Video

Lecture 06

BIL464 Multimedia Systems

Mustafa Sert

Asst. Prof.

msert@baskent.edu.tr

Department of Computer Engineering, Başkent University

Ankara 06810 TURKEY

Content

- Types of Video Signals
- Analog Video
- Digital Video

Types of Video Signals

- Video is a sequence of images
- Recorded/displayed at a certain rate
- Types of video signals
  - component video
    - separate RGB signals; e.g., VGA CRT

  - composite video
    - luminance and chrominance in one signal carrier

  - S-video
    - 1 luminance and 1 composite chrominance signal

Types of Video Signals – *Cont.*

- Component video: Higher-end video systems make use of three separate video signals for the red, green, and blue image planes. Each color channel is sent as a separate video signal.
  - Most computer systems use Component Video, with separate signals for R, G, and B signals.
  - For any color separation scheme, Component Video gives the best color reproduction since there is no "crosstalk" between the three channels.
  - This is not the case for S-Video or Composite Video, discussed next. Component video, however, requires more bandwidth and good synchronization of the three components.

Types of Video Signals – *Cont.*

- Composite video: color ("chrominance") and intensity ("luminance") signals are mixed into a *single* carrier wave.
  - **Chrominance** is a composition of two color components (I and Q, or U and V).
  - In NTSC TV, e.g., I and Q are combined into a chroma signal, and a color subcarrier is then employed to put the chroma signal at the high-frequency end of the signal shared with the luminance signal.
  - The chrominance and luminance components can be separated at the receiver end and then the two color components can be further recovered.
  - When connecting to TVs or VCRs, Composite Video uses only one wire and video color signals are mixed, not sent separately. The audio and *sync* signals are additions to this one signal.
- Since color and intensity are wrapped into the same signal, some interference between the luminance and chrominance signals is inevitable.

Types of Video Signals – *Cont.*

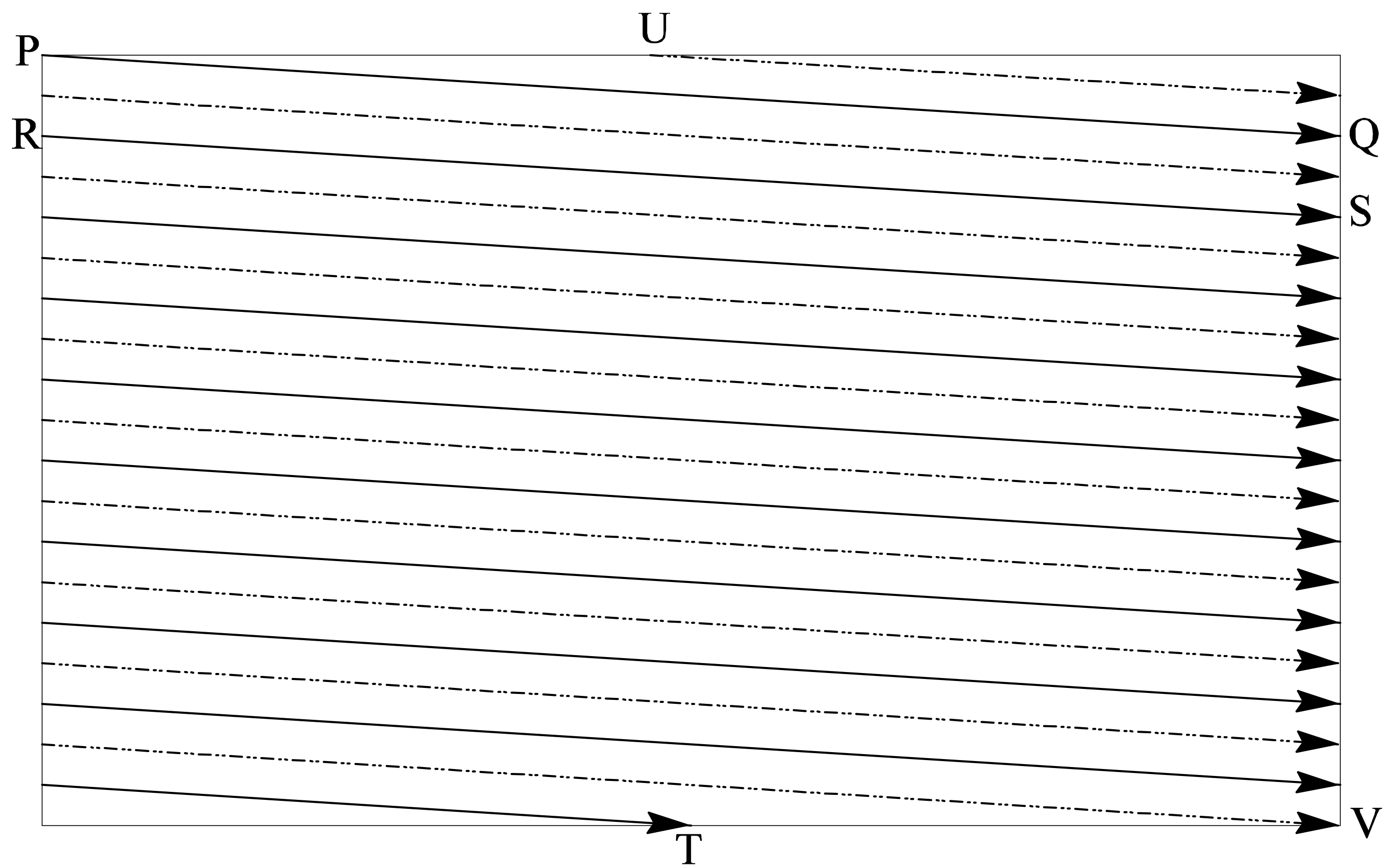
- S-Video: as a compromise, (separated video, or Super-video, e.g., in S-VHS) uses two wires, one for luminance and another for a composite chrominance signal.
- As a result, there is less crosstalk between the color information and the crucial gray-scale information.
- The reason for placing luminance into its own part of the signal is that black-and-white information is most crucial for visual perception.
  - In fact, humans are able to differentiate spatial resolution in grayscale images with a much higher acuity than for the color part of color images.
  - As a result, we can send less accurate color information than must be sent for intensity information — we can only see fairly large blobs of color, so it makes sense to send less color detail.

Analog Video

- An analog signal $f(t)$ samples a time-varying image. So-called “progressive” scanning traces through a complete picture (a frame) row-wise for each time interval.
- In TV, and in some monitors and multimedia standards as well, another system, called “interlaced” scanning is used:
  - The odd-numbered lines are traced first, and then the even-numbered lines are traced. This results in “odd” and “even” fields — two fields make up one frame.
  - In fact, the odd lines (starting from 1) end up at the middle of a line at the end of the odd field, and the even scan starts at a half-way point.

Analog Video – *Cont.*

Fig. 1:
Interlaced raster scan



- Figure 1 shows the scheme used. First the solid (odd) lines are traced, P to Q, then R to S, etc., ending at T; then the even field starts at U and ends at V.
- The jump from Q to R, etc. in Figure 1 is called the horizontal retrace, during which the electronic beam in the CRT is blanked. The jump from T to U or V to P is called the vertical retrace.

Analog Video – *Cont.*

- Because of interlacing, the odd and even lines are displaced in time from each other — generally not noticeable except when very fast action is taking place on screen, when blurring may occur.
- For example, in the video in Fig. 2, the moving helicopter is blurred more than is the still background.

Analog Video – *Cont.*

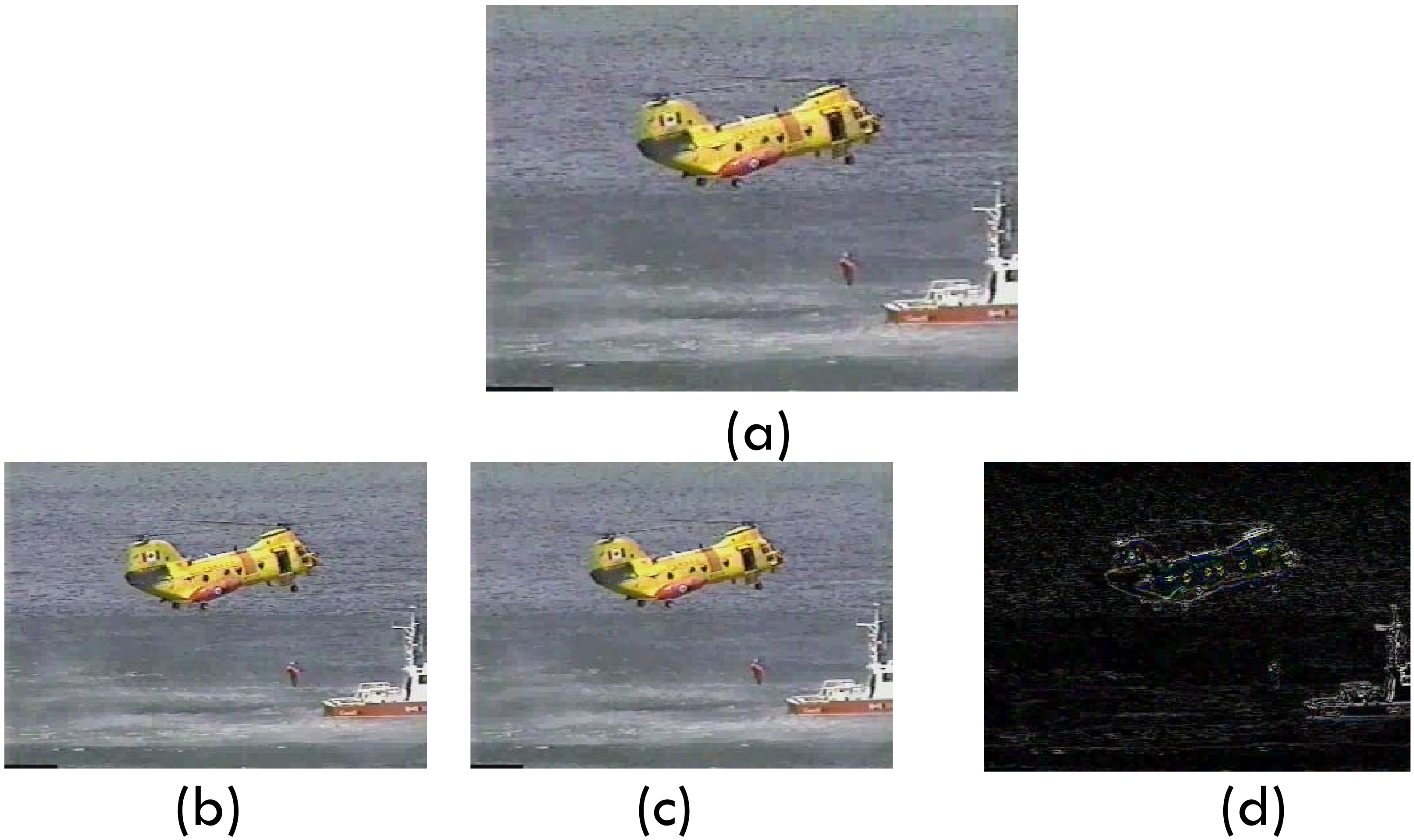


Fig. 2: Interlaced scan produces two fields for each frame. (a) The video frame, (b) Field 1, (c) Field 2, (d) Difference of Fields

Analog Video – *Cont.*

- Since it is sometimes necessary to change the frame rate, resize, or even produce stills from an interlaced source video, various schemes are used to "de-interlace" it.
  - The simplest de-interlacing method consists of discarding one field and duplicating the scan lines of the other field. The information in one field is lost completely using this simple technique.
  - Other more complicated methods that retain information from both fields are also possible.
- Analog video use a small voltage offset from zero to indicate "black", and another value such as zero to indicate the start of a line. For example, we could use a "blacker-than-black" zero signal to indicate the beginning of a line. (Fig. 3)

Analog Video – Cont.

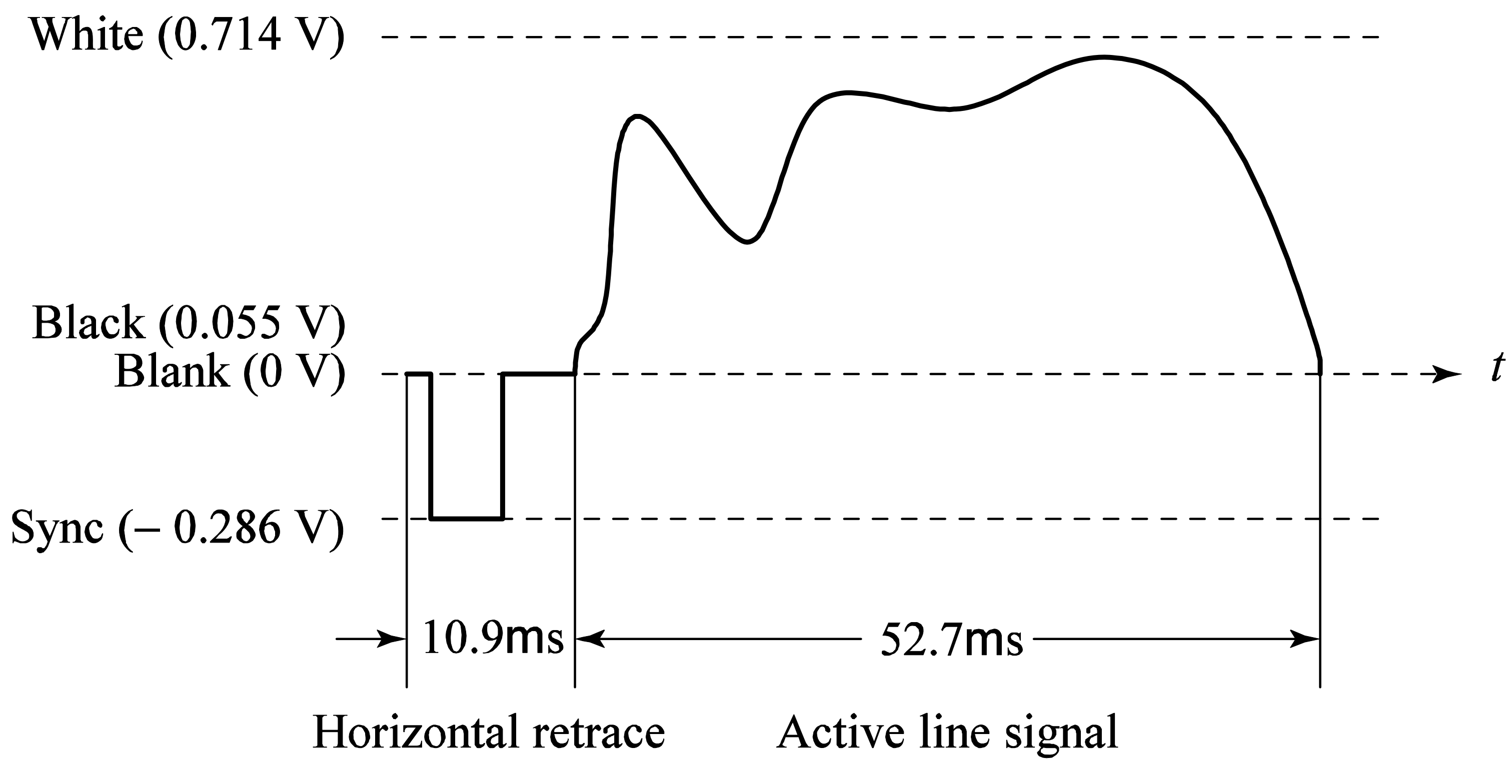


Fig. 3 Electronic signal for one NTSC scan line.

NTSC Video

- NTSC (National Television System Committee) TV standard is mostly used in North America and Japan. It uses the familiar 4:3 aspect ratio (i.e., the ratio of picture width to its height) and uses 525 scan lines per frame at 30 frames per second (fps).
  - NTSC follows the interlaced scanning system, and each frame is divided into two fields, with 262.5 lines/field.
  - Thus the horizontal sweep frequency is $525 \times 29.97 \approx 15,734$ lines/sec, so that each line is swept out in $1/15.734$ sec $\approx 63.6 \mu$sec.
  - Since the horizontal retrace takes 10.9 μsec, this leaves 52.7μsec for the active line signal during which image data is displayed

NTSC Video – *Cont.*

- Fig.4 shows the effect of "vertical retrace & sync" and "horizontal retrace & sync" on the NTSC video raster.

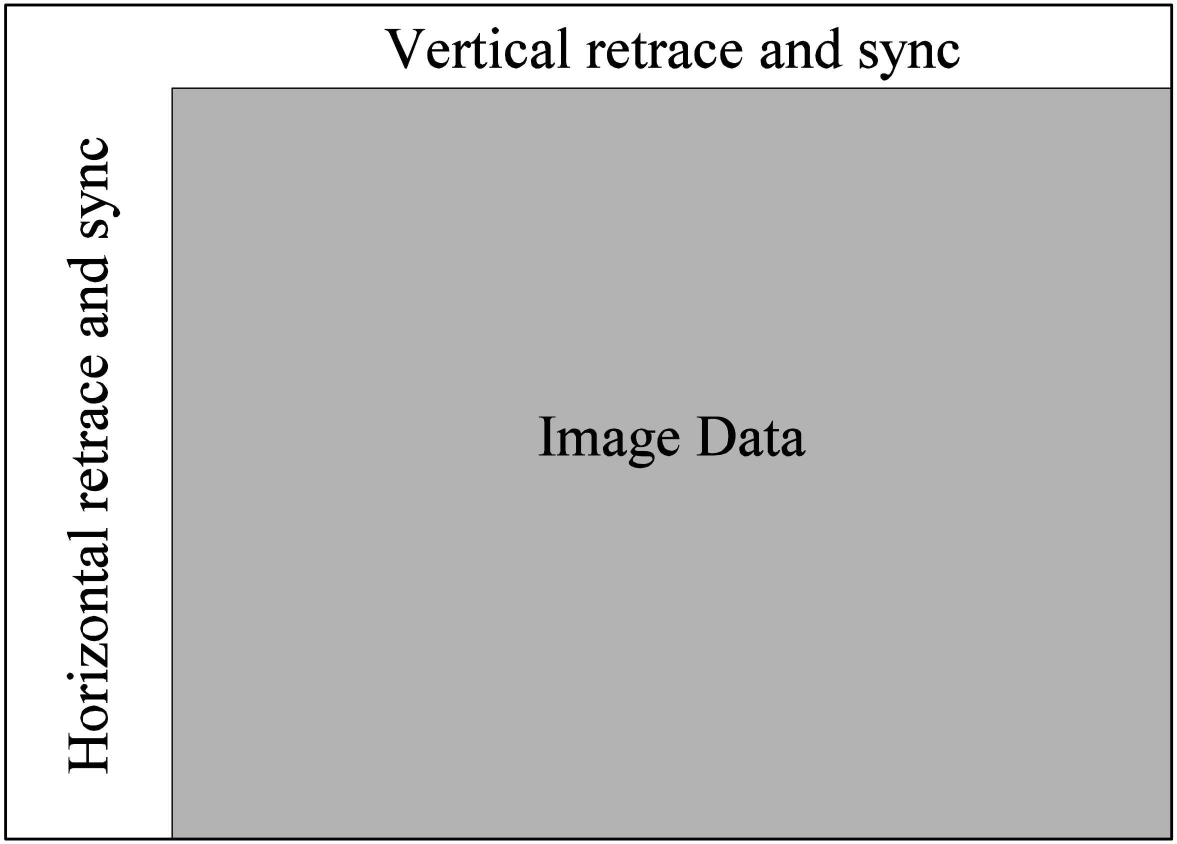


Fig. 4: Video raster, including retrace and sync data

NTSC Video – *Cont.*

- Vertical retrace takes place during 20 lines reserved for control information at the beginning of each field. Hence, the number of active *video lines* per frame is only 485.
- Since the horizontal retrace takes 10.9 μsec, this leaves 52.7 μsec for the active line signal during which image data is displayed (see Fig. 3).

NTSC Video – *Cont.*

- Different video formats provide different numbers of samples per line, as listed in Table 1.

Table 1: Samples per line for various video formats

Format	Samples per line
VHS	240
S-VHS	400-425
Betamax	500
Standard 8 m	300
Hi-8 mm	425

Color Model and Modulation of NTSC

- NTSC uses the YIQ color model, and the technique of quadrature modulation is employed to combine (the spectrally overlapped part of) I (in-phase) and Q (quadrature) signals into a single chroma signal C:

$$C = I\cos(F_{sc}t) + Q\sin(F_{sc}t) \tag{1}$$

- This modulated chroma signal is also known as the color subcarrier, whose magnitude is $\sqrt{I^2 + Q^2}$, and phase is $\tan^{-1}(Q/I)$. The frequency of C is $F_{sc} \approx 3.58$ MHz.
- The NTSC composite signal is a further composition of the luminance signal Y and the chroma signal as defined below:

$$\text{composite} = Y + C = Y + I\cos(F_{sc}t) + Q\sin(F_{sc}t) \tag{2}$$

Decoding NTSC Signals

- The first step in decoding the composite signal at the receiver side is the separation of Y and C.
- After the separation of Y using a low-pass filter, the chroma signal C can be demodulated to extract the components I and Q separately. To extract I:
  - Multiply the signal C by 2 cos($F_{sc}t$), i.e.,

$$
\begin{aligned}
C \cdot 2\cos(F_{sc}t) &= I \cdot 2\cos^2(F_{sc}t) + Q \cdot 2\sin(F_{sc}t)\cos(F_{sc}t) \\
&= I \cdot (1+\cos(2F_{sc}t)) + Q \cdot 2\sin(F_{sc}t)\cos(F_{sc}t) \\
&= I + I \cdot \cos(2F_{sc}t) + Q \cdot \sin(2F_{sc}t)
\end{aligned}
$$

Decoding NTSC Signals – *Cont.*

- Apply a low-pass filter to obtain I and discard the two higher frequency ($2F_{sc}$) terms.
- Similarly, Q can be extracted by first multiplying C by $2\sin(F_{sc}t)$ and then low-pass filtering.

PAL Video

- PAL (Phase Alternating Line) is a TV standard widely used in Western Europe, China, India, and many other parts of the world.
- PAL uses 625 scan lines per frame, at 25 frames/second, with a 4:3 aspect ratio and interlaced fields.
  - PAL uses the YUV color model. It uses an 8 MHz channel and allocates a bandwidth of 5.5 MHz to Y, and 1.8 MHz each to U and V. The color subcarrier frequency is $f_{sc} \approx 4.43$ MHz.
  - In order to improve picture quality, chroma signals have alternate signs (e.g., +U and -U) in successive scan lines, hence the name "Phase Alternating Line".
  - This facilitates the use of a (line rate) comb filter at the receiver — the signals in consecutive lines are averaged so as to cancel the chroma signals (that always carry opposite signs) for separating Y and C and obtaining high quality Y signals.

SECAM Video

- SECAM stands for *Système Electronique Couleur Avec Mémoire*, the third major broadcast TV standard.
- SECAM also uses 625 scan lines per frame, at 25 frames per second, with a 4:3 aspect ratio and interlaced fields.
- SECAM and PAL are very similar. They differ slightly in their color coding scheme:
  - In SECAM, U and V signals are modulated using separate color subcarriers at 4.25 MHz and 4.41 MHz respectively.
  - They are sent in alternate lines, i.e., only one of the U or V signals will be sent on each scan line.

Comparison

- Table 2 gives a comparison of the three major analog broadcast TV systems.

Table 2: Comparison of Analog Broadcast TV Systems

TV System	Frame Rate (fps)	# of Scan Lines	Total Channel Width (MHz)	Bandwidth Allocation (MHz)		
				Y	I or U	Q or V
NTSC	29.97	525	6.0	4.2	1.6	0.6
PAL	25	625	8.0	5.5	1.8	1.8
SECAM	25	625	8.0	6.0	2.0	2.0

Digital Video

Standards for Video

	HDTV	CCIR 601 NTSC	CCIR 601 PAL	CIF	QCIF
Luminance Resolution	1920 x 1080	720 x 486	720 x 576	352 x 288	176 x 144
Chrominance Resolution	960 x 540	360 x 486	360 x 576	176 x 144	88 x 72
Color Subsampling	4:2:2	4:2:2	4:2:2	4:2:0	4:2:0
Fields/sec	60	60	50	30	30
Aspect Ratio	16:9	4:3	4:3	4:3	4:3
Interlacing	Yes	Yes	Yes	No	No

CCIR – Consultative Committee for International Radio
CIF – Common Intermediate Format (approximately VHS quality)

Chroma Subsampling

- Chrominance subsampling (also called *chrominance downsampling*) is a process of throwing away some of the bits used to represent pixels—in particular, some of the color information.
  - For example, with YCbCr color mode, we might choose to save only one Cb value and one Cr value but four Y values for every four pixel values.
- The conventional notation for luminance/chrominance subsampling is in the form *a*:*b*:*c*
- Common subsampling rates are 4:1:1, 4:2:0, and 4:2:2
  - To understand what these numbers represent, count the number of samples taken for Y and Cb (or Cr, since they are the same) in each pair of four-pixel-wide rows. *a* is the number of Y samples in both rows. *b* is the number of Cb samples in the first row (and also the number of Cr samples). c is the number of Cb (and Cr samples) in the second row.

Chroma Subsampling

- Note that we have not specified how the Cb and Cr values are derived. Just one of the values in a sub-block could be used, or the values could be averaged. (In fact, MPEG-1 and MPEG-2 video compression use different methods for determining the single chrominance values corresponding to four luminance values in 4 : 2 : 0 downsampling.)
- Three commonly used subsampling rates are depicted below:

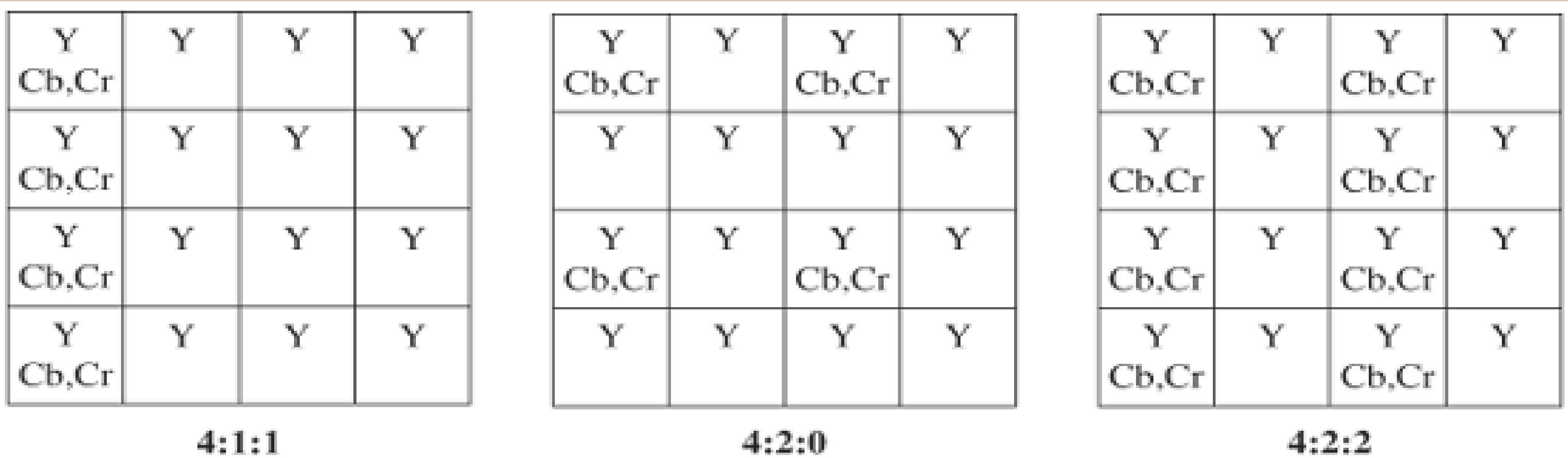
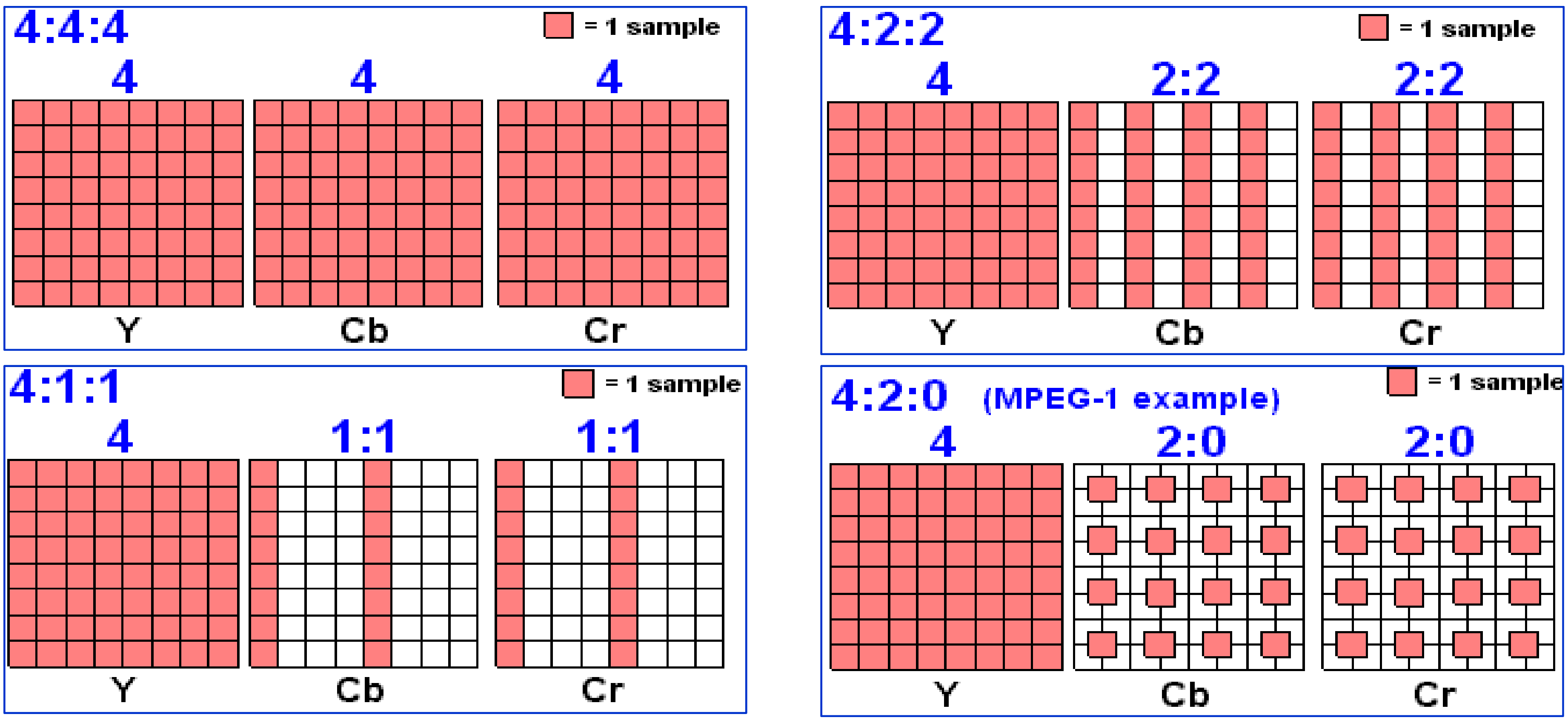


Figure Chrominance subsampling

Chroma Subsampling – *Illustrative Examples*

- Chroma Subsampling: YCbCr is designated as 4:n:n. The 4 represents a sampling rate of 13.5 MHz, which is the standard frequency (ITU-R BT.601) for digitizing analog NTSC, PAL and SECAM. The next two digits represent the Cb and Cr rate.



HDTV

- High Definition TV: better video/audio

# of Active Pixels per line	# of Active Lines	Aspect Ratio	Picture Rate
1,920	1,080	16:9	60I 30P 24P
1,280	720	16:9	60P 30P 24P
704	480	16:9 & 4:3	60I 60P 30P 24P
640	480	4:3	60I 60P 30P 24P

TV Resolution – Evaluation

- **LDTV**: low definition
  - 240i60, 288i50
- **SDTV**: standard definition
  - 480i60, 480p30, 576i50, 576p25
- **EDTV**: enhanced definition
  - 480p60, 576p50, 720i50/60, 720p24/25/30
- **HDTV**: high definition
  - 720p50/60, 1080p24/25/30, 1080i50, 1080i60