Simulating A CBS COLOR SIGNAL

Original design or conversion work on color sets need not stop for lack of CBS signals. Equipment described, based on flying spot scanner, produces a suitable color test pattern in your lab or shop as required.

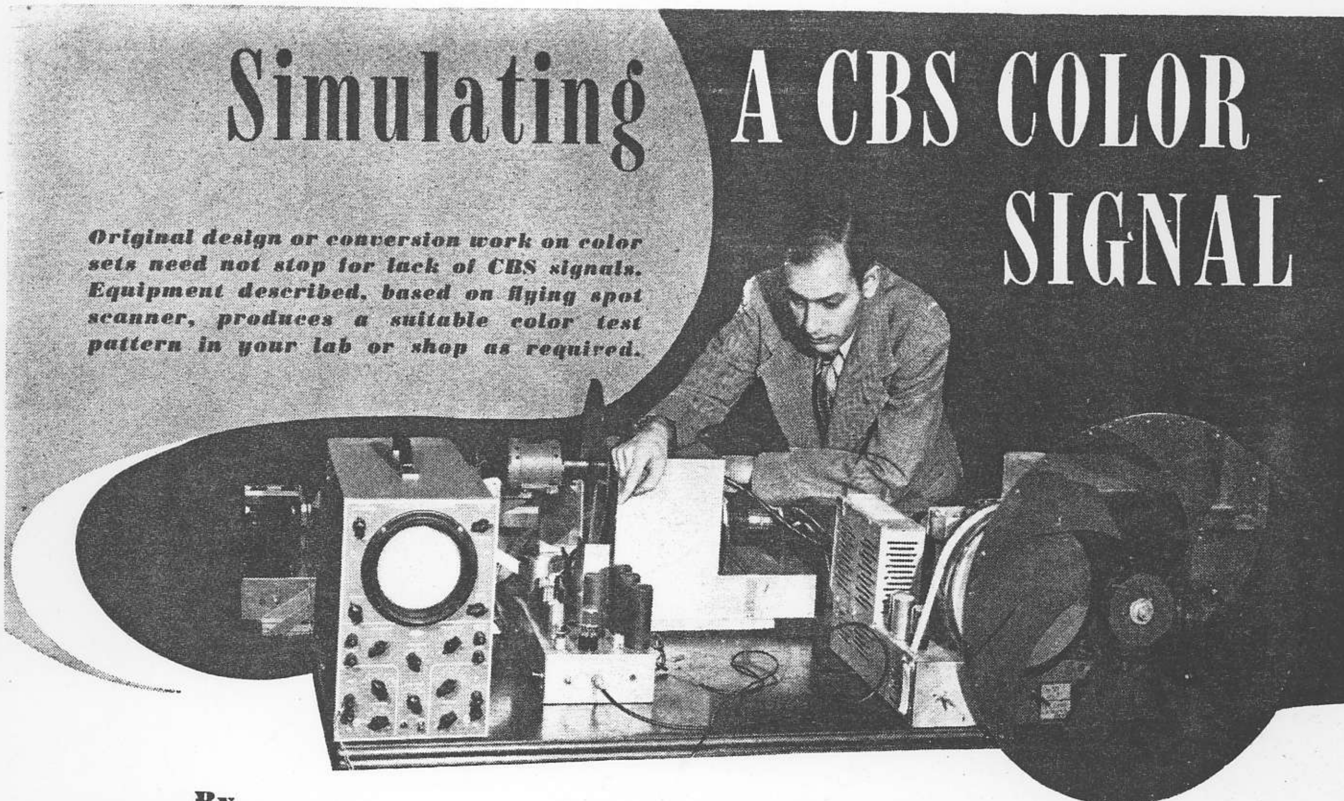

Fig. 1. Complete set-up of equipment used in color demonstration presented at the Radio Electronics School of New York.

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THE decision by the FCC to adopt the *CBS* color system was the spark that set off the biggest controversy that the radio-television field has experienced in years. An overwhelming demand for information about color television, both by the public and the technician, resulted. It was in response to this demand that the author, with the full cooperation of the staff of the *Radio Electronics School*, set up a series of public demonstrations and lectures on color television.

Since *CBS* was not transmitting color signals at the time, the problem was solved by constructing a "flying spot scanner" (Fig. 8) to take the place of the color camera.

Basically, the equipment consists of a high intensity CRT with its associated high voltage power supply and deflection circuits, a photoelectric pickup tube, and a high gain video amplifier. The picture to be transmitted is in the form of a transparency which is placed on the face of the CRT. The raster on the face of the CRT is produced by a rapidly moving spot of light. At any one instant, only one spot on the face of the CRT is giving off light. This spot of light passes through the transparency and falls on the photoelectric pickup tube. The phototube converts the light into an electrical voltage proportional to the intensity of the light. As the spot of light moves across the tube, the amount reaching the phototube will increase or decrease, depending upon the density of the different parts of the transparency.

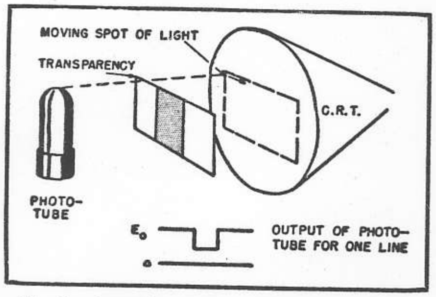
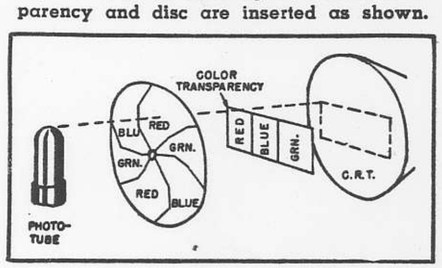


Fig. 2. Intensity of the light from the moving spot, impinging on phototube, varies with any change in transparency density.

EDITOR'S NOTE: *This setup was originally used as a closed-circuit system for demonstrating color television. From the ideas presented it is possible for manufacturers or service organizations who are doing work on color receivers to build a test unit so that work can continue even in the absence of on-the-air CBS signals. For additional details on constructing a flying spot scanner, see J. R. Popkin-Clurman's article "Simplified Ham TV Station" appearing in the May, June, and July 1950 issues of this magazine.*

As each line is scanned, a voltage is generated by the phototube which varies in amplitude directly as the light and dark variations on the transparency, Fig. 2. The output of the phototube is amplified and is the video signal containing all of the picture information. To adapt this principle to produce a color video signal, a color transparency is used in place of the black and white transparency and a color filter wheel is inserted between the transparency and the phototube. See Fig. 3. A simple color transparency, consisting of three vertical bands of color, will be used in place of a full color picture in our analysis of how the system works. As the spot of light moves across the first line from left to right, a section of the color filter wheel moves between the transparency and the phototube. Assuming the first section to be a red filter, which will allow only red light to pass through the output of the phototube will increase when the spot of light passes through the vertical red strip in the beginning of each line, as indicated in Figs. 4A and 4B. Each filter section of the color wheel will be between the transparency and the phototube for the time required for the light spot to scan an entire field. For a color signal conforming to the *CBS* standards, this time interval would be 1/144th of a second. During this interval, all of the red portions of a color image will pass through the color filter and produce a video signal representing the red image. At the start of the next field, the spot of light will be in the upper left hand corner and a blue section of the color wheel will now be coming into place. It will only allow the blue light to pass through and so the video signal produced during this field will repre-

Fig. 3. To obtain color signal, a color transparency and disc are inserted as shown.



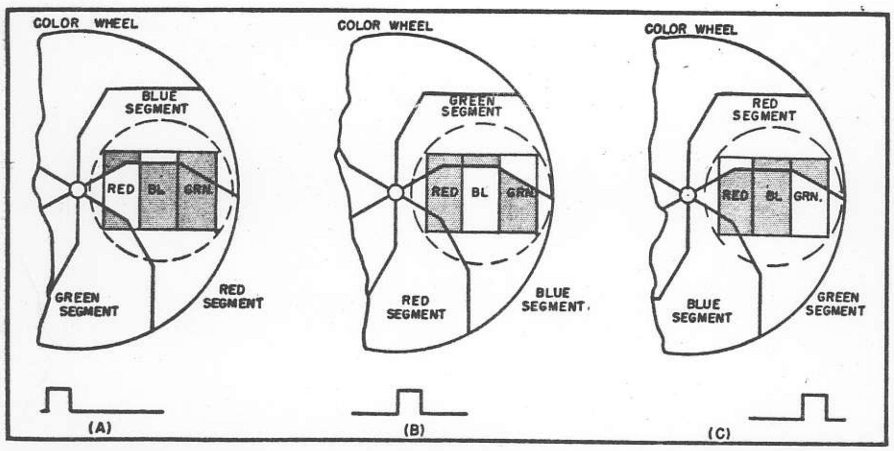


Fig. 4. Scanning sequence. Output of phototube is shown in (A) for red, (B) for blue, and (C) for green. Color disc rotates at a speed of 1440 revolutions per minute.

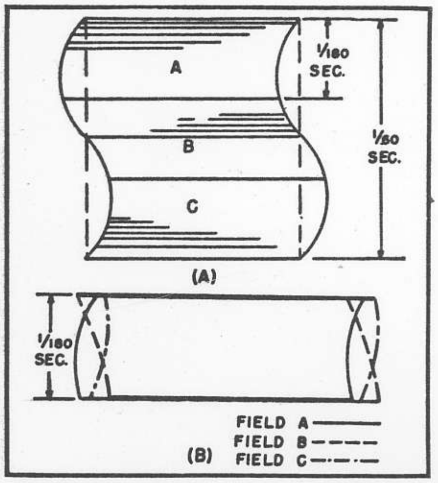


Fig. 5. Curvature caused by a 60-cycle magnetic field when operating at 180 field/sec.

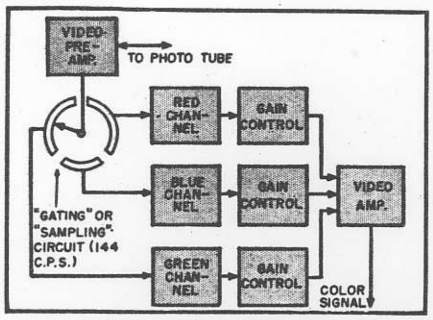


Fig. 6. Block diagram showing how gated circuit is used to select the proper channel.

sent the blue image. Next, the green filter comes into place and the process is repeated, producing the green video signal. In practice, a full color transparency takes the place of the three vertical color bars and the video signals produced during each field would have a more complex waveform.

The output of the video amplifier is applied to the grid of the CRT in a TV receiver.

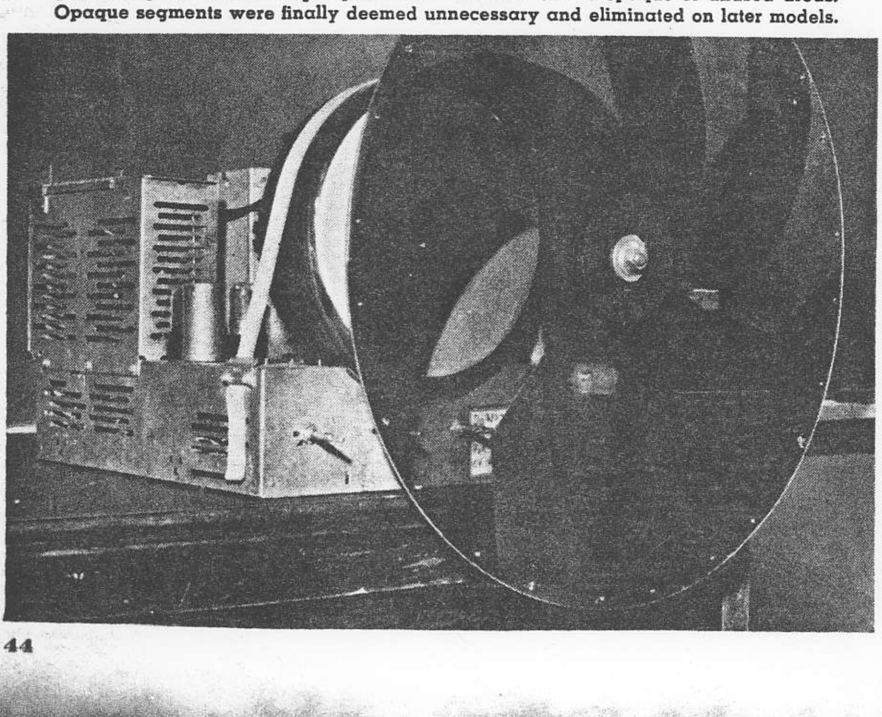
Sync pulses from the sweep circuits of the flying spot scanner are used to synchronize the sweep circuits of the receiver. During each field a picture is produced on the face of the CRT which is a black and white version of the primary color image being scanned at the time. If we look at this black and white image during the red field through a red filter, we would see a true reproduction of the red information in the transparency. The red filter tints the black and white image to its correct color. By using a color filter wheel at the receiver similar to the one at the flying spot scanner, and having it rotate in synchronism, the full color images are first separated into their primary colors, transmitted as black and white versions of the primary colors, tinted by the color wheel at the receiver, and reproduced in full color.

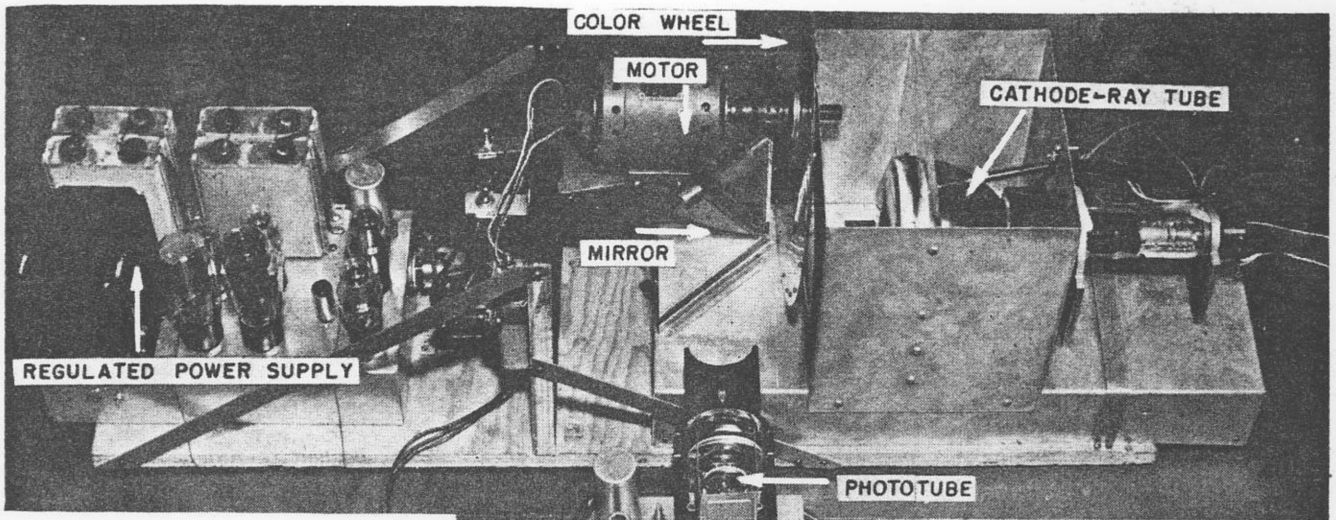
In the *CBS* system, the color fields are scanned at the rate of 144 per second. A color wheel containing six color filter segments, two each of the three primary colors, is rotated at a speed of 1440 revolutions per minute by a synchronous motor. (Since 1440 rpm synchronous motors are not available, an 1800 rpm motor with a 4 to 5 speed reduction is used to obtain the required speed of 1440 rpm.) This is equivalent to 24 revolutions per second. Since there are six equal segments in the wheel, the time required for a single segment to pass a given point would be one sixth of a 24th of a second, or a 1/144th of a second. This is the time required for a single color field.

By using a horizontal sweep frequency of 29,160 cps, interlaced at 144 fields per second, a 405 line picture is produced.

More than the usual amount of power supply filtering was necessary. This is a problem that technicians making color conversions of transmitting or receiving equipment will have to contend with. In the present black and white system using 60 fields per second, hum in the horizontal deflection circuits could cause the vertical sides of the raster to have a slight curvature as illustrated in Figs. 9A and 9B. This hum may be due to magnetic fields (60 cycle) from the power transformer or to the 120 cycle ripple due to insufficient filtering in the power supply. This curvature is hardly noticeable when the vertical sweep frequency is 60 cps. At sweep frequencies of 144 or 180 per second, the visible effect becomes serious. Figs. 5A and 5B illustrate the effect (intentionally exaggerated) when the interference is from a 60 cycle magnetic field and the equipment is operating at 180 fields per second. Three fields would occur in the time previously required for one field. Superimposing the three fields, as they would appear on the face of the CRT, it becomes apparent that

Fig. 7. Over-all view of the color receiver used by author in his simulated CBS color system. The color wheel consists of twelve segments with every other segment opaque. The sequence is red color filter, opaque segment, blue filter, opaque segment, green filter, opaque segment, etc., with a total of six color filter segments and six opaque segments. In developing the shape of the color filter segments it was apparent that light from the CRT did not pass through every part of the wheel but rather through "half moon" shaped areas. Since this was the case, it was not necessary for the wheel to be entirely transparent. Balance weights and metal strips used for generating the reference sync pulse were mounted on the opaque or unused areas. Opaque segments were finally deemed unnecessary and eliminated on later models.





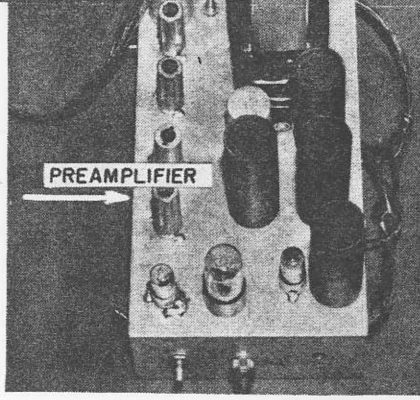


Fig. 8. Over-all view of flying spot scanner.

they are displaced with respect to each other. This makes it impossible for the three colors to "register" properly, producing a picture that is constantly shimmering, and one which has very poor detail.

To keep this from happening it is necessary to thoroughly filter the "B" supply, and protect the CRT against the influence of stray magnetic fields. A mu-metal shield around the picture tube and a heavy copper band around the power transformer are some of the possible solutions to the problem.

Color Balance

The spectral response of the 931A phototube used as the pickup device drops off rapidly at the red end of the spectrum. To correct this, a thin sheet of very lightly tinted red acetate was permanently fastened to the face of the CRT used in the flying spot scanner. This cut down the intensity of light of the colors other than red to compensate for the lack of sensitivity of the phototube to red. A better method might be to use two or more 931A phototubes feeding the video amplifier with a red color filter permanently mounted in front of one tube thus making it sensitive only to red light. This would boost the level of the video signal produced by the red image. Our equipment is presently being modified to include a "gating" circuit operating at the field frequency which will switch the output of the phototube to a separate video amplifier every time a different color filter segment of the color wheel comes into place (Fig. 6). This will connect the video signal output of the phototube to the red video amplifier for the duration of the red field. Immediately after the red field the signal is switched to the blue video amplifier for the duration of the blue field, and finally to the green video amplifier for the duration of the green field. By adjusting the gain of the video amplifier for each color channel, the relative amplitudes of the color signals can be properly balanced.

Synchronizing the System

Proper sync and phasing of the complete system is accomplished in the following manner. Six thin pieces of soft iron are fastened along the outside edge of the color wheel at the flying spot scanner (Fig. 11). The pickup coil from a magnetic phonograph pickup is mounted close to the edge of the wheel. As the iron segments move past the pickup coil, a pulse is produced. Since there is a piece of iron for every color segment, the output of the pickup coil will be a series of pulses at the field frequency. These pulses are used to synchronize the vertical sweep circuits and thereby control the timing of the entire system. A phase shifting network is connected between the magnetic pickup coil and the vertical sweep generator. By adjusting this control the start of each field can be varied with respect to the position of the color wheel. Once set, this control usually doesn't have to be readjusted, unless the position of the pickup coil is changed.

Color phasing at the receiver is accomplished by mounting the motor which rotates the color wheel so that it can be rotated through approximately 160 degrees, as illustrated in Fig. 10. The motor is rotated until the segment of the color test pattern marked "blue" becomes blue.

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Fig. 9. An example of the curvature of the vertical edges of the raster caused by (A) 60 cycle and (B) 120 cycle interference.

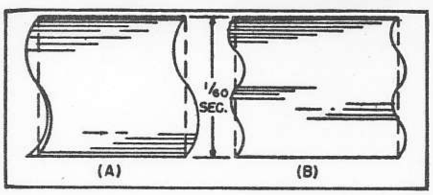

Fig. 10. Provision must be made for rotation of the motor in order to obtain the proper color phasing at the TV receiver.

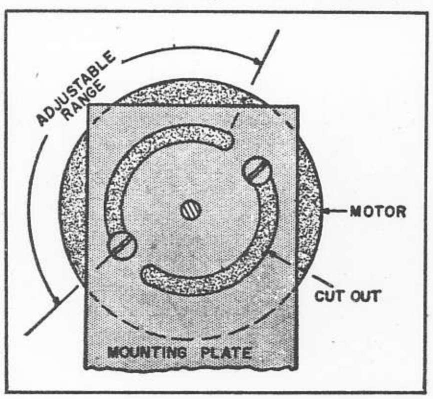

Fig. 11. Mechanical details of synchronizing system. Six pieces of soft iron are fastened to outside edge of color disc.