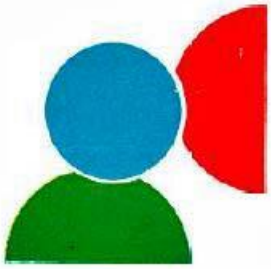


COLOR Television SYSTEMS

By FRED SHUNAMAN

OF THE three main systems of color television that have been battling for FCC and public recognition, the tentatively approved CBS *field-sequential* system is most prominent today. The FCC has stated, however, that the door is not irrevocably closed against other systems, so interest remains strong in the runners-up. These are the *line-sequential* system of Color Television Incorporated (CTI) and the *dot-sequential* system developed by RCA.[1]

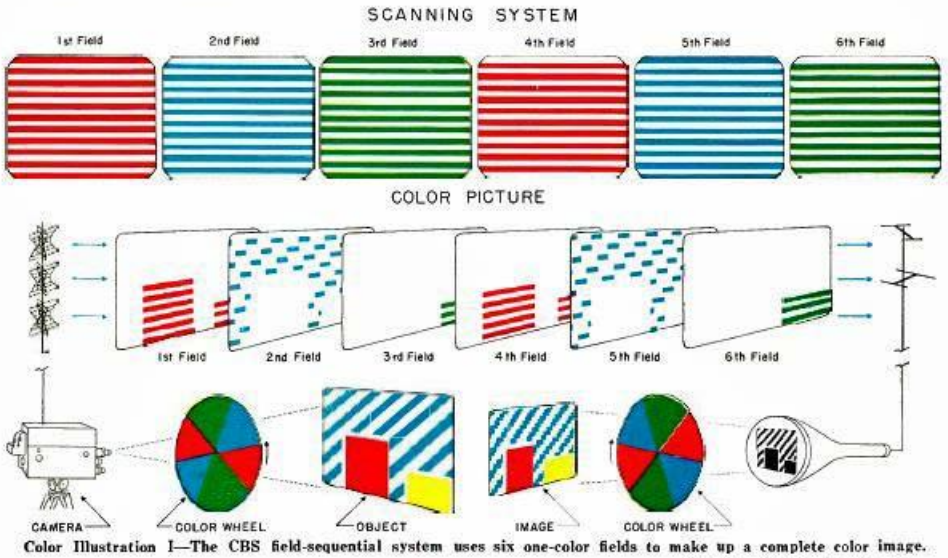
The pros and cons of these systems have been discussed with so much heat and so little moderation that the radioman is not quite sure of any one of their technical features. The public—at whom this barrage of facts and near-facts has been directed—is hopelessly confused. The terms "compatible" and "incompatible" have been bandied about to such an extent that many laymen believe that it would be possible to get color pictures without modifying their present sets, if only a "compatible" system of transmission were used. At the other extreme is a sizeable number who believe that present sets will become useless as soon as color television starts.

Let us review some of the technical facts to help clear up the nonsense. We have one system using relatively simple mechanical apparatus and two systems using more complex electronic equipment to produce roughly similar results. All three systems use standard black-and-white tubes with colored gelatine filters to insert the color into the images.

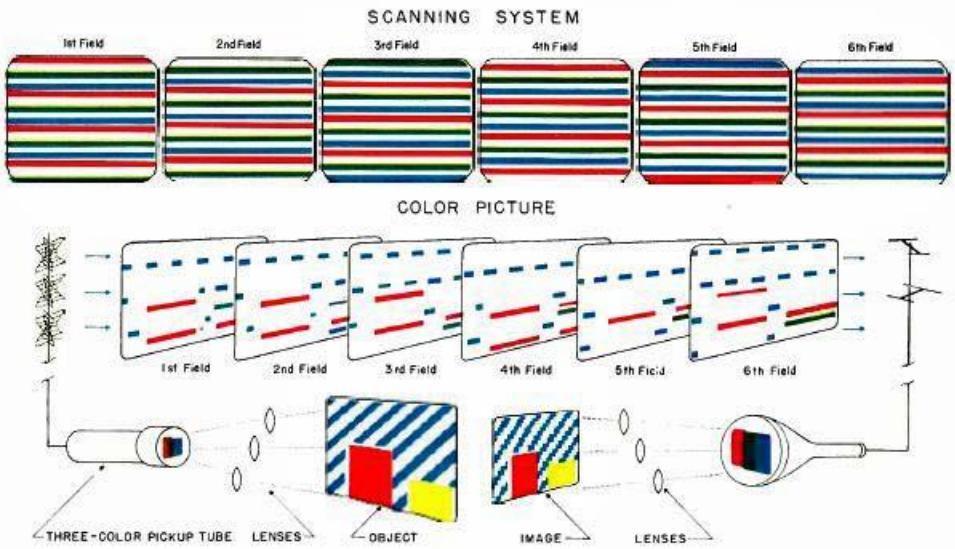
RCA has, it is true, demonstrated a single tube which produces the three colors with its own phosphors.[2] This promises a color system without filters and with only one instead of three kinescopes as used in the present RCA setup, but whether a three-color tube can be mass-produced economically enough to be used in home receivers remains to be seen. At least three types of three-color tubes (RCA, Geer, and Du Mont) have been patented; none have yet been proven to be (or not to be) practical.

Another abused catchword is "mechanical system." It is made even more puzzling when CBS spokesmen remark in passing that their system could also work with electronic color tubes. The fact is that the adaptability of any of the systems is a function of the speed of switching from one color to another. Equipment that can be used by the fastest-switching one can be used by the other two, but not vice versa! Colors are switched more than ten million times a second in the RCA system, 15,750 times in the CTI system, and only 144 times per second by the CBS method. Therefore either CBS or CTI could transmit and receive with equipment suitable for the RCA method. CBS could also use equipment of the type required by CTI's line sequences.

However, should CBS decide to rid itself of the stigma of a "mechanical system" and go electronic, it would have to accept some of the disadvantages as well as the advantages of the more complex systems. An excellent field-sequential system could be built up with three cameras and three kine-



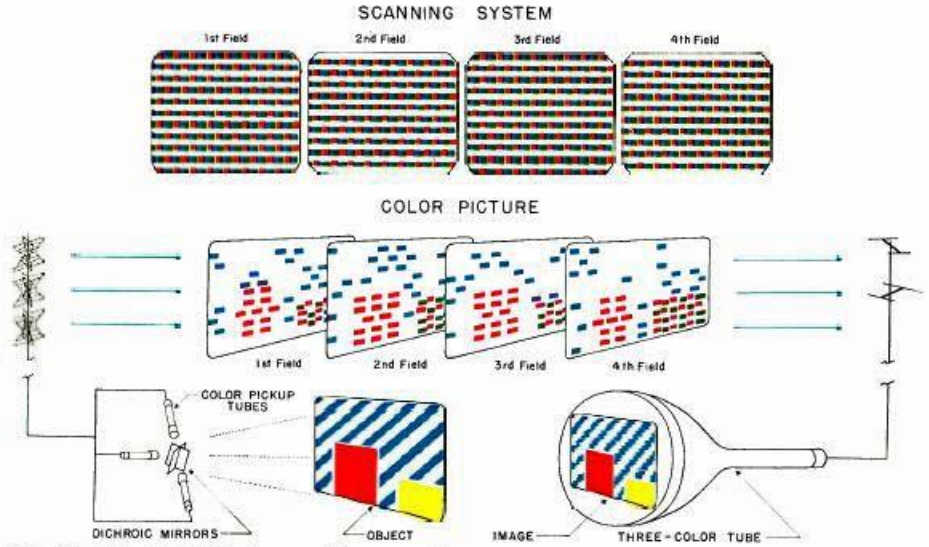
Color Illustration I—The CBS field-sequential system uses six one-color fields to make up a complete color image.



Color Illustration II—The CTI line-sequential system combines all three primaries in each of its six fields.

scopes, but it would be much more costly than the color wheel. A field-sequential system could undoubtedly use a three-color tube if such were available, but would be up against the same problems of color crawl, etc., as is the dot-sequential system, and similar complex and expensive methods would have to be used to solve them.

With the color-wheel system now used by CBS (Color Illustration I), receiving and transmitting equipment differ little from that used for black-and-white.[1-3] Color is supplied by transparent discs divided into red, blue, and green segments which rotate in front of camera and kinescope. The discs must be synchronized so that each segment



Color Illustration III—RCA's dot sequential system, with four fields per picture, has a complex interlace of dots.

is in position while the corresponding color field is transmitted. Thus, during a red field, a red filter ahead of the camera lens permits it to "see" only the red light from the scene, and the blue and green are not photographed. At the same instant, a red filter in front of the kinescope colors the partial image for the viewer. The same thing happens during the blue and green frames, and the eye receives the red, green, and blue primary images in such rapid succession that it sees a picture in full color.

Instead of black-and-white's two interlaced fields per frame, with 30 complete pictures per second, CBS pictures are composed of two interlaced color frames of three fields each. There are 144 fields per second, with 24 complete pictures. It was necessary to cut the number of lines from the standard 525 to 405 to transmit the 144 fields within the regular 6-mc channel. This is the reason for Columbia's *incompatibility*.

Main advantages of the CBS system are its simplicity and low cost. Since the only modifications required are the above-mentioned changes in the scanning frequency and the addition of a color wheel, the CBS system requires no extensive or complex new equipment. Transmitters and receivers for color—or for color and black-and-white—can be constructed or modified at a fraction of the cost of adapting for either of the other systems.

The chief disadvantage of CBS color is its incompatibility. Because of the different line frequency, a standard receiver tuned to a CBS color broadcast will see nothing, either in black-and-white or color. Another disadvantage is its lower definition, either in black-and-white or color. Its 405 lines cannot reproduce fine detail as well as systems using standard 525-line pictures. When used with a mechanical color wheel, picture size is limited to about 12 inches.

Other disadvantages are *flicker* and fringing. Its sponsors claim that the high field rate (144 per second) has fairly well eliminated flicker. Fringing—the breakup of color at the edges of rapidly moving objects—is still something of a problem.

The CTI system

The system demonstrated by CTI (Color Illustration II) is line sequential. Instead of transmitting a whole field or frame in one of the primary colors, the color is switched at the end of each line. Proponents of CTI's method claim that flicker is reduced enough by line switching to permit the system to be compatible. However, the 525 lines of the standard system introduce a problem. Since 525 is a multiple of 3, the same line in each field would always be scanned in the same color. A system had to be designed to skip lines regularly, so that all parts of the picture would be scanned in three colors. By skipping, line 1 (for example) in the first field may be scanned in red, in the third field in green, and in the fifth field in blue. (Even-numbered lines would be scanned in the second, fourth, and sixth fields.)

CTI uses three lenses and three color filters ahead of its camera tube, so that three images, identical except for color, are formed on the mosaic. Instead of being speeded up as in the CBS system, the horizontal sweep is slowed down to one-third standard, so that a single sweep will give three lines, one in each primary color. Three cameras could of course be used. In that case a switching system would select lines successively from each of them.

The CTI receiver may consist of three kinescopes, each with a color filter and lens ahead of it. The lenses are so placed as to superimpose the three images on a screen, where they appear as a full-color picture. It may also be a single tube, with the three color rasters side by side on it, and the same optical mixing system.

CTI's great advantage is its compatibility. It uses the old 525-line interlaced system. The disadvantages are complexity (as compared to CBS) and another peculiar to a line-sequential system. This is *line flicker* or *line crawl*, in which the lines seem to be crawling up or down the picture. It can be avoided to some extent by the complex color interlace in which six fields are required for a single color picture. The number of complete pictures is thereby decreased to ten per second, which seems slow. Sponsors of the system say that the line-by-line color switch prevents this from producing objectionable flicker.

RCA dot-sequential color

Probably more has been said about the RCA (Color Illustration III) dot-sequential system than both others combined. It is the most complex, the hardest to understand, and offers the greatest possibilities for future development of any of the three systems. Instead of breaking the color up into its primaries by fields and lines, the RCA system breaks each line up into dots of primary color. Each color is scanned or "sampled" 3.6 million times per second, and a stream of colored dots appear on the viewing screen. These combine to form a color picture much as do the dots of a color plate used in printing books or magazines. The dots of color printing do not fill the whole area, however, whereas those of RCA color television overlap about 50%. The small size and rapid succession of dots reduces problems of flicker and fringing to where they can be ignored.

Four fields are required for a picture. Two are the standard line interlace; the other two trace over the same lines, but the color dots are displaced so that a dot in field 3 is halfway between two dots of field 1 and one in field 4 halfway between those of field 2. This, plus the 50% overlap, insures that all parts of the scene are scanned in all three colors. There are 15 pictures a second, since the standard 60-field system is used.

RCA's great advantage is compatibility, but it has another—that of greater definition than its rivals. The high frequencies from each of its three color cameras are mixed together, and the low frequencies are sent through the color sampler which transmits the signals to produce color in the received picture. Fig. 1 shows how this is done. Mixing the highs causes the fine detail of a scene to be reproduced in each of the colors, no matter what its original color. Therefore large bodies (which are reproduced by the low-frequency signals) are transmitted in color, while points, edges, and outlines are actually in black and white.

Strange as it sounds, this actually works. If, for example, two adjacent sides of a building appear in deep green, and the fine corner line that separates them appears as black or white (depending on whether it is in sun or shadow) the eye is satisfied. Indeed, there is reason to believe that the eye does not perceive color in fine detail, and the mixed-highs principle may produce pictures closely resembling what the eye sees in nature.

Disadvantages of the RCA system are the complexity and cost of the equipment and its operation. Colors are switched more than 10 million times a second, instead of 144 times as in the CBS system or the 15,750 times of the CTI system. The difficulty of keeping the apparatus in perfect adjustment is enormously increased. Color drift was one of the early problems of this system, and produced some interesting (but to the engineers hair-raising) effects. Thus bananas on a plate might apparently age, turning from yellow to brown as they were being carried to or from the center of the picture.

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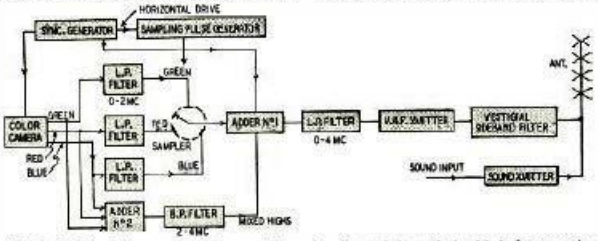

Fig. 1—RCA dot-sequential transmitter, showing mixing of the high frequencies.

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This problem has been solved with a synchronizing system in which timing pulses are transmitted to provide exact dot registry.

Many engineers point to these very problems, and the ones that still exist, as one of the strong points in favor of RCA's system. This admittedly crude development already produces images which some feel are equal to those of any system, and cannot lag far behind by anyone's reckoning. Yet the system is new and at the beginning of its development, whereas others are well in sight of the end of theirs. To say that a system shows great room for improvement may not always be praise, but it is a significant factor when planning for the future.

In typical RCA receiving equipment, three kinescopes are used, one for each of the primary colors. The separate colors are mixed with the aid of dichroic mirrors, which are transparent to two of the primaries and reflect the third. The viewer sees a full-color picture on what appears to be the screen of the green tube, though actually the red and blue components are reflected from the mirrors. As stated before, a single three-color direct-viewing tube has been demonstrated, but is still in the developmental stage.

Besides the three methods described, a number of other incipient color television systems—not developed to the point of demonstration—have been proposed to the FCC. None of them are likely to replace one of the present systems as the final answer to color television, but the possibility cannot be excluded.

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