Color Television
theory and servicing

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Preface

Color-television technology is now dominated by solid-state devices such as bipolar and field-effect transistors, silicon controlled rectifiers, and integrated circuits. The trend has been to all solid-state receivers, although thousands of hybrid receivers (using both transistors and electron tubes) are still in use. In turn, the need for a state-of-the-art book covering the theory and troubleshooting of solid-state, color television receivers is evident. This coverage necessitates application data for color television test equipment to the extent required in setup and basic servicing procedures.

It is assumed that the reader has either completed courses in electricity, electronics, radio communication, and black-and-white television or has attained a practical background in these areas. Relevancy is stressed throughout the profusely illustrated text. Mathematical treatment has been minimized, and equations are employed only in topics that have a basic quantitative context. A prerequisite background in arithmetic, algebra, geometry, and trigonometry is also necessary. It is essential that the reader have an elementary understanding of analytic geometry, to the extent that he can work with curves and graphs.

Acknowledgement is made to those who have preceded the author by their development of other books on color television, and to the faculty of San Jose City College, who have made many helpful suggestions and criticisms. This book can be properly described as a team effort, although the individual members would choose to minimize the measure of their own contributions. It is appropriate that this volume be dedicated as a teaching tool to the instructors and students of our junior colleges and technical schools.

Clyde N. Herrick

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Color Fundamentals and Colorimetry

SECTION 1.1

Light and Color Vision

Visible light consists of a small interval in the spectrum of electromagnetic radiation, as shown in Fig. 1-1.

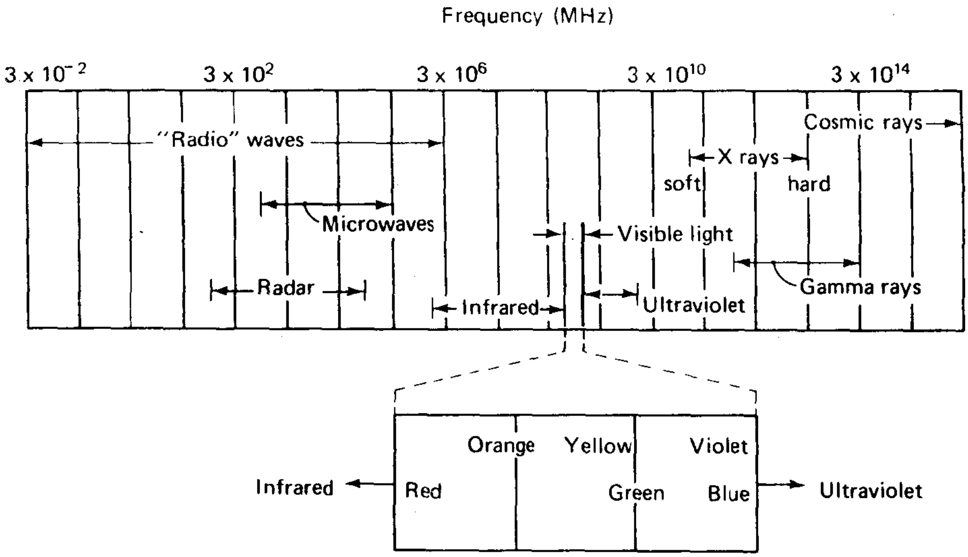

FIGURE 1-1

Spectrum of electromagnetic radiation.

All visible colors are contained in this spectrum. The wavelengths of visible electromagnetic radiation extend from 400 to 700 millimicrons, or from 16 to 28 millionths of an inch. Although we name the colors of the rainbow red, orange, yellow, green, blue, indigo, and violet, these are merely the most obvious hues. Hundreds of variations in colors can be distinguished, even by a comparatively untrained observer. Physics teaches us that a beam of white light passed through a prism, as depicted in Fig. 1-2, splits up into a color spectrum. Conversely, if a color spectrum is passed through a prism, the reverse process

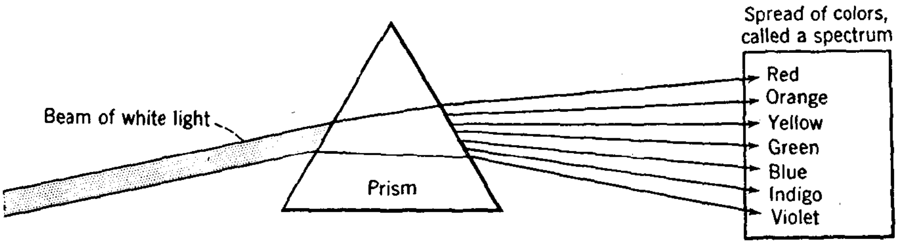

FIGURE 1-2

A prism refracts electromagnetic waves. White light is split up into a color spectrum, (a color spectrum can be recombined into white light).

takes place—spectral colors are recombined to form a beam of white light.

A beam of white light can also be formed by combining a minimum of three colored lights, which are called *additive primaries.* The most useful additive primaries are red, green, and blue; these are the primary hues that are utilized in color television. Additive primaries must not be confused with the *subtractive primaries* used in printing processes and in paintings. Subtractive primaries are viewed by reflected light, and the most useful subtractive primaries are red, yellow, and blue. To anticipate subsequent discussion, a color picture tube is a source of colored lights that are viewed directly. A color picture tube employs red, green, and blue phosphors.

Red, green, and blue are the most useful additive primaries because they allow the formation of the maximum range or gamut of hues when blended in various proportions. Figure 1-3 shows how the primary colors blend in pairs to form the complementary colors and how all three primary colors blend to form white. Thus, red and blue blend to form their complementary color, magenta; blue and green blend to form their complementary color, cyan; and red and green blend to form their complemen-

FIGURE 1-3

The additive primary and complementary colors. (See inside front cover of book for artwork.)

tary color, yellow. Technically, white is not a color, but rather is light that is free of color. Black is defined as the absence of light.

SECTION 1.2

Principles of Colorimetry

Colorimetry is the science of specifying colors. Any color utilized in a technical process such as color television can be produced by some suitable blending of the three primary colors. This fact is shown to good advantage by means of a *chromaticity diagram.* Figure 1-4 exemplifies a useful form of chromaticity diagram with wavelengths along the *boundary* (or range) noted in millimicrons. (A micron is equal to one-millionth of a meter.) Any color on the chromaticity diagram can be obtained by suitable blending of red, green, and blue primary hues. Note that white occurs at a point on the diagram that corresponds to equal proportions of red, green, and blue. Note also that colors in the whitish area are very pale or *unsaturated,* whereas colors near the boundary of the diagram are intense or highly *saturated.*

Colors utilized in technical processes have a smaller gamut than those enclosed by the chromaticity diagram. For example, a color picture tube uses the primaries denoted by R_1, B_1, and G_1 in Fig. 1-5. Thus, the range of a color-TV image is enclosed by the associated triangle. Note that this color-TV range is somewhat greater than the range utilized in color printing processes. In summary,

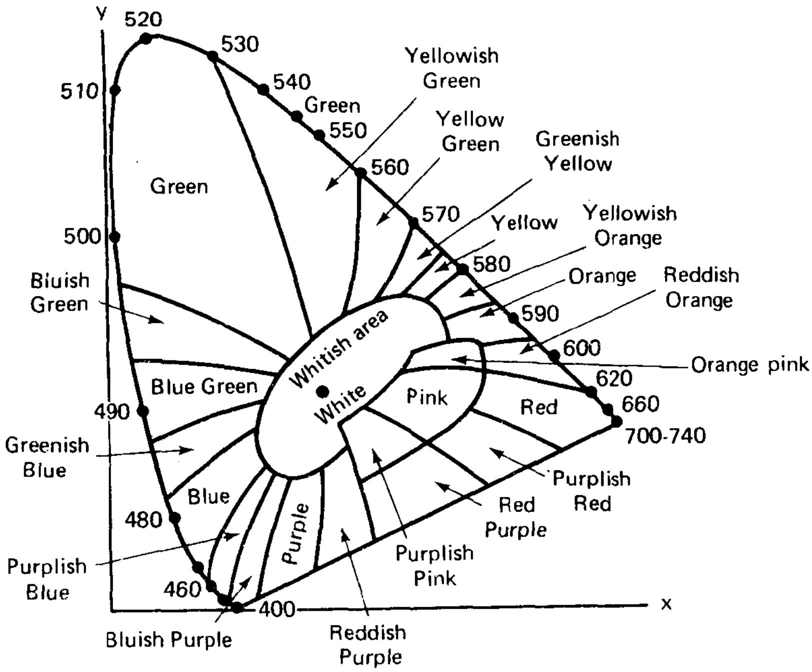

FIGURE 1-4

A standard chromaticity diagram.

a color-TV system can reproduce any color that occurs in nature, although certain hues such as green and purple cannot be reproduced at maximum saturation. However, this is a minor limitation because it is very seldom that any hue occurs in nature in maximum saturation.

SECTION 1.3

Color Vision versus Black-and-White Vision

Some of the fundamental characteristics of the color-TV system are based on principles of color vision. For example, black-and-white vision is more acute than color vision. An important aspect of this distinction is the

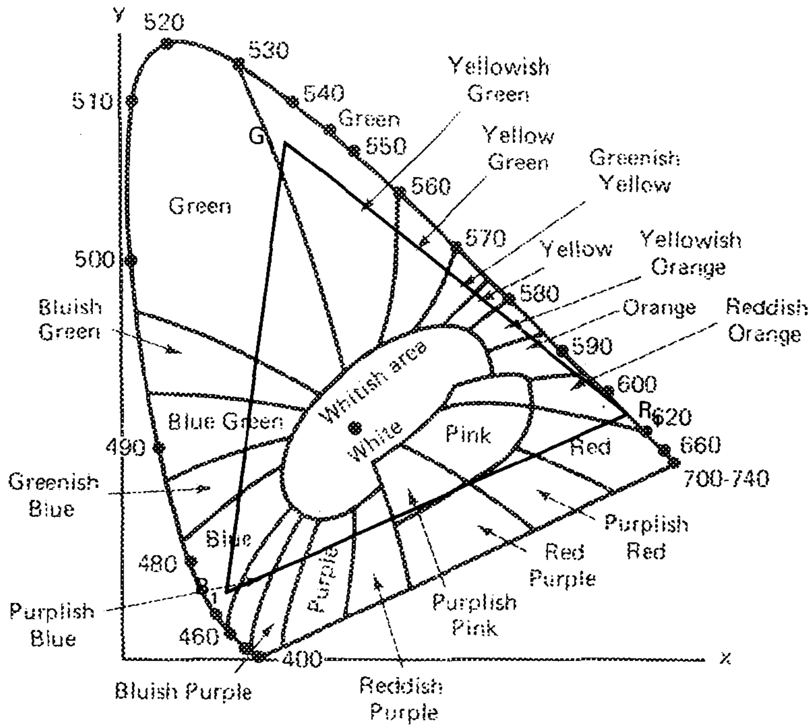

FIGURE 1-5

Chromaticity diagram showing range employed in color television.

inability of the eye to perceive very small colored areas in a scene. Thus, although the eye has three-primary vision for large colored areas, it has only two-primary vision for small areas. Finally, the eye has only black-and-white vision for even smaller areas. Purple and green-yellow hues become indistinguishable from gray in small areas of an image, although red and cyan colors remain visible. As a colored area is further reduced in size, the red and cyan hues also become indistinguishable from gray. The technical importance of these facts is that a highly detailed reproduction of black, white, and gray areas is required for TV, whereas colored areas do not need to be as sharply defined. Also, less definition is required for the blue hues than for the orange hues.

The eye is also more critical of some off-hue situations than of others. For example, a color-TV viewer tends to be very critical of variation in flesh tones, whereas variation in brown and green tones is likely to be accepted. In other words, the orange tints need to be reproduced with the minimum departure from the original scene, whereas green tints can vary appreciably from the original without recognition of this variance by the viewer. This requirement places stringent demands on the color-TV system, as is evident from inspection of Fig. 1-5. That is, as we proceed around the triangle $R_1G_1B_1$, the orange hues occupy a comparatively small interval. On the other hand, the green hues occupy an extended interval. Technically, this means that orange hues (and flesh tones in particular) must be reproduced with minimum error. Special circuits are often included in color receivers to contend with this problem.

Colors are technically described in terms of brightness, hue, and saturation. *Brightness* denotes relative light levels; for example, a sunlit scene is brighter at noonday than at twilight. *Hue* denotes the basic distinction between different kinds of colors; thus, red is a hue different from green. *Saturation* denotes the extent to which a hue is diluted by white light; for example, a red traffic light is highly saturated, and is often described as a *vivid* red light. On the other hand, a pastel pink color is considerably less saturated, and is said to be a weak shade of red. Note that a vivid shade of red and a weak shade of red have the same hue. They may also have the same brightness. In summary, brightness, hue, and saturation are independent variables in the science of colorimetry.

SECTION 1.4

The Transmission Primaries

Although only three primary colors are required to reproduce any desired hue, these three primaries are not the only colors usable. Four primaries may be employed if we choose to do so. In fact, four transmission primaries