because self maintained by inertialess elements.

It will be further observed that the receiver devices which respond to the picture currents also have a natural period equal to the rate at which current variations are received, are also substantially without mechanical inertia and will, therefore, respond to current variations of the highest required rate of variation.

By a simple and novel arrangement, I have separated the color components of an image and recombined these in the same proportions at the receiving station for transmitting pictures in colors. This I accomplish by either a plurality of independent scanners or by the same single pair of scanners at each station.

Although I have shown my invention as applied to a specific system, it will be understood by those skilled in the art that it has many other adaptations and I do not intend to limit myself except insofar as set forth in the appended claims.

I claim:

1. In a television system, a transmitting station, a receiving station, an image located at said transmitting station, a piezo electric crystal at said transmitting station arranged to scan said image, a piezo electric crystal at said receiving station, means common to said piezo electric crystals at each station for operating said crystals in synchronism, a photo electric cell at said transmitting station, means including said scanning crystals at said transmitting station for subjecting said photo electric cell to light rays from successive portions of said image, means including said photo electric cell for transmitting currents to said receiving station in accordance with the intensity of light from said image to which said photo electric cell is subjective, and a piezo electric crystal at said receiving station responsive to said picture current for varying a source of light thereat in accordance with the variations of said current.

2. In a television system, a transmitting station, a receiving station, an image at said transmitting station, means for transmitting a varying current at a definite frequency from said transmitting station to said receiving station in accordance with the variations of light intensity of successive portions of said image, a piezo electric crystal having a natural period of expansion and contraction equal to the scanning frequency, said crystal being responsive to said varying current to vary its extent of expansion and contraction, a source of light at said receiving station, and a screen in the path of said ray of light, the intensity of said ray of light impinged on said screen being varied by said crystal in accordance with the variation of expansion and contraction thereof by said picture current and movements thereof being amplified by successive deflections.

3. In a television system, means for transmitting varying currents at a definite frequency in accordance with light variations from portions of an image, a source of light, an element having a natural period of oscillation equal to the rate at which said currents are varied, said element being varied in accordance with said varying current and means for varying the intensity of said source of light in accordance with the operations of said element by said current and movements thereof being amplified by successive deflections.

4. In a television system, a transmitting station, a receiving station, an image at said transmitting station, means at said transmitting station for simultaneously generating picture currents of variable amplitude in accordance with variations of color in said image, a source of white light at said receiving station, a device responsive to said currents for displacing the ray of white light from said source in accordance with the amplitude of said currents, and means for rotatably polarizing said beam of light in accordance with the extent of its displacement whereby an image equivalent in color to that of the image at the transmitting station is produced at said receiving station.

5. In a picture transmitting system, a photo electric cell, means to subject said cell to light intensities varying in accordance with a scanning of an image, a source of pulsating electric current in operative relation with said photo electric cell and a by-pass connection across said photo electric cell whereby a minimum pulsating current flow is maintained irrespective of variations in the light intensities.

6. In a television system, a transmitting station, an image comprising various combinations of colors at said transmitting station, a single scanning element for scanning said image along one of its co-ordinates, a second scanner for scanning said image along the other of its co-ordinates, each of said scanners being arranged to separate light from a successive point on said image into three light rays and means for filtering from each of said three light rays, a component primary color.

7. In a television system, a transmitting station, a receiving station, an image comprising various combinations of colors at said transmitting station, a single scanning element for scanning said image along one of its co-ordinates, a second scanner for scanning said image along the other of its co-ordinates, each of said scanners being arranged to separate light from successive positions on said image into three light rays, means for filtering from each of said three light rays a component primary color, means for producing currents in accordance with the intensity of each of said filtered primary colors, a screen at said receiving station and means for impinging rays of said three primary colors on said screen in the same proportion as emitted from said image at said transmitting station.

8. In a television system, a transmitter, an image to be transmitted, a source of light, a plurality of photo electric cells, means for impressing on all of said cells current waves of the same frequency, means for impinging all of said light on successive points of said image and means for reflecting the light from any one point on said plurality of photo electric cells whereby said cells all operate at the same frequency.

9. In a television system, a transmitter, an

image to be transmitted, a source of light, a plurality of photo electric cells, means for impressing on all said cells current waves of the same frequency, means for impinging all of said light on successive points of said image, means for reflecting the light from any one point on said plurality of cells, a source of carrier currents and means for modulating said source accordance with the currents flowing through said photo electric cells.

10. A television transmitter having, an oscillator for generating currents of picture current frequencies, a double wave rectifier, means for impressing said oscillations across the double wave rectifier, a photo electric cell subjected to light from an image connected in operative relation with said rectifier and means cooperating with said cell to maintain the resultant pulsation frequency in said rectifier constant and to vary the amplitude thereof in accordance with the light variations impinged on said cell.

11. In a picture transmitting system, a transmitter having a source of alternating current of a definite frequency, a double wave rectifier in operative relation with said source of alternating current for rectifying said currents, a photo electric cell for receiving light from an image to be scanned and means including circuit connections for impressing said rectified waves across said cell and for permitting constant flow of said circuit even when said cell is nonconducting.

12. In a television system, a piezo-crystal, a mounting therefor, a reflecting member movably supported by said mounting, means for subjecting said crystal to a varying electric current to cause deformations thereof, and a movement multiplying connection between said crystal and said reflecting means whereby movements of said crystal due to varying currents will cause amplified movements of said reflecting means.

13. In a television system, an image to be transmitted, a plurality of photo electric cells, means for moving a beam of light over the surface of said image, means for impinging said light upon all of the said cells and a single source of pulsating current of constant frequency in operative relation with said cells for simultaneous modulation in accordance with the light impinged in said cells.

14. In a television system, a transmitter, an image to be transmitted, a plurality of photo electric cells, means for impressing pulsating currents of the same frequency on all of said cells, a source of light, means for moving said light over the surface of said image, means for reflecting the light from said image on said photo electric cells, a source of carrier currents and means for simultaneously modulating the source in accordance with the currents flowing through all of said photo electric cells.

15. In combination, an image, a plurality of photo electric cells, means for simultaneously varying all said photo electric cells in accordance with variations of successive points of said image, a source of carrier current, means controlled by all of said photo electric cells for jointly controlling said source of carrier current, a receiving station, a piezo electric crystal, means for varying said piezo electric crystal in accordance with the variations of said light responsive means and a source of light controlled by said piezo electric crystal.

16. A television transmitter having a photo electric cell, means to impress thereon light varying in accordance with a scanned image, an oscillator for generating currents of constant frequency, a double wave rectifier connected to said oscillator, and means for impressing the rectified current from the rectifier on said photo-electric cell whereby the cell varies the amplitude only of the constant frequency current waves.

17. In a picture transmitting system, a photo-electric cell, means to impress thereon a light ray varying in accordance with the scanning of an image, and means for impressing on said cell uni-directional current waves at a constant frequency, whereby the current waves are varied in amplitude by the varying light ray, the frequency thereof remaining constant.

In testimony whereof I affix my signature.

SAMUEL FEINGOLD.