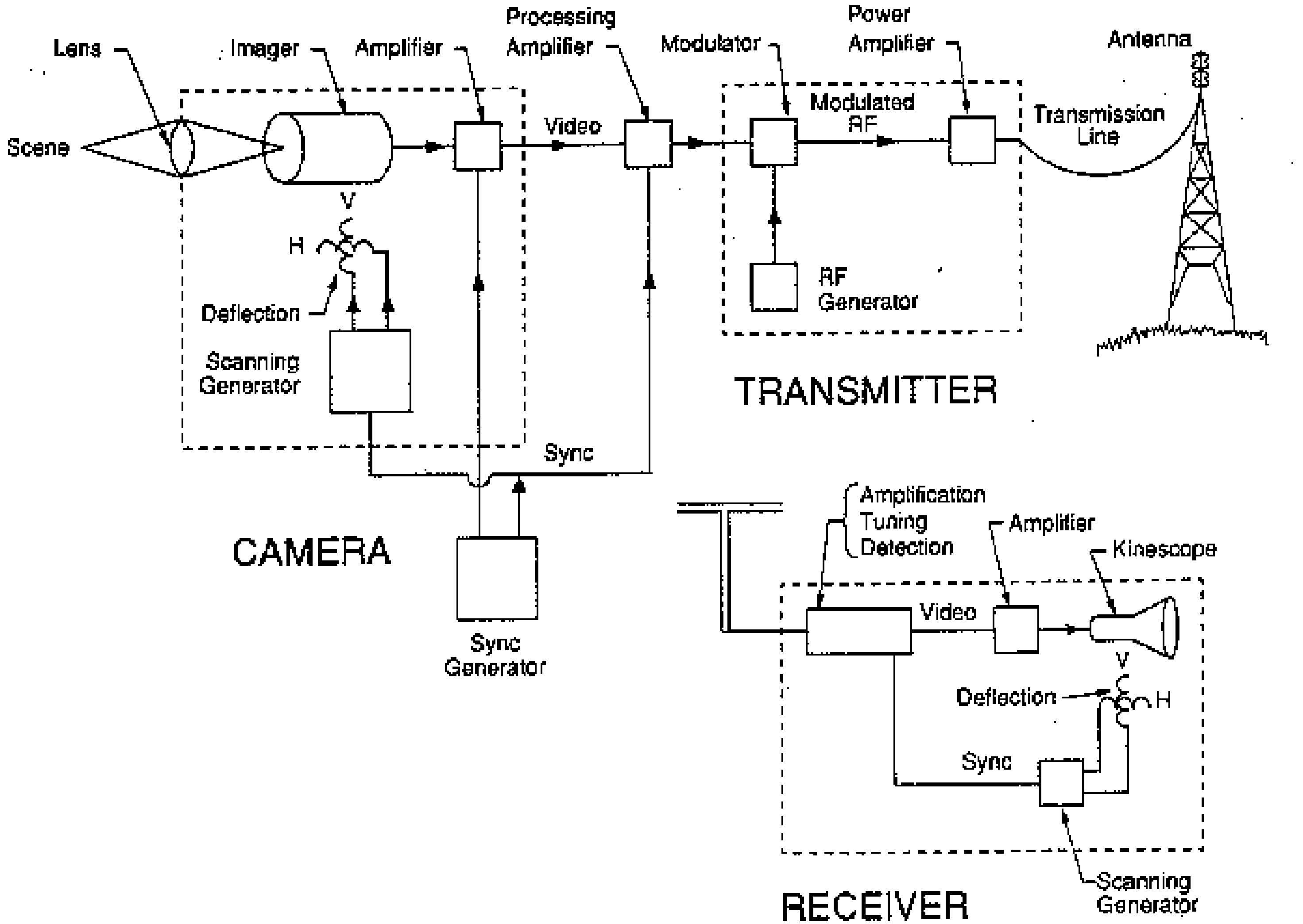
Video

- TV system fundamental
- Element of Picture Quality
- Color Video Signals
- Digital TV
- Video Camera, VCR, TV Receiver
- Comparison of NTSC and HDTV

Reference:
Video Engineering, Andrew Inglis, McGraw-Hill

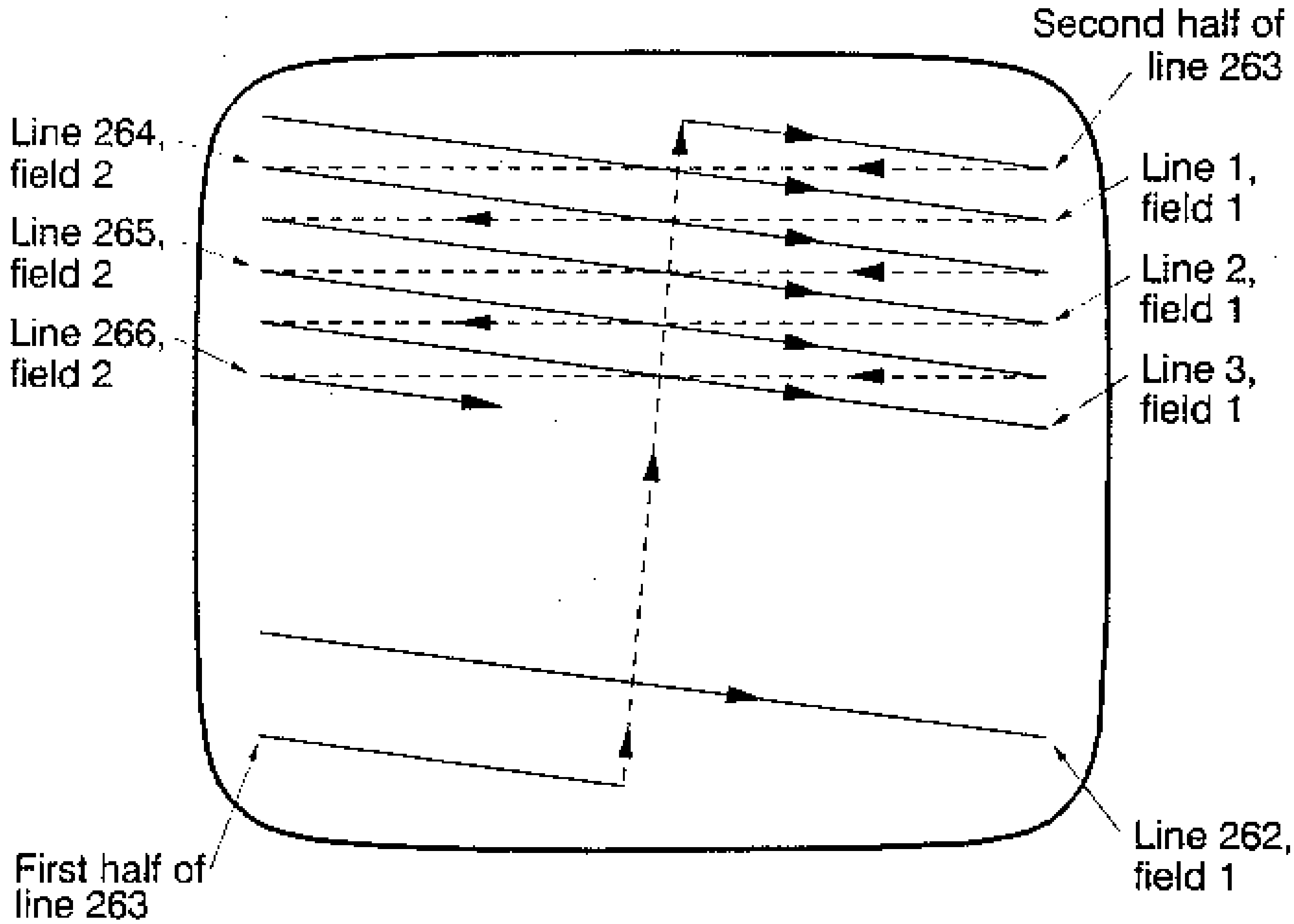
Basic Monochrome Television System



TV scanning principle-Interlaced Scanning

A frame is divided into two fields to save bandwidth.

It takes advantages of the image retention of our eyes



Bandwidth Requirement

$$B_W = 0.8 F_R N_L R_H$$

Bw = required bandwidth for a TV signal

F_R = number of frames or complete pictures transmitted each second

N_L = number of scanning lines

R_H = horizontal resolution defined to be number of pixel in horizontal dimension within Y, where Y is the picture height. (Note that H is not the picture width)

The 0.8 number is derived as follows:

$$B_w = (\text{Cycles per frame})\ F_R$$

$$\text{Cycles per frame} = (NL)(\text{Cycle per line})$$

$$\text{Cycle per line} = \frac{(0.5)(AspectRatio)(R_H)}{0.84} = 0.8R_H$$

AspectRatio = the ratio of the image width to its height, here it is 4/3 for conventional TV. The AspectRatio of HDTV is 16/9.

0.5 is contributed by the interlaced scanning.

0.84 is the fraction of the horizontal scanning interval devote to signal transmission. (The remainder is utilized for horizontal blanking).

The trade-off between Bw, F_R, N_L, and R_H is a big concern for original TV design.

Scanning Standards

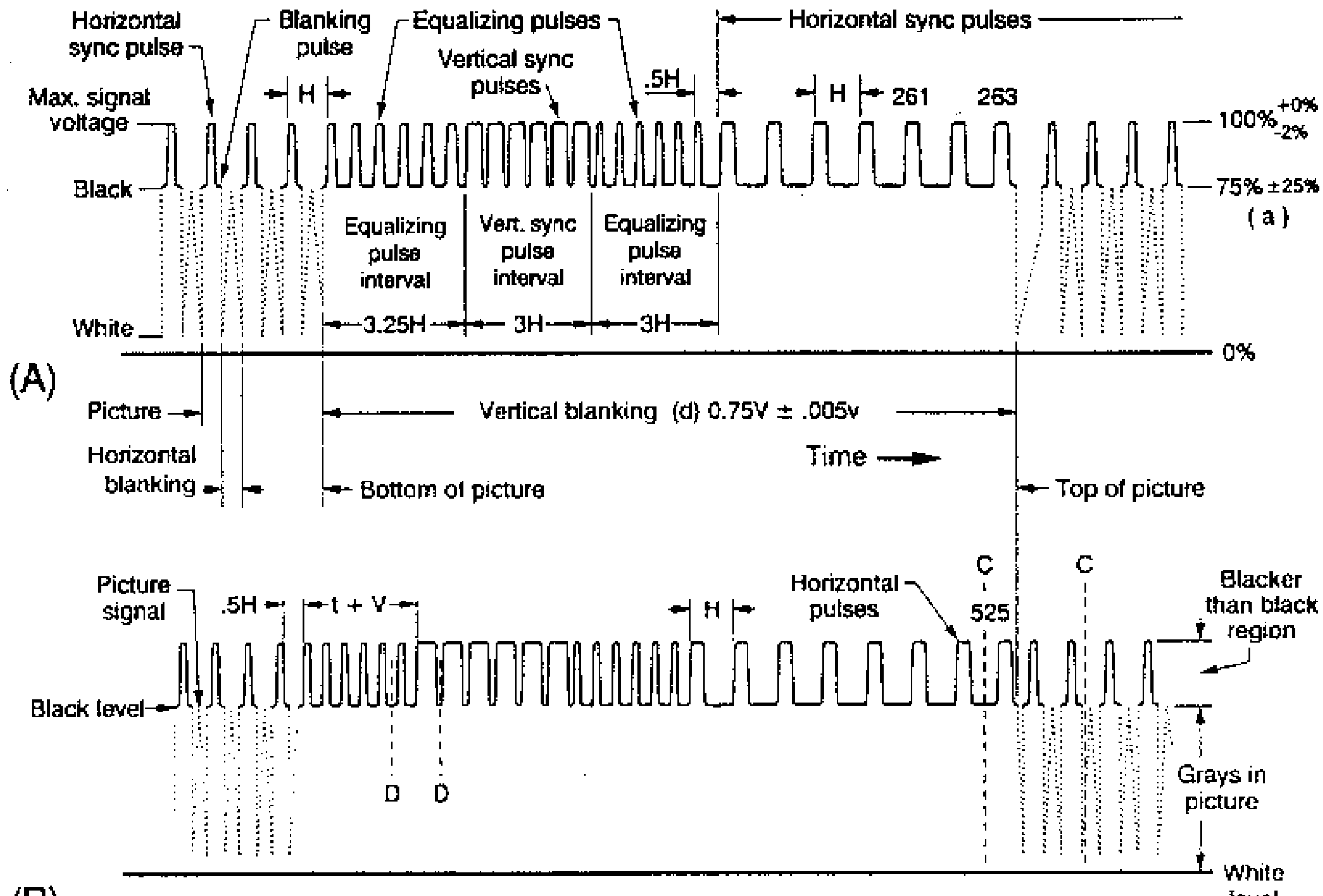
The frame rate must be larger enough to reduce flicker to an acceptable level.

It is also needed to be multiple or submultiple of the primary power frequency so that the "humming" effect resulting from imperfect filtering of the power source are minimum.

TABLE 1.1 U.S. and Foreign Scanning Standards

	Color type	Fields per second	Frames per second	Lines per frame	Lines per second
United States					
Monochrome		60	30	525	15,750
Color	NTSC	59.94	29.97	525	15,734
England					
Monochrome		50	25	405	10,126
Color	PAL	50	25	625	15,625
Japan					
Color	NTSC	59.94	29.97	525	~~17,734~~ 15,734
France					
Monochrome		50	25	819	20,475
Color	SECAM	50	25	625	15,625
Germany					
Color	PAL	50	25	625	15,625
Former USSR					
Color	SECAM	50	25	625	15,625

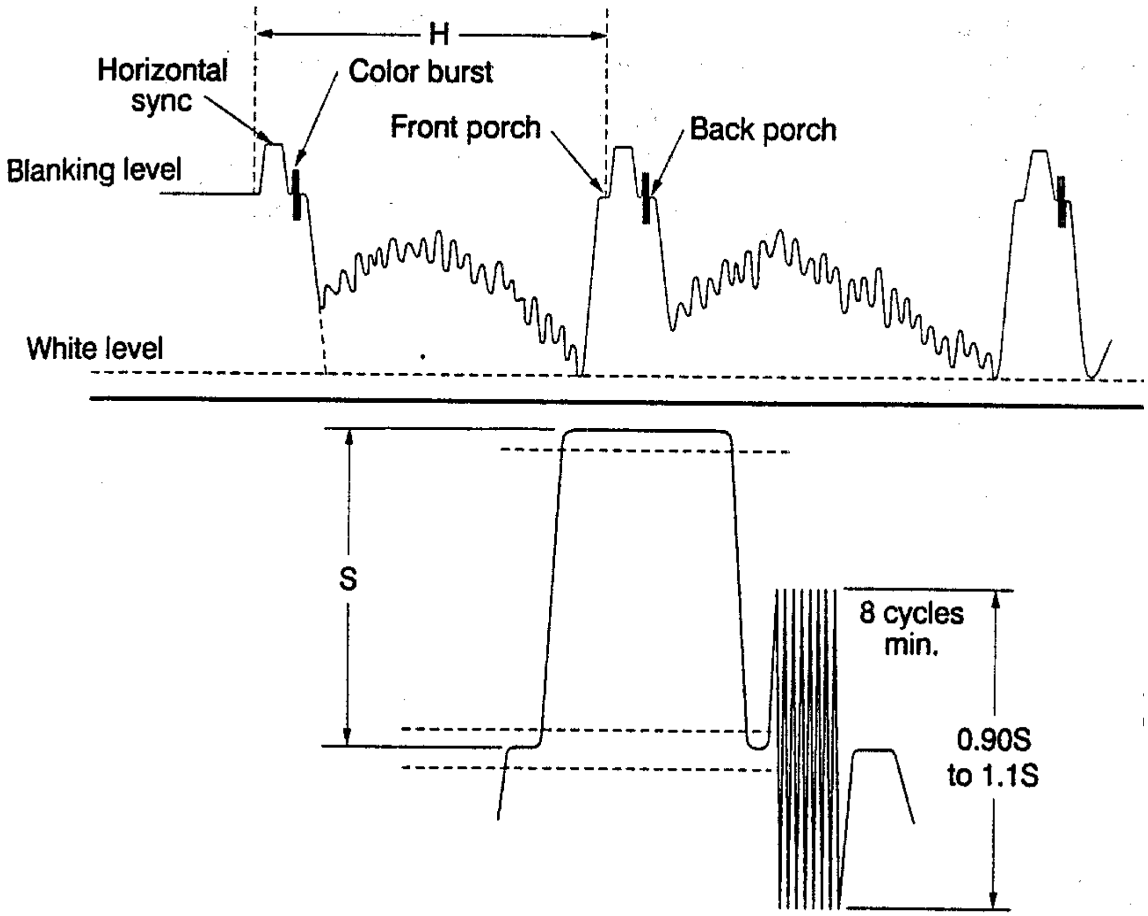
Luminance Video Signal Waveform



Horizontal dimensions not to scale in A, B, and C

Chrominance Signal Components

NTSC(National Television System Committee) uses AM and PM to insert the color information to the video signal. PAL (Phase Alternating Lines) and SECAM (Sequential Colour avec Memoire) use slightly different methods.



US TV Broadcast Channels regulated by FCC

TABLE 9.1 Television Broadcast Channels

Channel	Frequency, MHz	Channel	Frequency
Low-Band VHF		UHF (cont.)	
2	54–60	35	596–602
3	60–66	36	602–608
4	66–72	37	608–614
5	76–82	38	614–620
6	82–88	39	620–626
High-Band VHF		40	626–632
7	174–180	41	632–638
8	180–186	42	638–644
9	186–192	43	644–650
10	192–198	44	650–656
11	198–204	45	656–662
12	204–210	46	662–668
13	210–216	47	668–674
UHF		48	674–680
14	470–476	49	680–686
15	476–482	50	686–692
16	482–488	51	692–698
17	488–494	52	698–704
18	494–500	53	704–710
19	500–506	54	710–716
20	506–512	55	716–722
21	512–518	56	722–728
22	518–524	57	728–734
23	524–530	58	734–740
24	530–536	59	740–746
25	536–542	60	746–752
26	542–548	61	752–758
27	548–554	62	758–764
28	554–560	63	764–770
29	560–566	64	770–776
30	566–572	65	776–782
31	572–578	66	782–788
32	578–584	67	788–794
33	584–590	68	794–800
34	590–596	69	800–806

6MHz Standard US TV broadcast channel

It has two carriers, the visual carrier 1.25 MHz above the lower channel edge and the aural carrier 4.5 MHz above the visual. The visual carrier is amplitude-modulated by the video signal. The aural carrier is frequency-modulated with a pick deviation of ±25kHz (compared to ±75kHz for FM broadcasting).

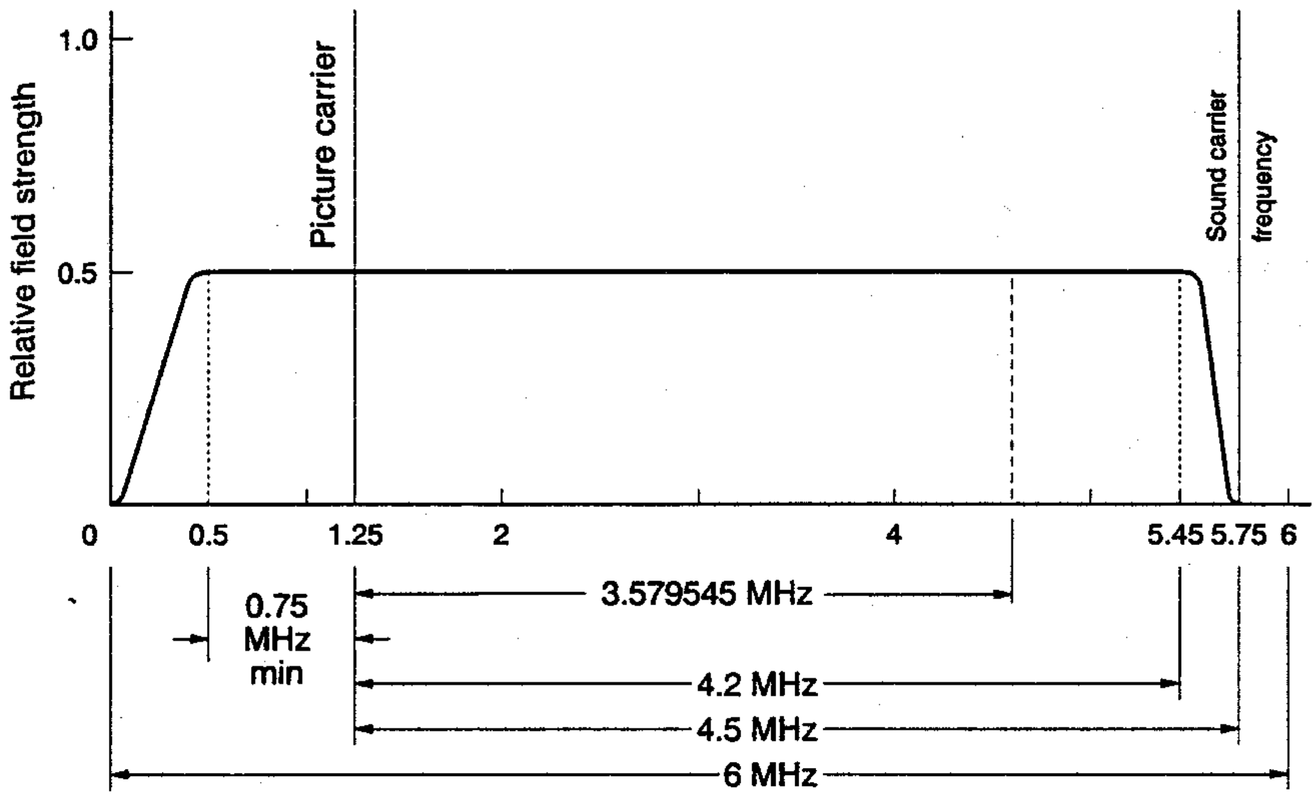


Figure 9.1 Standard U.S. television broadcast channel.

Basic Image Quality Criteria

- **Image definition**—the distinctness of the outlines in the image; the degree to which the image appears to be "in-focus"; a measure of the sharpness of the transitions or edges between its dark and light areas.
  In the high-definition system, these edge must be very sharp.
  This quality criterium is where the High Definition TV gets its name.
  It is closely related to **visual acruity**, the smallest angular separation at which individual lines can be distinguish.
- **Gray scale**—specified by three parameters:
  highlight brightness—the brightness of the brightest area of the image
  contrast ratio—the ratio of the brightness of the brightest area to that of the darkest, expressed in dB.
  gamma—the slope of the image brightness as a function of the scene brightness.
- Signal-to-Noise ratio

Note that brightness is a subjective term that indicates the magnitude of the visual sensation produced by a source of light. Weber's Law: ***The increase in stimulus necessary to produce an increase in sensation of any of our senses is not an absolute quantity but depends on the proportion that the increase bears to the immediately preceding stimulus.***

Image Defects (Some unique to TV images)

- Flicker—an effect results when the frame rate is not high enough to cause the eye to perceive a continuous image.
- Aliasing—the production of spurious signals as the result of sampling in space and time.
- Lag—a measure of the rate of change of the video signal at a fixed point on the raster when the scene changes. Big lag causes loss of resolution/trailing tail.
- Geometric distortion
- Hum—the interference caused by spurious power source voltages.
- Co-channel interference—two TV stations operating on the same frequency, alternating black and white horizontal bars across the picture.
- Receiver-generated interference
- Ghosts a duplicate of the main image, slightly displaced from it, usually to the right, and much fainter. It is caused by multipath transmission (reflection of building or mountain). A 1000-ft path difference would produce a displacement of 1/63 of the scanning line length.

Bandwidth and Horizontal Resolution

The R_H, horizontal limiting resolution of TV, the number of black and white vertical lines that can be distinguished in a dimension equal to the picture height.

$$R_H = \frac{2C_H B_w}{A_R N_L F_R}$$

C_H = fraction of time each scanning line devoted to the transmission of picture information after subtracting the time required for horizontal blanking

B_W = system bandwidth

A_R = aspect ratio

N_L = total number of scanning lines per frame

F_R = frame rate per second

	NTSC	PAL	HDTV
B_w (MHz)	4.2	5.0	20
N_L	525	625	1125
C_H	0.85	0.80	0.83
Aspect ratio	1.33 (4/3)	1.33 (4/3)	1.78 (16/9)
F_R (frames per second)	29.97	25	30
R_H (lines)	340	409	593

Scanning lines and vertical resolution

The R_V, vertical limiting resolution of TV, the number of vertical lines that can be distinguished in a dimension equal to the picture height, is limited by the number of active (visible) scanning lines but not equal to it, because the vertical detail in the image is randomly located w.r.t. the scanning line

$$R_V = C_V K_f N_L$$

C_V = fraction of scanning line that are visible (after subtracting the lines that are removed by vertical blanking)

K_f = Kell factor, the ratio of vertical resolution to the number of scanning lines

N_L = total number of scanning lines

	NTSC	PAL	HDTV
C_V	0.92	0.92	0.96
N_L	525	625	1125
K_f	0.7	0.7	0.7
R_V (lines)	343	408	767

Picture elements (pixels)

Np, is the number of pixel is broadcast TV system

$$N_p = \frac{2CK_fB_w}{F_R}$$

C = fraction of time occupied by active scanning (after substracting vertical and horizontal blanking periods)

NSTC TV system has 148000 pixels
HDTV system has 743000 pixels.

Aperture Response

a universal criterion for specifying picture definition and other image system performance, including that of films, lens, TV camera imagers, video amplifier, scanning process, receiver picture tubes, and the human eye.

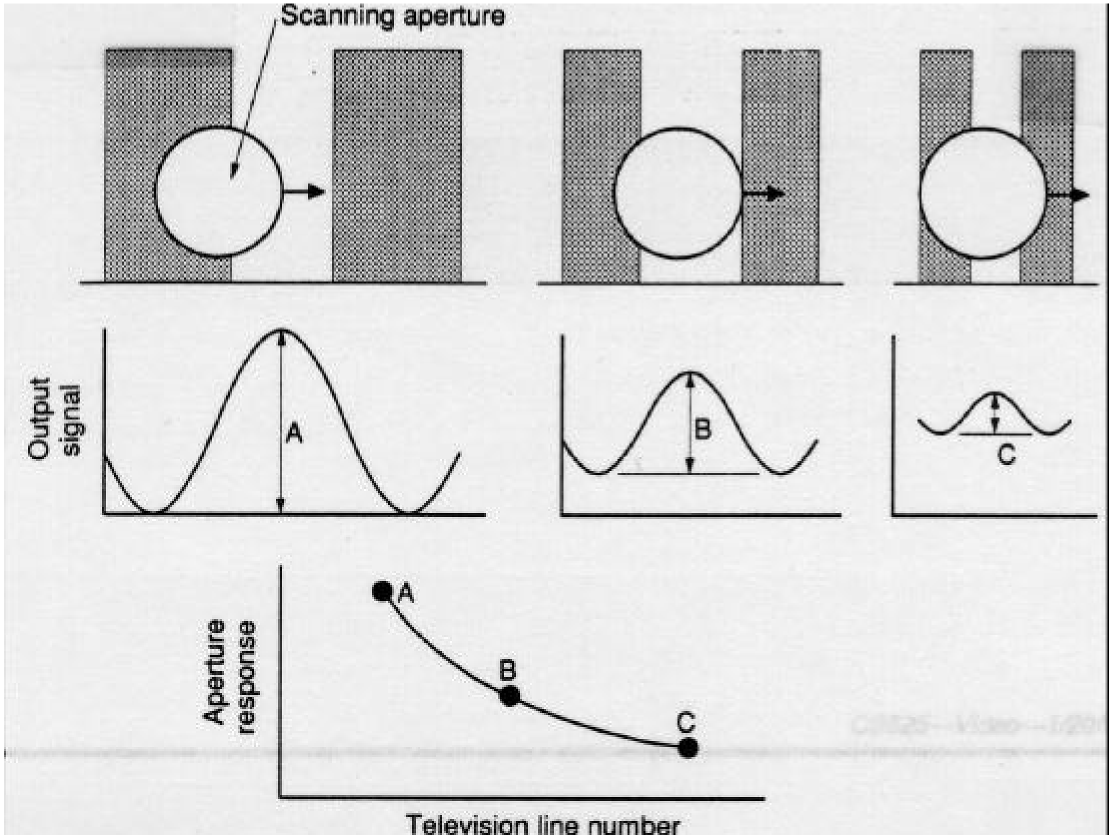
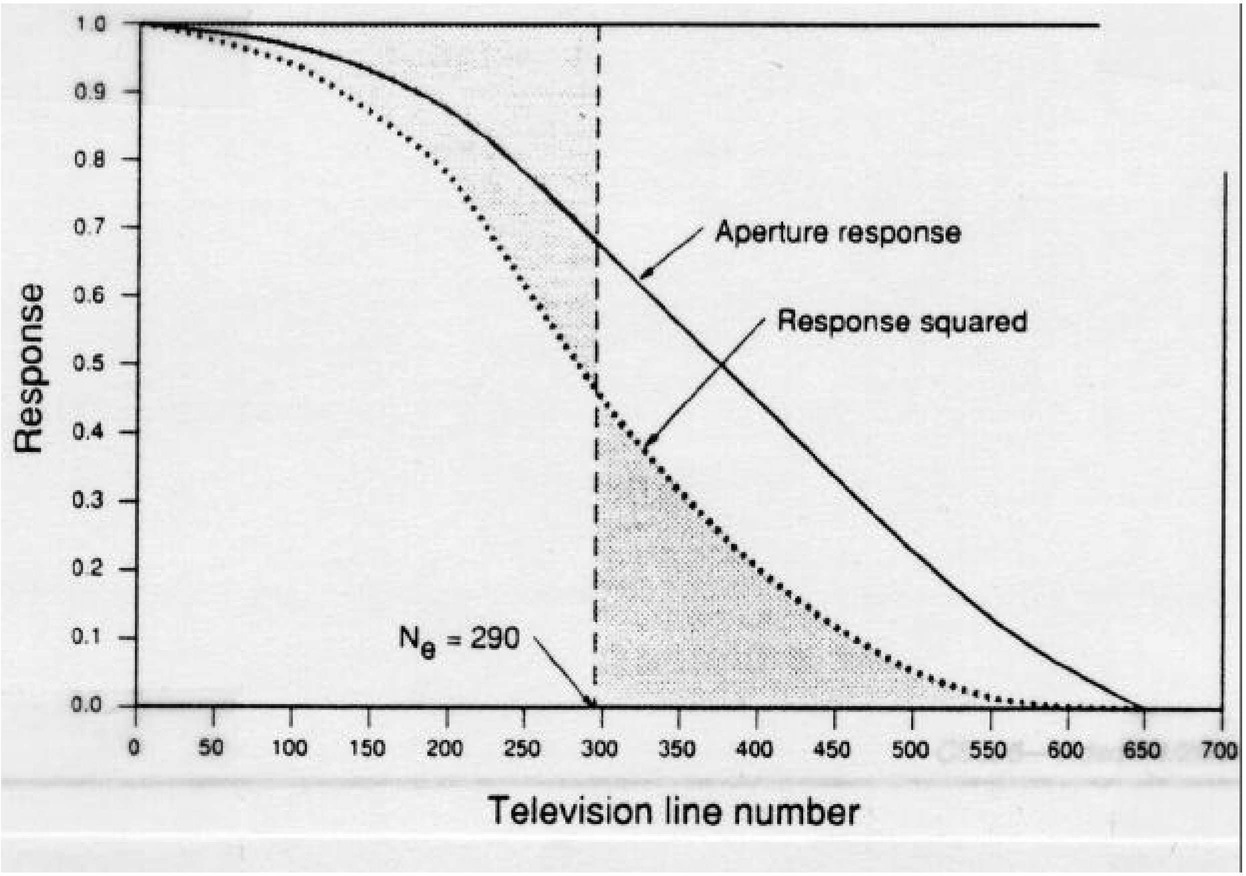


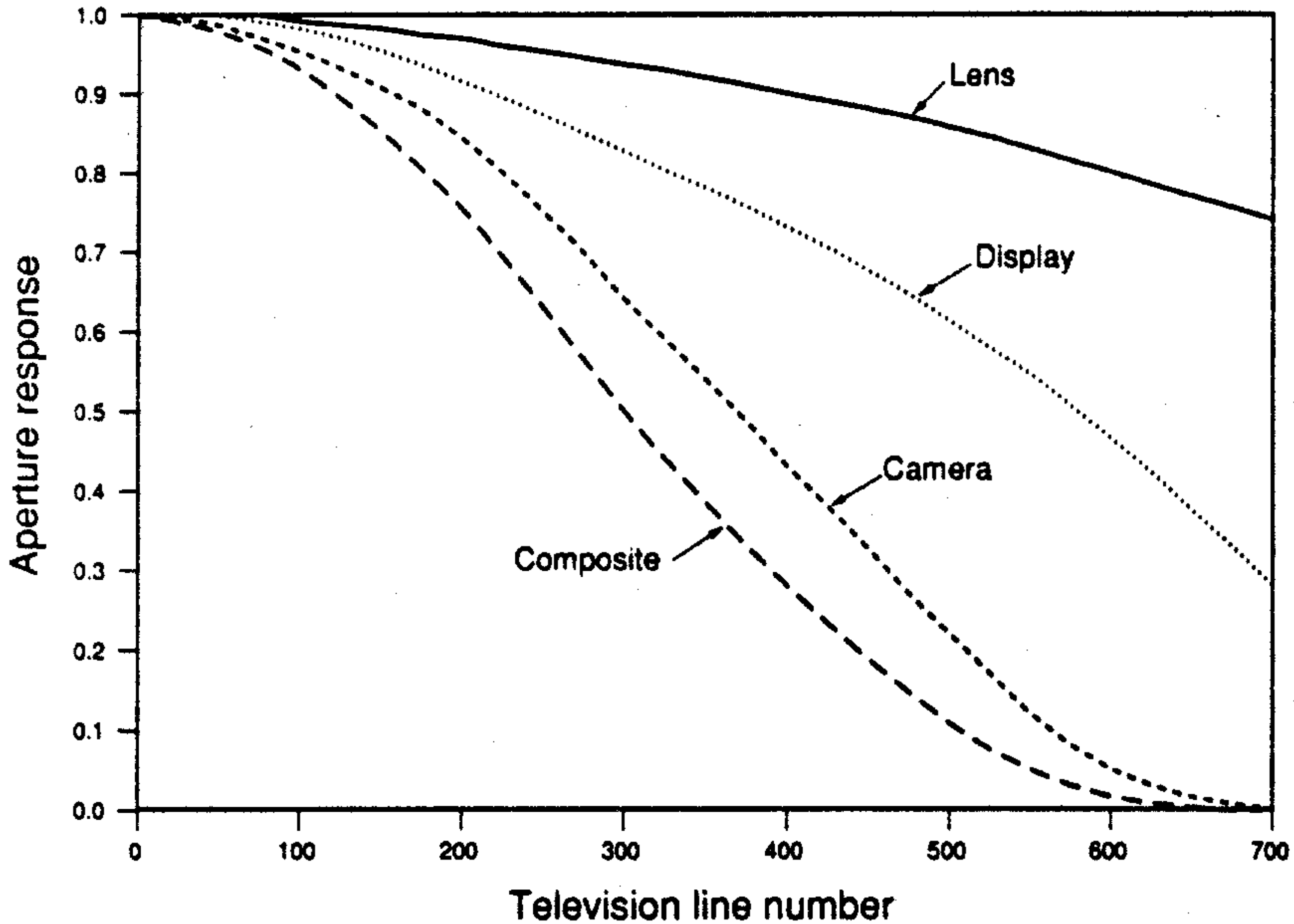
Figure 2.3 Definition of aperture response.

Equivalent line number Ne

An aperture curve is the most complete indication of the definition of a system. Ne is a number trying to approximate the overall definition. It is the line number that defines a rectangle having the same areas the area under the aperture response squared curve**.**



Aperture Response of TV Broadcast System



Comparison of Film and Television Performance

TABLE 2.3 Comparison of Film and Television Performance

	Limiting resolution	N_e
16-mm film	1100	300
NTSC TV		
Horizontal	312	310
Vertical	312	310
35-mm film	1800	450
HDTV		
Horizontal	553	513
Vertical	767	481

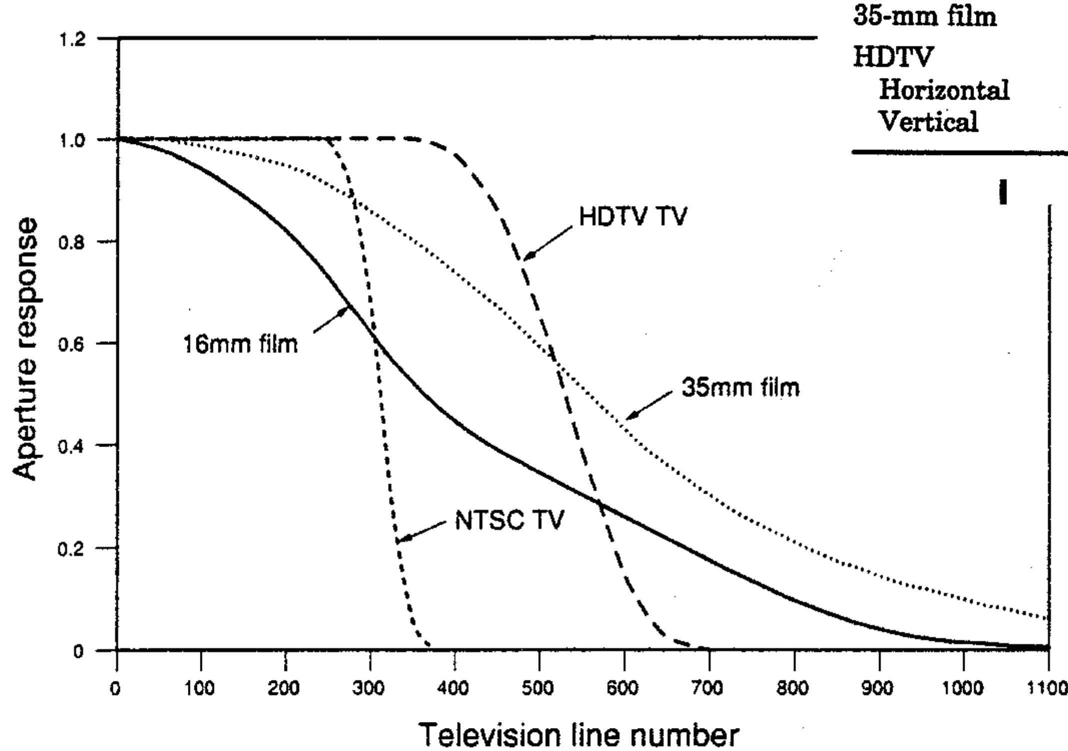


Figure 2.14 Comparison of television and film aperture response.

Color Video Signal

Color has a dual meaning

a physical property of visible light

the perception of this property by human vision.

Each pixel in a color image has thee basic properties

luminance, hue, and saturation in objective terms, and

brightness, color, purity in corresponding perceptual terms.

Hue, Wavelength, and Saturation

The following table is based on monochromatic light (light with single wavelength)

Hue	Approximate wavelength, nm
Violet	400
Blue	450
Cyan	490
Green	520
Yellow	575
Orange	590
Red	640

The colors that appear in nature are polychromatic (mixture of many wavelength)

The wavelength of a visible light ranges from 400 to 780 nm.

White and gray light results when the radiation at all wavelengths is present in approximately equal amount.

Saturation the ratio of the magnitude of the energy in the spectral (dominant wavelength) component to the total energy of the light. A pure spectral color has a saturation of 100%, while the saturation of white or gray light is 0%.

The appearance of any color can be duplicated by a mixture of white or gray light and a pure spectral color in the proper proportions.

Subtractive and Additive Primary Colors

Photography and paining are subtractive color systems. The picture or scene is illuminated by an external source of light with many hues. The hue of the image is produced by the subtraction of color components by absorption. The subtractive primaries are magenta, yellow, and cyan. Since magenta has reddish cast and cyan is bluish, it is popularly (and erroneously) stated that the primary colors are red, yellow, and blue.

TABLE 3.2 Subtractive Primaries

Primary	Reflects or transmits	Absorbs
Magenta	Red and blue	Green
Yellow	Red and green	Blue
Cyan	Blue and green	Red

Color TV is an additive system, since it produces hues by adding the primary color components. The additive primaries are red, blue, green.

TABLE 3.3 Additive Primaries

Combinations	Hue of combination
Red plus green	Yellow
Blue plus green	Cyan
Blue plus red	Magenta

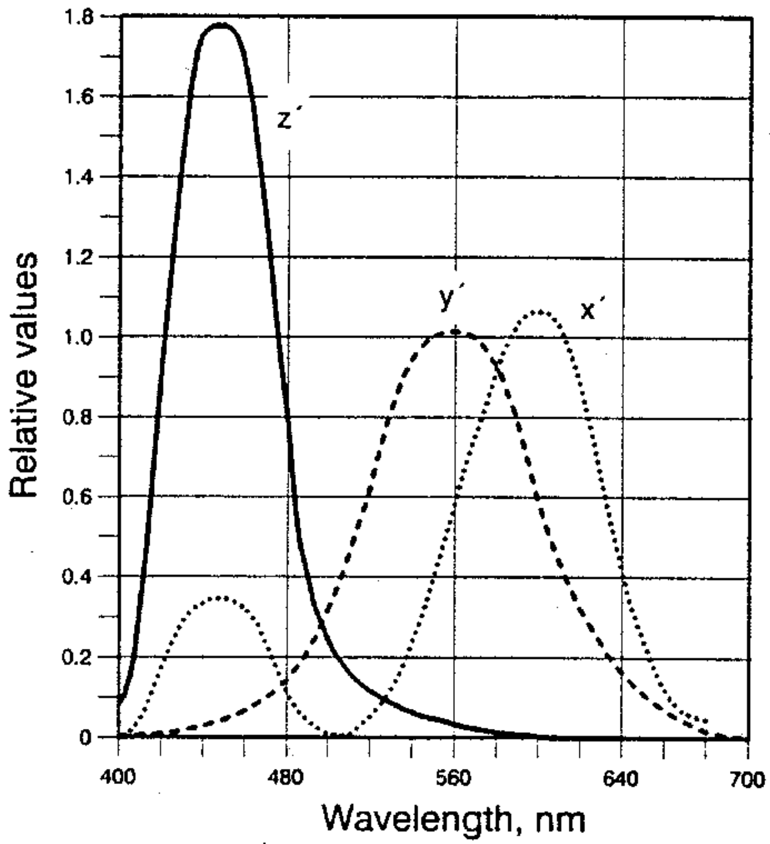
Define Color using CIE Chromaticity Coordinates

Using three color matching functions to produce X, Y, Z tristimulus values.

$$X = 380\int_{380}^{780} L(\lambda)x'(\lambda)d\lambda$$

$$Y = 380\int_{380}^{780} L(\lambda)y'(\lambda)d\lambda$$

$$Z = 380\int_{380}^{780} L(\lambda)z'(\lambda)d\lambda$$



The chromaticity coordinates, x and y are calculated by

$$x = \frac{X}{X+Y+Z}$$

$$y = \frac{Y}{X+Y+Z}$$

CIE (Comité Internationale de l'Eclairage)

The CIE Chromaticity Diagram

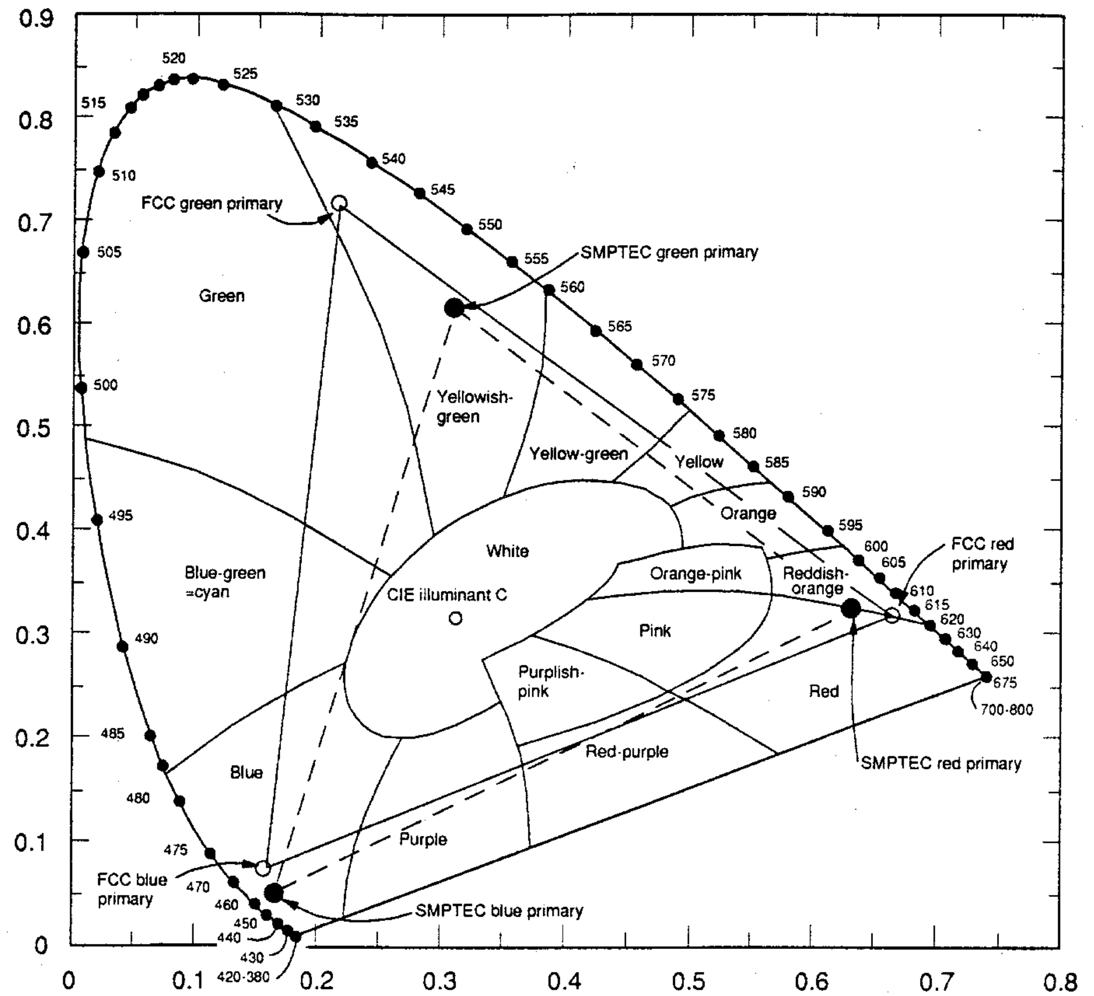
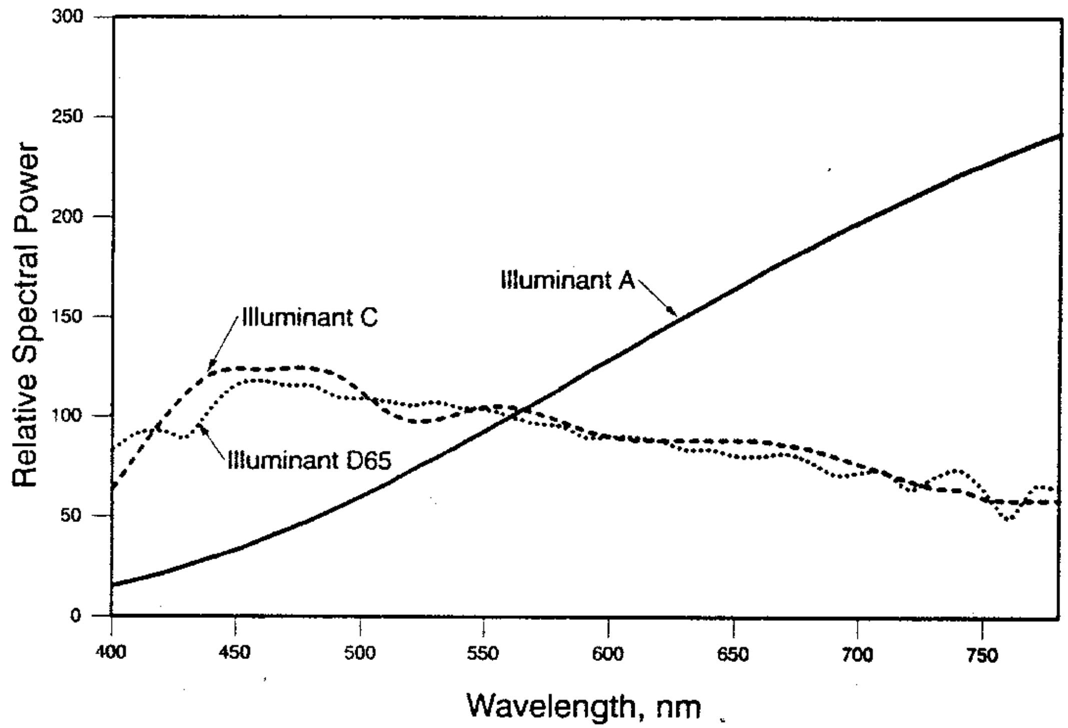


Figure 3.3 The CIE Chromaticity Diagram.

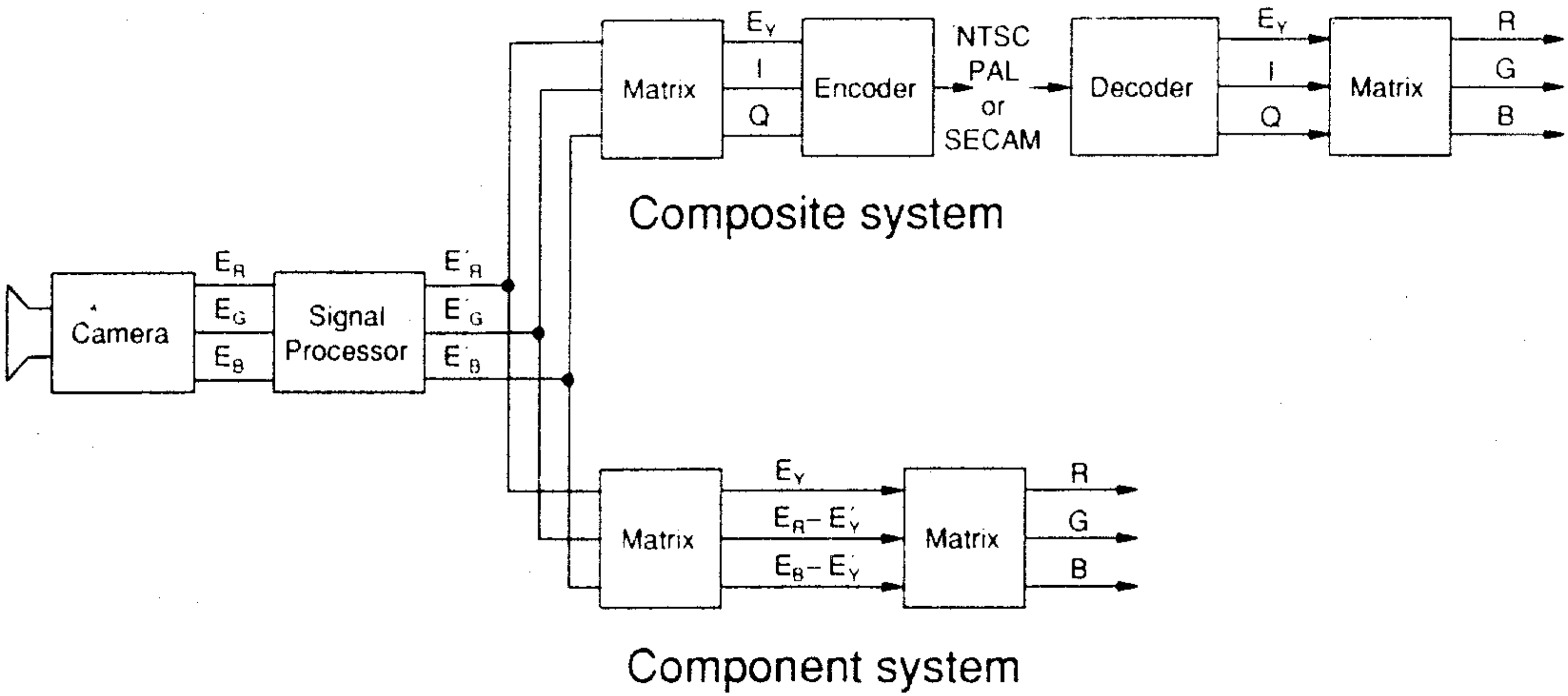
Standard illuminants

TABLE 3.4 Chromaticity Coordinates of Standard Illuminants

Designation	Source	x	y
Illuminant A	Tungsten at 2856 K	0.4476	0.4074
Illuminant C	Daylight	0.3101	0.3516
Illuminant D_{65}	Daylight (revised)	0.3127	0.3290



Analog Color TV System Configuration



Video Signal Formats for Color

Color can be specified by luminance, Y, and
color difference, R-Y and B-Y components.

NTSC uses Y, I, Q format.

PAL uses Y, U, V format.

The three signal components in each format are generated by the gamma-corrected signal E_R’ E_G’ and E_B’.

In all formats, the luminance signal component, E_Y’ is generated by

$E_Y' = 0.299E_R' + 0.587E_G' + 0.114E_B'$

The coefficients of the components E_R’, E_G’, and E_B’ are based on the relative sensitivity of the human eye to the primary colors. E_Y’ is then proportion to the perceived brightness of the scene.

NTSC use $E_I' = 0.60E_R' - 0.28E_G' - 0.32E_B'$ called I signal (orange-cyan)

$E_Q' = 0.21E_R' - 0.51E_G' + 0.30E_B'$ called Q signal (green-magenta)

The ability of the eye to discern fine detail is less in colors than for monochrome, and it is less for magenta than for orange. NTSC take advantages of this.

PAL chominance signal component

PAL systems have 5-5.5 MHz video bandwidth. They use YUV format.

$E_U' = 0.493(E_B' - E_Y')$

$E_V' = 0.877(E_B' - E_Y')$

TABLE 3.7 Color Television System Bandwidths

Country	System	Bandwidth, MHz
United States, Japan	NTSC	4.2
Canada, Mexico	NTSC	4.2
Great Britain	PAL	5.5
Germany, Austria, Italy	PAL	5.0
France	SECAM	6.0
Former USSR	SECAM	6.0

Digital TV

A commonly used format for composite signals

- sampling rate at 4 time subcarrier frequency, or 14.4 MHz (NTSC).
- use 8-bit word to encode each sample.
- the bit rate is 115.2Mbits/s. (very high)

TABLE 4.2 Sampling Frequencies

	NTSC, SMPTE D-2		PAL, SMPTE D-2
Designations:	$3f_{sc}$	$4f_{sc}$	$4f_{sc}$
Composite Signals			
Bandwidth, MHz	4.2	4.2	5.5
Subcarrier frequency (f_{sc}), MHz	3.58	3.58	4.43
Sampling frequency, MHz	10.6	14.4	17.7
Samples per total line	674	915	1132
Samples per active line	557	757	939
Bit rate, Mbits/s (8-bit words)	85.9	114.5	141.9

Sampling Freqency for Component Signals

Component Signals

	525 lines, 59.95 fields	625 lines, 50 fields
Designations:	SMPTE D-1 SMPTE RP 125 CCIR 601 4-2-2	SMPTE D-1 EBU 3246/3247 CCIR 601 4-2-2
Luminance channel		
Bandwidth, MHz	5.5	5.5
Sampling frequency, MHz	13.5	13.5
Samples per total line	858	864
Samples/active line	710	716
Bit rate, Mbits/s	108.0	108.0
Color difference channels		
Bandwidth, MHz	2.2	2.2
Sampling frequency, MHz	6.75	6.75
Samples per total line	429	432
Samples per active line	355	358
Bit rate, Mbits/s (8-bit words)	54.0	54.0

Charge Coupled Device Imager in TV Camera

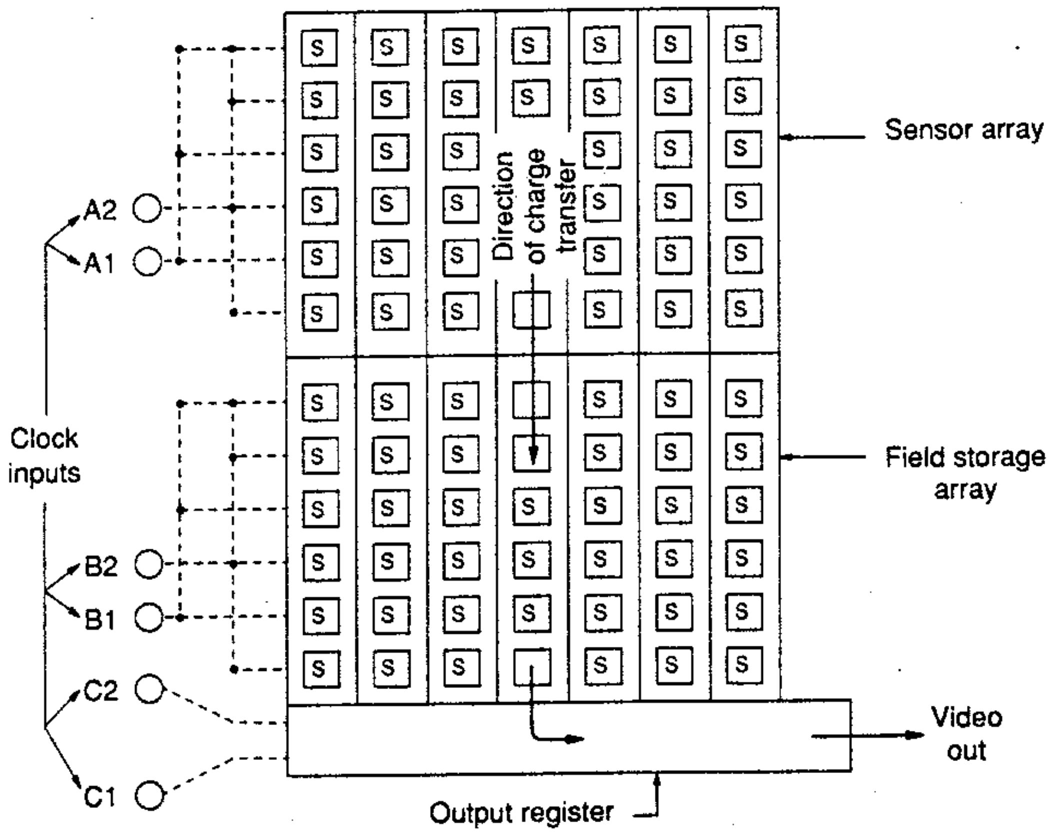


Figure 5.4 Frame transfer architecture. (From Donald G. Fink Donald Christiansen, Electronic Engineers' Handbook, 3d *McGraw-Hill, New York, 1989, Fig. 20.44a.)*

VCR: Helical Scan Recording Principle

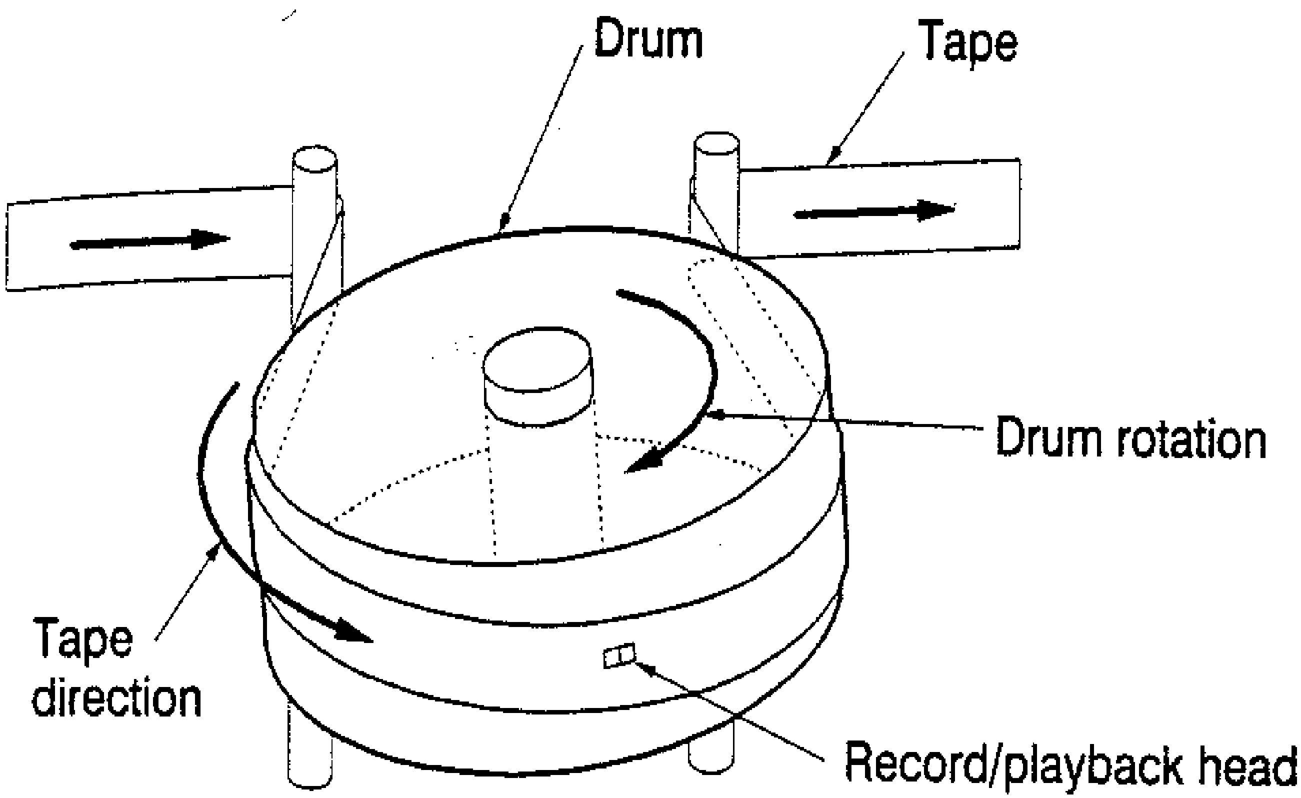


Figure 6.1 Helical scan recorder principle.

SMPTE Type C Recording Format

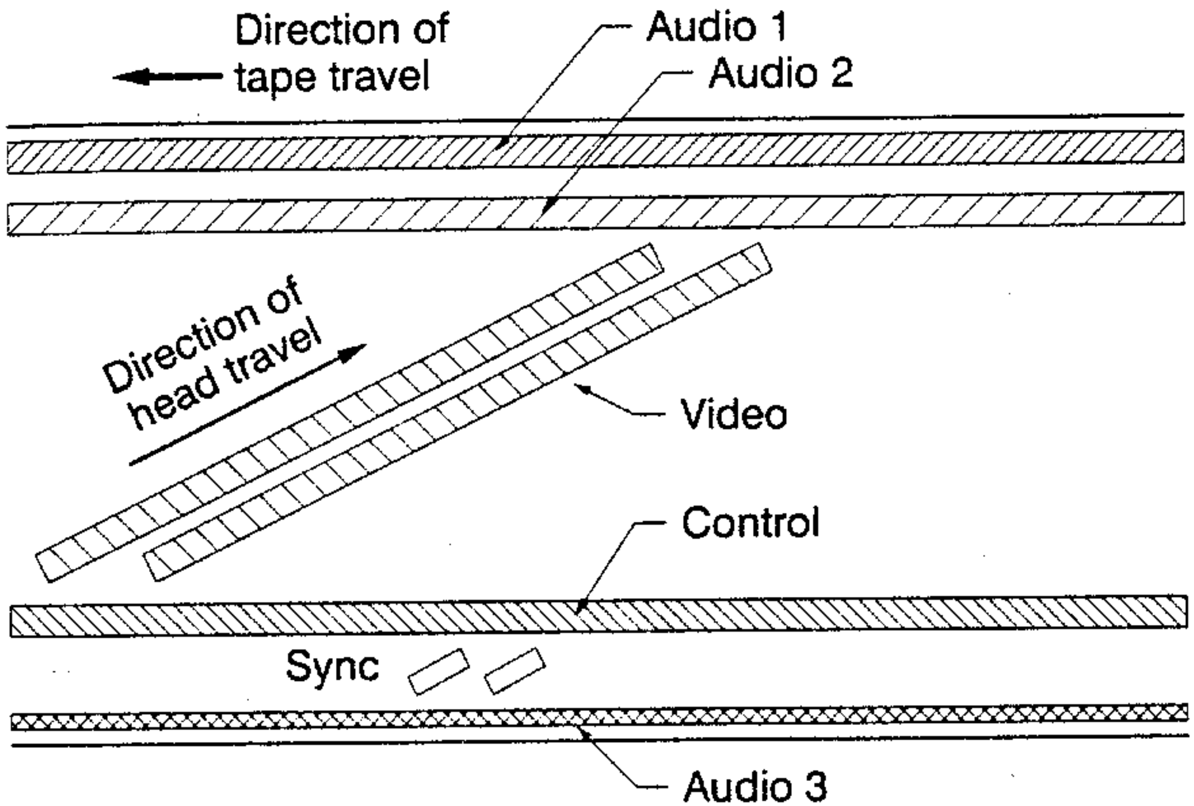


Figure 6.2 SMPTE Type C record format. Ref. SMPTE Type C recording format. (*From SMPTE/ANSI Standards*, V98.18M-1983, V98.19M-1983, V98.20M-1979 (Src), RP85-1979, RP86-1979.)

Slow Motion, Still Frame, Picture-in-Shuttle