High Frequencies for Color Television

Mechanism Required to Produce Images in True Colors Will Present Few Difficulties, But Great Width of Frequency Bands Will Create Some Problems of Transmission

By C. Sterling Gleason

SOME day television will not be limited to the dull monotony of mere black and white, but will be accomplished in all the colors of the rainbow. A short time later, some manufacturer will place upon the market apparatus for transmitting images in their natural colors, and the reproduction will be so lifelike and realistic that everyone will admit that radio, so long in its infancy, has grown to full stature, to take its place beside interpretative dancing, china-painting, bridge, the movies, and other full-fledged arts and sciences.

This possibility is not as remote as it may seem at first glance. Color television meets obstacles not greatly different from nor more difficult than those which now prevent the extensive application of television. Ordinary television outfits can be adapted to color vision simply by the addition of some mechanism which will analyze each elementary area of the picture as to its color and tone intensity; so that at the receiving end the proper color will be selected and thrown upon the screen in the necessary intensity.

A SIMULTANEOUS METHOD

How could this be accomplished? A method is suggested by the fact that various materials showing photoelectric properties respond most strongly each to a certain color or frequency of light. For each material there is a definite frequency of light at which photoelectric activity commences, and this activity reaches a peak at a critical frequency. If this selective effect can be intensified and regulated, by means of color filters or otherwise, three photoelectric cells, each sensitive to one of the primary colors, might be connected to three separate television transmitters. If, then, three receiving outfits were arranged to throw their light upon the same screen, the combined images, each representing the amount of a primary color in the original scene, would be superimposed to reproduce the image in its natural colors. At each moment, the light falling upon an elementary area of the screen would be the resultant of whatever red, yellow, and blue light was being projected from the three receiving sets; and the *quantity* of each color of light would be that dictated by that particular receiving connection or channel.

Such a method is, of course, so complicated, and would require such an accuracy of synchronization, as to be entirely out of the question. Just as the first suggested television system (requiring as many separate photoelectric cells and connecting circuits as elementary areas of the screen) was too complicated; so this color system would allow too many possibilities of error in synchronization and in getting the right proportions of color to be practical. Now the great advance, by which the objections to the early method were escaped from, was

Mr. Gleason is well known to our readers as a contriver of humorous stories, each of which, however, is based on a phenomenon of radiation. This article is a serious consideration of the scientific side of color television.

the use of the "scanning disc," by means of which all the unit areas of the screen are covered in rotation instead of being presented independently and simultaneously; thus enabling a single photoelectric cell and transmission channel to handle all the vision impulses. It is made possible by the tendency of the eye to "hold over" after being stimulated. So long as the entire image is presented, serially or as a unit, at least fifteen times per second, the eye will fuse the individual impulses into a complete picture.

SUCCESSIVE COLORED IMAGES

Here is a key to color television. If the eye will blend fifteen short flashes a second into a continuous picture, it will surely fuse colored fragments as well. Suppose, then, that the transmitter is equipped with a device causing it to respond first to the reds in the image, then to the yellows, then to the blues. The receiver synchronously reproduces the image according to the relative strength of the impulses it receives; presenting it first in red, then in yellow, then in blue. The whole cycle repeats itself often enough to allow the eye to blend the impressions into a smooth picture. Since red and yellow make purple, yellow and blue make green, and red, yellow and blue make grey or a neutral color, the combination of the primary colors in varying proportions will cause the image to be reproduced in its natural colors.

But how can the transmitter analyze the colors of the object? We may image a scene being "televised" in colors by an operator sitting, microphone in hand, beside an ordinary television outfit, and describing each dot or unit area of the picture as it came opposite the aperture. "Red, red, green, blue, yellow, orange, violet, brown—" he names the colors and, as he calls each, an operator holds before the television lamp by which the received picture is built up, a transparent screen or slide of that color, so that the light, whose intensity is automatically regulated by the televisor itself, is given the proper color. Such a scheme would work very well—if it were fast enough. But in television, the whole image, consisting of many thousand unit areas, must be scanned several times each second. This means that hundreds of thousands of dots must be analyzed, transmitted, and reproduced every second—a rapidity far beyond human possibilities.

Before considering the method of translating color into electrical impulses let us recall a simple fact in optics. Every woman knows that cloth purchased in the store under artificial illumination often appears entirely different in daylight. The reason is that daylight contains all frequencies of light, while in the artificial light, certain wavelengths predominate, others often being entirely absent. A colored picture viewed under red light appears all out of proportion—certain portions receive undue prominence, others are thrown into obscurity. If the same picture is seen under a blue light, its aspect is entirely different. Areas which under red light were dim are now accentuated, other portions which were bright are darkened. Why? Simply because, under red light, the portions of the picture normally red reflected the light to the eye; those colored otherwise absorbed it. When blue light is used, those portions responsive to that region of the spectrum come into prominence, the light being "reradiated" to the eye, while other portions absorb it.

Suppose a white object—that is, one which reflects all frequencies of light—is viewed first under red light, then under blue, the two colors being alternated very rapidly. Because the eye continues to respond to the light for a fraction of a second after the stimulus is removed, the two colors are blended into one—a purple. Let three colors be alternated—red, green, and blue-violet, the optical primary colors—and the resulting color is some shade of grey, some neutral color; its exact shade depending upon the relative proportions of the mixture. It is apparent that, by rapidly alternating the primary colors, we may obtain the effect of any color we wish, just as an artist mixes pigments to get the desired tones.

TRIPLE COLOR ANALYSIS

This, then, is our method: to illuminate the object being televised with light of the three primary colors—alternated. Each portion of the object responds to its own color, and reflects more or less light to the photoelectric cell, thereby translating the image into variations corresponding to the light and shade values of that particular color. So far as the electrical characteristics of the output are concerned, the transmitted rendition of the image is not different from ordinary black-and-white-image currents. The coloring is entirely an illusion of the eye, just as the motion in motion pictures is purely imaginary. The receiver gives the primary colors synchronously with the transmitter, the photoelectric cell regulates the amount of each color going into the combination, and the rapidity with which the alternation occurs enables the eye to fuse the separate impulses into a composite image in natural colors.

Let us visualize the operation of a transmitter operating according to these principles. Instead of the standard scanning disk of black-and-white television, let us use one of the same design, except that instead of each of the spiralled holes through which the light passes (in many systems containing a lens to focus the light), it contains three; those of each trio being close together and equidistant from the center. The line traced by a scanning hole is thus covered three times in succession. Before each of these holes or lenses is set a colored, transparent disc or screen of one of the primary colors, so that the light is colored in passing. A single hole in the scanning disc comes opposite the aperture, admitting a thin pencil of light—red light, which is reflected to the photoelectric cells in amounts depending upon the amount of red contained in each unit area of the object. As the ray reaches the edge of the field and is cut off by the aperture, another simultaneously appears and retraces the line in green. This, in turn, gives way to a ray of blue-violet, and the same line takes on a still different aspect as the darker shades of the spectrum come into prominence. This cycle has taken the same time as to scan one line, in ordinary television. The next trio of holes now comes into play, and a line parallel to and just below the previous line is scanned in the three primary colors. The spiral of the disc moves on, until the whole of the picture has been covered, and the rotation brings the first trio into play once more. (*The reader will at once note the identity of this layout with the Baird color-television system, described in our October issue; the details of which had not been published when this manuscript was received.*—EDITOR.)

At the receiving end, the motor, running in synchronism with that at the sending station, carries upon its shaft a disc exactly similar to that used for transmission. Out of the ether comes an electrical impulse which, traveling swiftly through the amplifier and associated circuits, flashes the television lamp behind the scanning disc. Colored by the glass slide or transparent screen, through the hole in the scanning disc at that moment before the aperture passes a ray of red light, which fluctuates from bright to dark, exactly as the photoelectric cell of the distant transmitter analyzes the object. A single line of the picture is built up in red, then immediately in green, then in blue-violet. In a fraction of a second the whole picture has been traversed—too rapidly for the eye to see each change individually. It sees, not a rapidly-changing series of lines in primary colors, but the result of blending of these colors into their proper proportions: a picture in the true colors of Nature!

REFINEMENTS OF THE METHOD

Let us simplify this method still further. In front of the ordinary scanning disc of black-and-white television, let us place a circular disc of a transparent material (Fig. 1) divided into three pie-shaped sectors, each of a primary color. This disc, geared to revolve at a speed one-third that of the scanning disc, colors the light passing through. Now the whole picture is scanned while the coloring disc makes one-third of a revolution; and as each color occupies one-third the area of the disc, the entire picture is scanned in one color before the next sector has come opposite the aperture. Three times the operation repeats itself, rendering three versions of the picture, each entirely in terms of a primary color.

The receiver (Fig. 2) carries a tricolored transparency identical with that at the transmitter, and of course revolving synchronously, so that the picture is viewed through the right color at the right time. Thus, the three versions of the picture are superimposed, resulting in the reconstruction of the picture in its natural colors.

Still another method is conceivable. Let the light, after passing through the scanning disc and lenses, be directed into a prism, which breaks it up into its constituent colors, producing a rainbow-like spectrum. A revolving disc passes between this prism and the photoelectric cell, traversing the spectrum so that the passage of light of one color only is permitted at a time. The receiver employs a similar arrangement. The light passing from the local source (*which, unlike a neon lamp, must be white*) is broken into its constituents; the disc then allowing each color to emerge in its turn. The slotted disc is geared to advance one color each time the picture is scanned. This method, while possibly resulting in greater fidelity of color, would not only be much more critical of adjustment, but would require an enormously high speed of scanning to prevent flicker. Since a series of color gradations must intervene between the reproductions of corresponding points in successive cycles, the eye would have to hold over the images a comparatively long time; while at the same time each color is shown for so brief a time that the illumination of the whole picture is reduced.

These systems seem delightfully simple in theory. The actual application is, of course, another matter. The advantages resulting from the use of color television are obvious; but what about the difficulties?

RADIO PROBLEMS

The first and probably most important problem to be solved is the same as that now foremost in the minds of those working with television: namely, the width of channel necessary for transmission of the vision current. In order to understand the relation between the size of the image and

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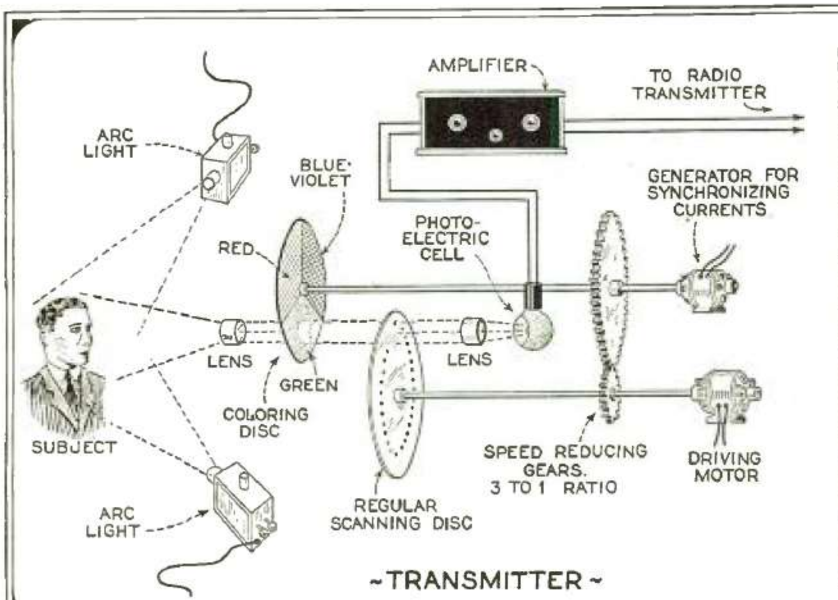

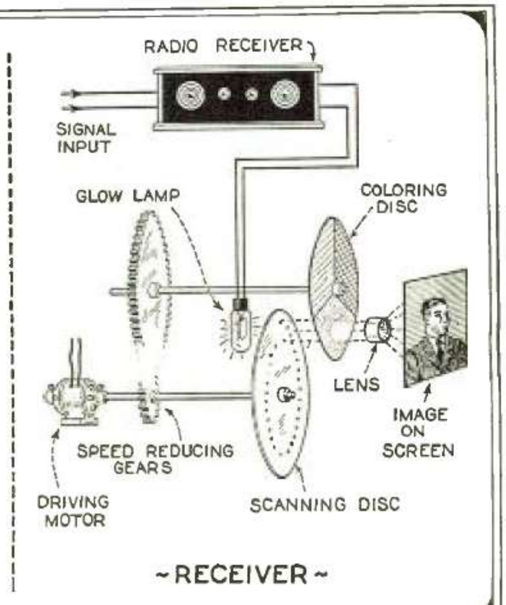

Fig. 1. The elements of the color-television transmitter. The scanning disc is run at high speed, and its revolutions alternately transmit the red, green and blue of the image. The cells used must respond well to all three of the primary colors.

Fig. 2. The reproducing televisor also produces red, green and blue images, all blended by their speed. The lamp light must be white.

Color Television

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the width of the sideband, let us think of the picture as composed of a great number of unit areas. For a picture of a quality comparable with half-tone engravings, about 10,000 areas or dots per square inch will be necessary. The larger the screen, the more are the elementary areas necessary for the same fineness of texture or grain. This means that a great many more unit areas must pass before the aperture each second for a large picture than for a small one.

Now it is evident that, for each two successive areas passing before the aperture, the photoelectric current will pass through one cycle of change; that is, the greatest possible variation in current will be produced by the change from a unit of solid color to one completely dark. According to engineers of the Bell Telephone Laboratories, the highest frequency necessary to be transmitted per second is equal to half the number of dots or areas scanned per second; any change smaller than from one area to another is too small to be of consequence. The 50-line picture used by Bell engineers required a transmission channel of which the highest frequency was half the unit-frequency of 40,000 areas per second, or 20,000 cycles. Actually, an even narrower channel was found to give satisfactory results. Now, with a system whereby each line is successively traced in the primary colors, the number of fluctuations per picture would be tripled—and hence, the width of sideband. The same would be true of the others, especially of the prism method last outlined. Here is room for much experimentation; will it be necessary to scan each line successively in each color, or to complete a picture in one color before beginning another? Will the speed of scanning need to be greater than that of black-and-white television, or would a lower speed prove satisfactory? Experiment alone will tell.

WIDE CHANNELS SCARCE

The use of a sideband wider than 5,000 cycles is prohibited by the regulation prescribing ten-kilocycles separation between broadcasting channels. Technical difficulties also make the use of an extremely wide sideband difficult. Modern receivers now represent a compromise between selectivity and quality: that is, a receiver must separate stations ten kilocycles apart without cutting sidebands. A set which is tuned sharply to 1,000 kilocycles practically rejects frequencies of 1020 kilocycles. What, then, if the sideband is widened even more than that required for ordinary television? A single receiver can respond to frequencies of only a limited width without attenuation of the higher frequencies, which means coarsening of grain and loss of detail. Single-sideband transmission, much advocated as a panacea for the crowded conditions prevalent on the broadcast waves, is much too complicated for general use; as are also double-modulation schemes and others which require an accuracy of adjustment beyond the abilities of the average listener. Short waves offer a less difficult problem, so far as the problem of sideband is concerned; for at 1,000 kc. (300 meters), 20,000 cycles constitutes a 2% sideband, while at 4,000 kc. (75 meters) it is merely ½ of 1%. But the short waves are already facing a congestion hardly less acute than that on the higher wavelengths.

When television is perfected to the point that it no longer requires studio lighting conditions, one of its chief values will be as a field reporter of important events. Chain broadcasting, also, will be highly desirable. Both of these require telephone circuits for long-distance connection. The limits of present long-distance wire transmission circuits do not allow the use of a channel wider than 40,000 cycles. Thus a large panorama, such as a football game, pageant, or any large spectacle would necessarily be reduced to a small size, or else detail would be negligible. To be sure, the frequency range can be divided; so that different wide circuits might transmit various portions of the spectrum, the sections being separated by band-pass filters for transmission and re-assembled at the receiver. But the expense and the difficulty of such arrangements would be tremendous. Radio re-transmission from field cars is perhaps less expensive, but no less complicated, to say nothing of bugbears such as selective fading, static, etc.

THE EYE AND THE CELL

A peculiarity that will perhaps need to be compensated for in design is the distortion resulting from the response-characteristics of the photoelectric cell; *i. e.*, the selective effect mentioned early in this article. Since the photoelectric cell is not uniformly responsive to all colors, certain portions of the picture would be over-emphasized; thus altering the relations between colors. This distortion might be compensated, either by the use of a number of photoelectric cells of differing characteristics, or optical means, such as regulating the transmission properties of the transparencies used for coloring.

An interesting physiological question suggests itself with regard to the visual response to color television. The nerve cells of the eye which respond to light waves are of two kinds, the "rods" and the "cones." Color vision is accomplished by the cones, light and shade by the rods. How quickly do the cones respond to color changes? This element might affect considerably the speed necessary for color television.

A set receiving pictures in color would produce queer effects if slightly out of synchronism with the transmitter. A picture "out of frame" would also be out of the right relation with the coloring disc at the transmitter, and hence, the order of the colors would be transposed. Our favorite soprano might surprise us with a blue face, red eyes, green lips, and white hair. Static would show up as a purple blush or a row of yellow dots sweeping across the screen. Any transient variation in atmospheric conditions would throw the colors out of their correct proportions. This latter effect would probably be slight; because a momentary discoloration would be quickly covered up as the scanning beam swept over the screen again, smoothing out and concealing the discolorations.

A phenomenon that has caused noticeable distortion in television is the so-called "envelope delay," which is due to the difference in time required for currents of differing frequencies to traverse the filters and various circuits encountered in transmission and reception. A group of closely-related frequencies suffers a distortion of wave form because of the altering of phase relations between the various frequencies. With color television, this would not only result in distortion and poor resolution of images, but cause an aberration from the true color relations. Bell engineers have compensated this distortion by balancing against it another distortion opposite in its nature; that is, what is called "aperture distortion." After the edge of a single hole of the scanning disc comes opposite an illuminated spot, more and more of the hole gradually permits the passage of light; that is, the hole does not fall into position instaneously, but gradually, and as a result, the photoelectric current from a given image-area builds up gradually instead of rising to its full value instaneously. In color television, will this compensation be possible? Experiment alone will tell.

Lest he be misunderstood, the writer wishes to make clear that he does not believe it likely that practical television in natural colors will be possible tomorrow, that next year's television receivers will be provided with color attachments such as described above. He does maintain, however, that, when the obstacles above sketched are overcome, and television on a commercial scale is actually accomplished, color television will represent merely a refinement of detail, a further development along the same lines that make universal television possible. If a picture of 240,000 dots per second can be successfully transmitted in black-and-white, surely our engineers can produce a picture of one-third the size in three colors. It seems hardly likely that television will be applied on a universal scale until some major advance overcomes the chief difficulties mentioned above; but when such an advance is achieved, the possibilities of the future seem unlimited. Meanwhile, television rests upon the knees of the gods.

A "Wireless" Relay

A CURIOUS contrast to American methods is shown by a dispatch from Beziers, France, stating that its broadcast station has been hindered in an endeavor to present programs, by remote control, from the Roman amphitheatre in that city, through the refusal of the "P.T.T." (French governmental telephone monopoly) to allow the use of telephone lines for the purpose; and the Beziers broadcasters will be compelled to fall back on a short-wave radio relay for the purpose of getting the program to the studio.

A Couple of Ear Twisters

WHAT words do you think would be the best to test transmission and reception? In the Bell Telephone Laboratories, where telephones are tested, two sentences are repeated over and over by phonographs: "Joe took father's shoe bench out," and "She was waiting at my lawn." The radio "ham" who can get these across by phone to his fellow-workers may know that his modulation is good.

FORCE OF HABIT

HAMLET (bitterly): "This bunch out in front tonight must be a crowd of radio fans."

POLONIUS: "Why, what gives you that notion?"

HAMLET: "Because they just sit there like Stoughton bottles and don't give you a peep of applause!"—*(Miss) Micky Burke.*