Fundamental Concepts in Video

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Content

1. Types of Video Signals

- Component Video
- Composite Video
- S-Video

1.1 Component video

- High-end video systems, such as for studio
  - Three separated video signals -- Red， Green and Blue image plane
  - Three wires connecting to Camera or other devices to TV or monitor
- Giving the best color reproduction
  - No “crosstalk” between the different channels
  - Requiring more bandwidth and good synchronization

- Besides RGB， YIQ, YUV and other model can be used
  - Luminance-chrominance transformation from RGB

1.2 Composite Video

- Chrominance and luminance signals mixed into a single carrier wave
  - Chrominance -- I and Q (or U and V)
  - Only one wire – some interference

- Used by broadcast color TV, downward compatible with black-and-white TV

Composite Video Cable and Connection

1.2 Composite Video

- a) Chrominance is a composition of two color components (I and Q, or U and V).
- b) 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.
- c) The chrominance and luminance components can be separated at the receiver end and then the two color components can be further recovered.
- d) 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.

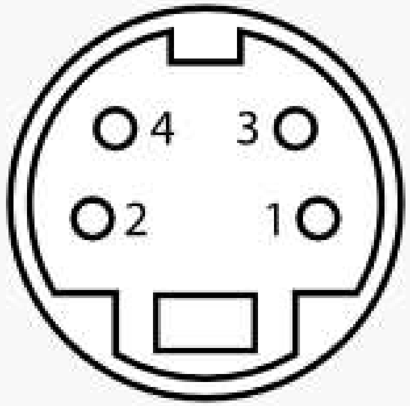
1.3 S-Video

- **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.

1.3 S-Video

- S-Video Connector Example

A standard 4-pin S-Video cable connector, with each signal pin paired with its own ground pin.



Connector Pinout (looking at the socket).

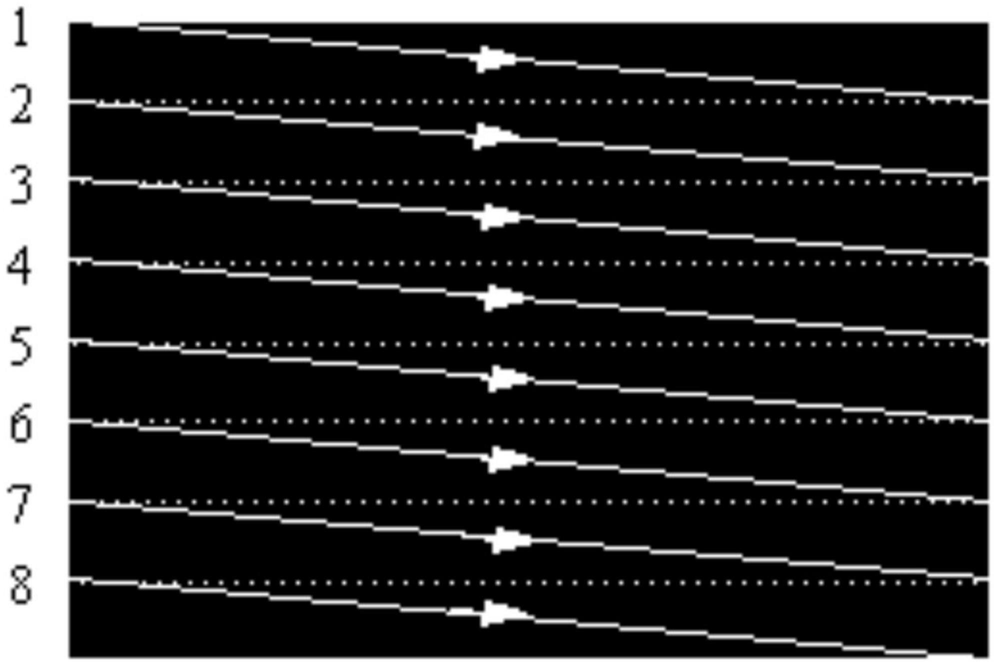
Pin 1	GND	Ground (Y)
Pin 2	GND	Ground (C)
Pin 3	Y	Intensity (Luminance)
Pin 4	C	Color (Chrominance)

2. Analog Video

- Related Concepts
- NTSC Video
- PAL Video
- SECAM Video
- Comparison of NTSC, PAL and SECAM

2.1 Related Concepts

- Analog signal : f(t) -- time-varying images
- "progressive" scanning traces through a complete picture (a frame) row-wise for each time interval.
- CRT Monitor (85Hz above)



2.1 Related Concepts

- 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 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.

2.1 Related Concepts

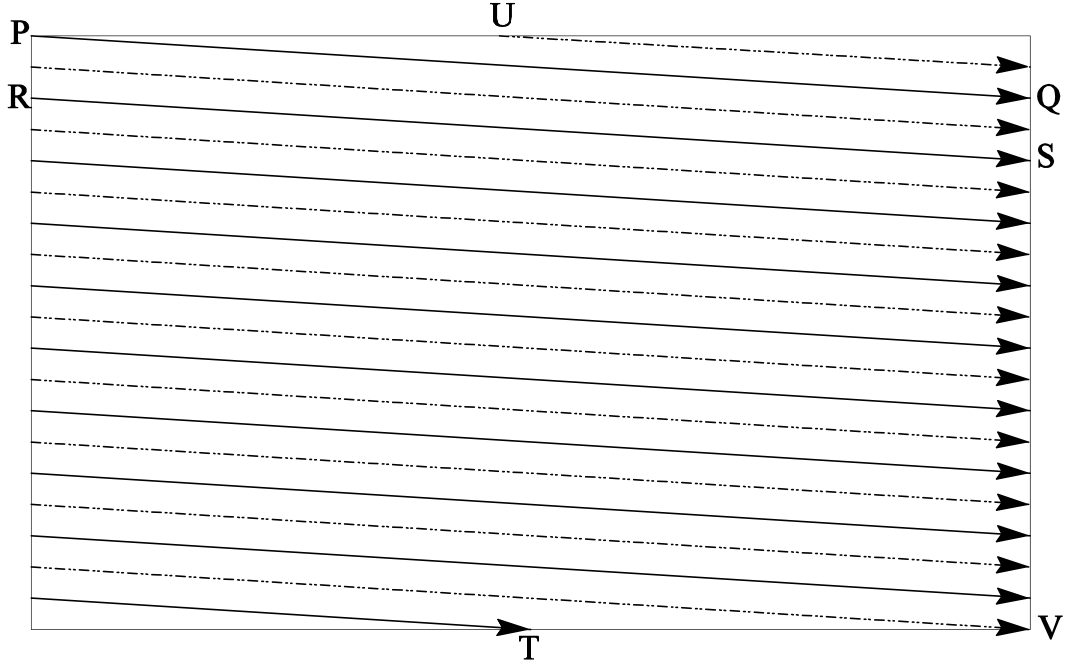
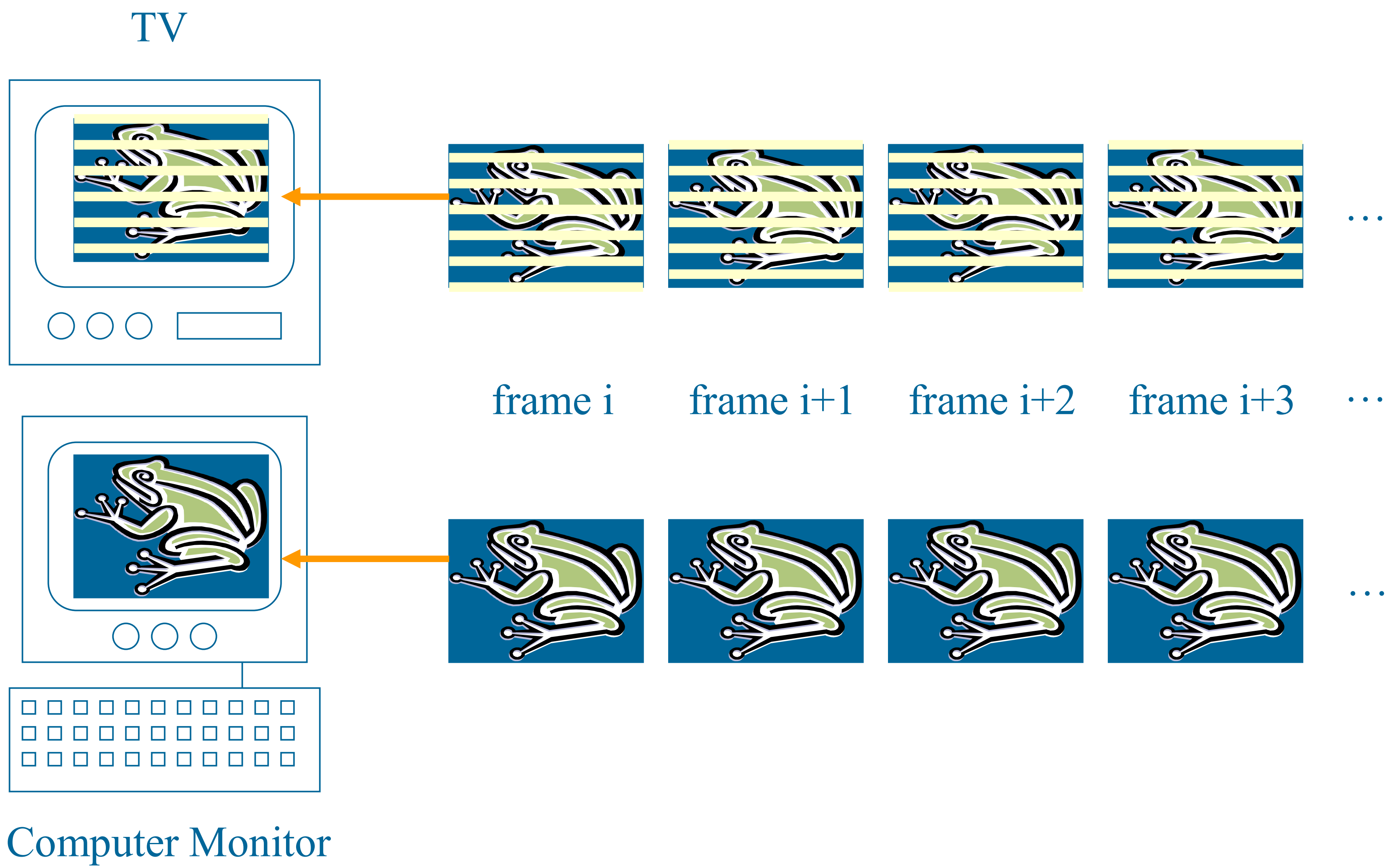


Fig. 5.1: Interlaced raster scan

Figure 5.1 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 5.1 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**.

2.1 Related Concepts



2.1 Related Concepts

- 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. 5.2, the moving helicopter is blurred more than is the still background.

(a) (b) (c)

Fig. 5.2: Interlaced scan produces two fields for each frame. (a) Field 1, (b) Field 2, (c) Difference of Fields

2.1 Related Concepts

- 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.

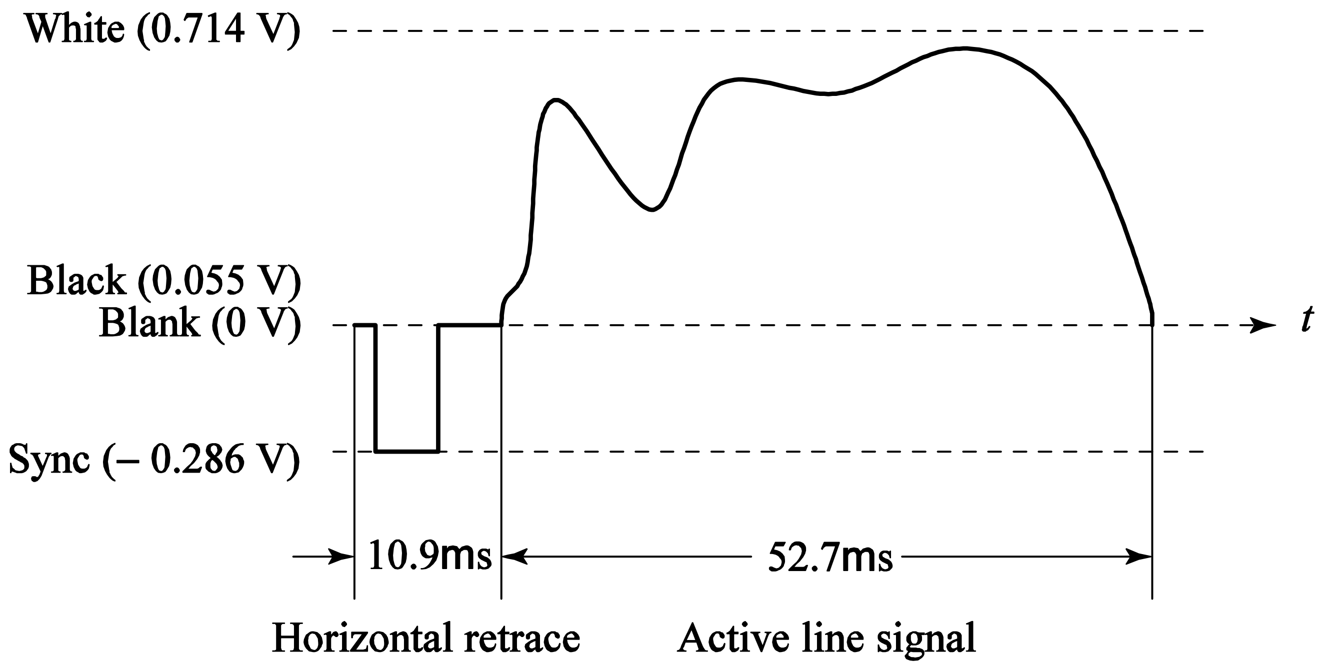


Fig. 5.3 Electronic signal for one NTSC scan line.

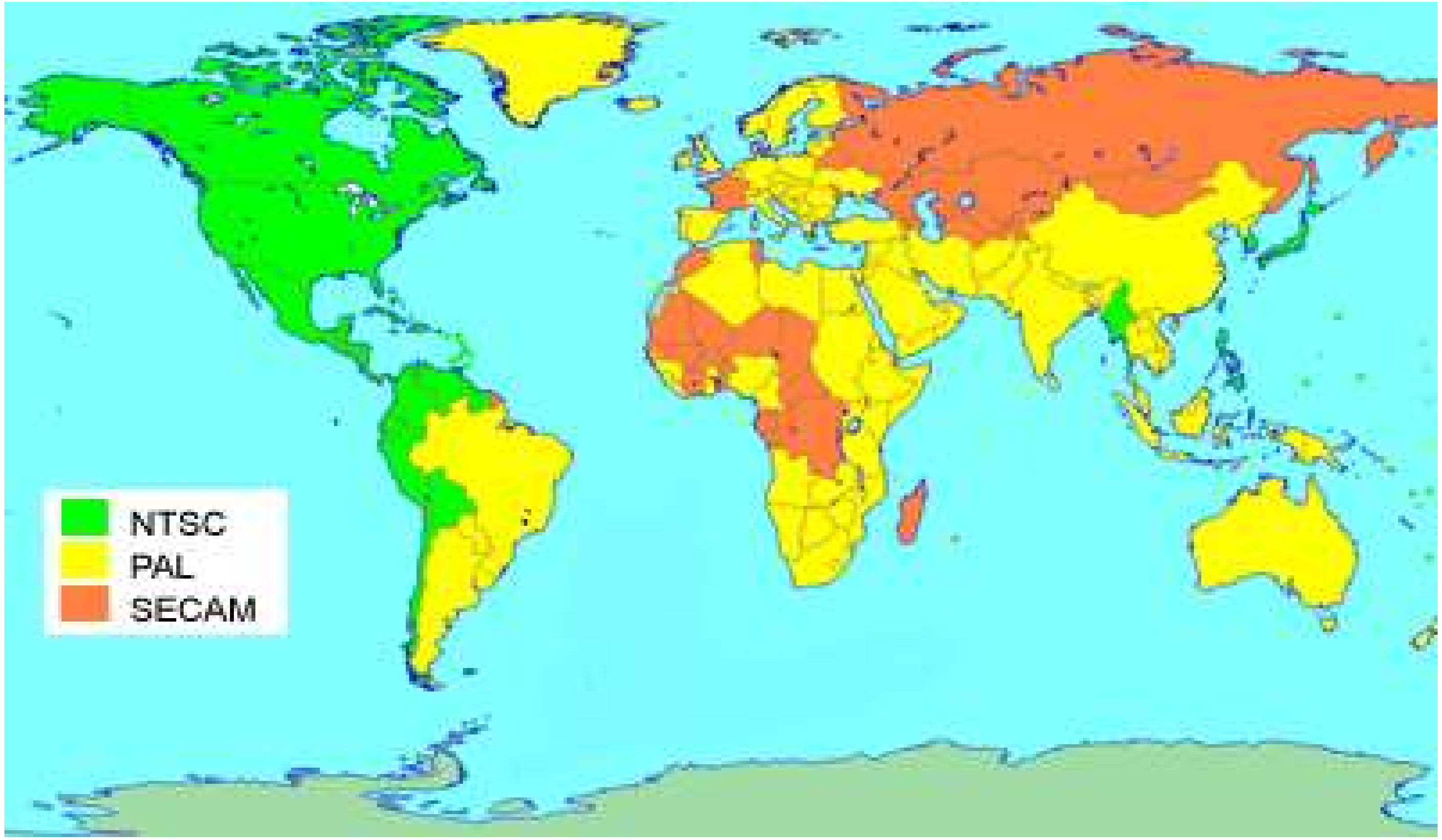
2.1 Related Concepts

- Television Standards for analog TV
  - NTSC Video（正交平衡调幅）
    - USA, Canada, Japan and Korea，1953 by USA
  - PAL Video（逐行倒相正交平衡调幅）
    - Germany, England and China, 1962 by Germany
  - SECAM Video（顺序传送彩色与存储）
    - France, Russia，1966 by France

- Downward compatible with black-and-white TV system
  - Parameters Consistence：scan method, scan row-frequency, field frequency, frame frequency, image carrier-frequency, audio carrier-frequency
  - Signal transmission Consistence: Luminance signal, two chrominance signals

2.1 Related Concepts

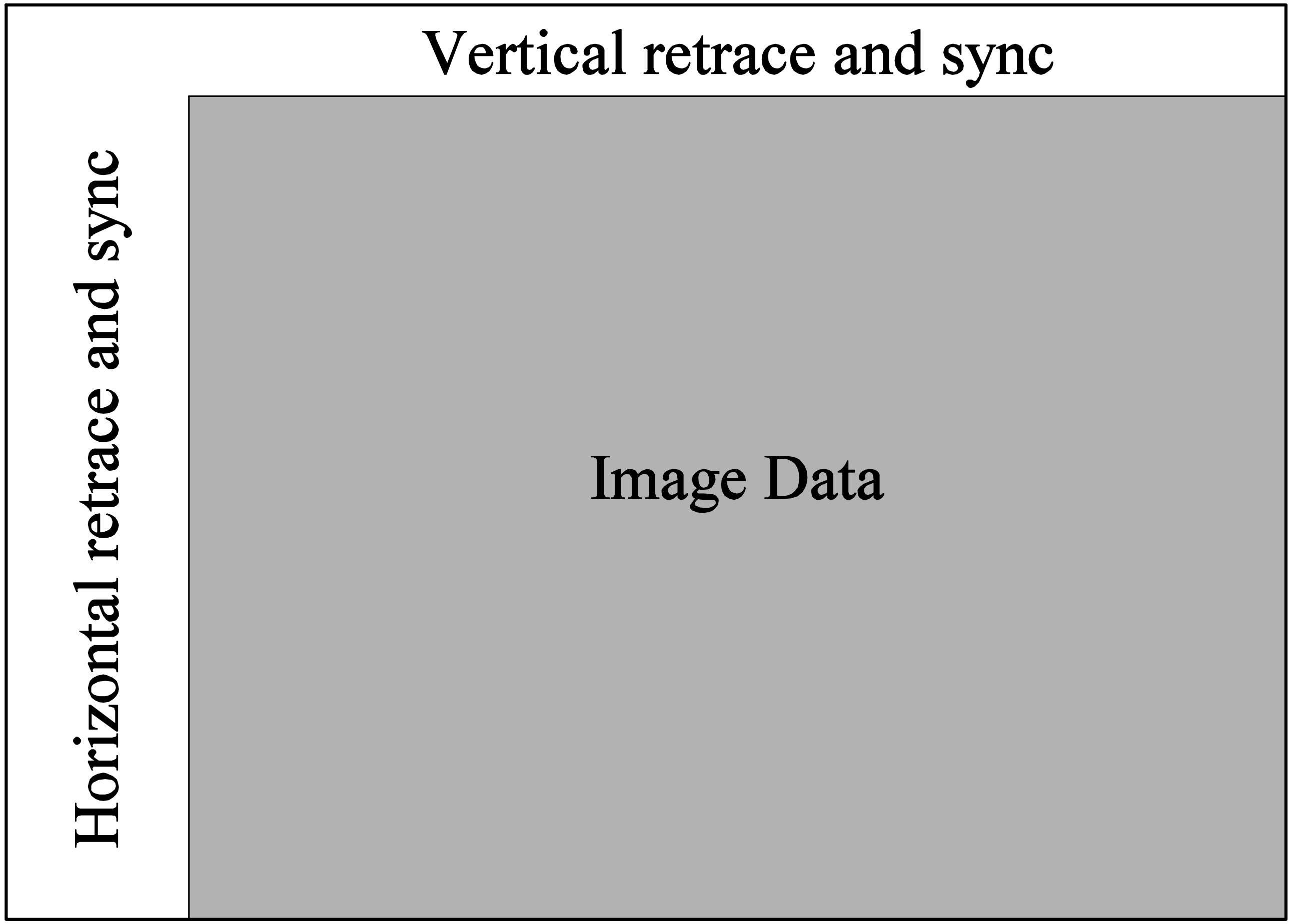
- Standards distribution



2.2 NTSC Video

- NTSC (National Television Standards Committee)
  - 4:3 length and width ratio；
  - 525 line per frame；
  - 30 frames per second (30 fps);
  - YIQ Color Model
- Detailed parameter
  - 29.97 fps； or 33.37ms per frame；
  - Interlace scan， 262.5lines/fields
  - Horizontal scan frequency， 525 × 29.97 = 15,734 lines；
  - Time per line： 1/15,734 = 63.6*u*sec （10.9+52.7）
  - Vertical Retrace， reserved 20 lines per fields； 485 lines
  - Horizontal scan， 1/6 of raster reserved
  - Horizontal resolution – sample number per line

2.2 NTSC Video



2.2 NTSC Video

- NTSC video is an analog signal with no fixed horizontal resolution. Therefore one must decide how many times to sample the signal for display: each sample corresponds to one pixel output.
- A “pixel clock” is used to divide each horizontal line of video into samples. The higher the frequency of the pixel clock, the more samples per line there are.
- Different video formats provide different numbers of samples per line, as listed in Table 5.1.

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

2.2 NTSC Video

Color Model and Modulation of NTSC

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

$$C = I\cos(F_{sc}t) + Q\sin(F_{sc}t) \tag{5.1}$$

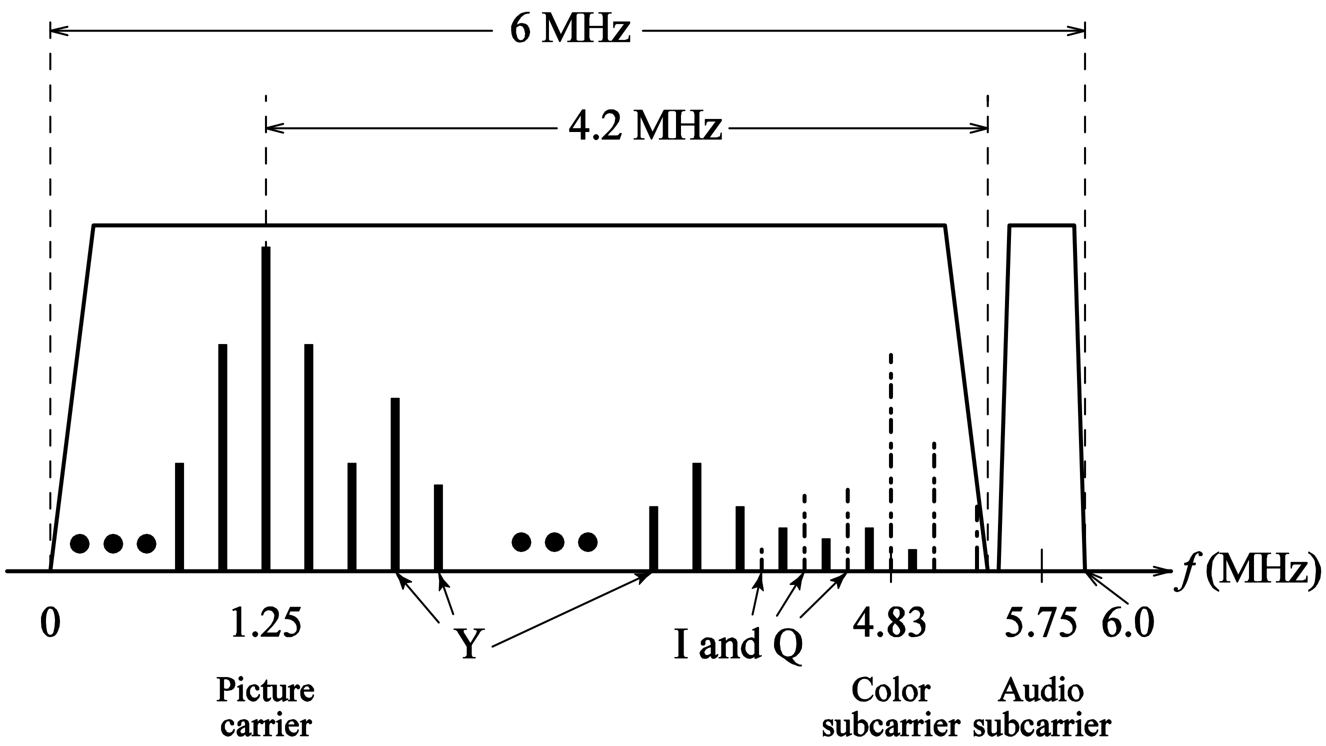
- This modulated chroma signal is also known as the **color subcarrier**, whose magnitude is $\sqrt{I^2 + Q^2}$, and phase is $\tan^{-1}(Q/I)$. The frequency of C is $F_{sc} \approx 3.58$ MHz.

- The NTSC composite signal is a further composition of the luminance signal Y and the chroma signal as defined below:

$$\text{composite} = Y + C = Y + I\cos(F_{sc}t) + Q\sin(F_{sc}t) \tag{5.2}$$

2.2 NTSC Video

- Fig. 5.5: NTSC assigns a bandwidth of 4.2 MHz to *Y*, and only 1.6 MHz to *I* and 0.6 MHz to *Q* due to human insensitivity to color details (high frequency color changes).



2.2 NTSC Video

- The NTSC bandwidth of 6 MHz is tight. Its audio subcarrier frequency is 4.5 MHz. The Picture carrier is at 1.25 MHz, which places the center of the audio band at 1.25+4.5 = 5.75 MHz in the channel (Fig. 5.5). But notice that the color is placed at 1.25+3.58 = 4.83 MHz.
- So the audio is a bit too close to the color subcarrier — a cause for potential interference between the audio and color signals. It was largely due to this reason that the NTSC color TV actually slowed down its frame rate to $30 \times 1,000/1,001 \approx 29.97$ fps.
- As a result, the adopted NTSC color subcarrier frequency is slightly lowered to

$$f_{sc} = 30 \times 1,000/1,001 \times 525 \times 227.5 \approx 3.579545 \text{ MHz},$$

where 227.5 is the number of color samples per scan line in NTSC broadcast TV.

2.2 NTSC Video

- Steps for decoding the composite signal:
  - First, extract Y using low-pass filters
    - $Y + I\cos(F_{sc}t) + Q\sin(F_{sc}t)$
  - After separation from Y, demodulate C to extract I and Q
  - 1. C multiply 2 cos(Fsc t)
    - $C \cdot 2\cos(Fsc\ t) = I + I \cdot \cos(2Fsc\ t) + Q \cdot 2\sin(2Fsc\ t)$
  - 2. Apply low-pass to extract I

2.3 PAL Video

- PAL: Phase Alteration Line
  - 625 scan lines, 25 frames/second, 4:3 aspect ratio
  - 25 fps； or 40 ms per frame；
  - Interlace scan， 312.5lines/fields
  - Horizontal scan frequency， 625×25＝15,625 lines；
  - Time per line： 1/15,734＝64 *u*sec （11.8+52.2）
  - Vertical Retrace, reserved 25 lines per fields； 575 lines
- Color Model -- YUV， Y –Luminance, U and V – Two Chrominance
- In PAL standard: Y with bandwidth 5.5 MHz， U and V with bandwidth 1.8 MHz respectively

2.4 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:

  (a) In SECAM, U and V signals are modulated using separate color subcarriers at 4.25 MHz and 4.41 MHz respectively.

  (b) They are sent in alternate lines, i.e., only one of the U or V signals will be sent on each scan line.

2.4 Comparison of NTSC, PAL and SECAM

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

3. Digital Video

- Advantage of digital representation
- Chroma Subsampling
- Digital video CCIR standard
- CIF standard
- High Definition TV
- Video image quality

3.1 Advantages of digital representation

- Storing video on digital devices or in memory
- Ready to be processed and integrated into various multimedia applications
- Direct access – nonlinear video editing
- Repeated recording without degradation of image quality
- Ease of encryption and better tolerance to channel noise

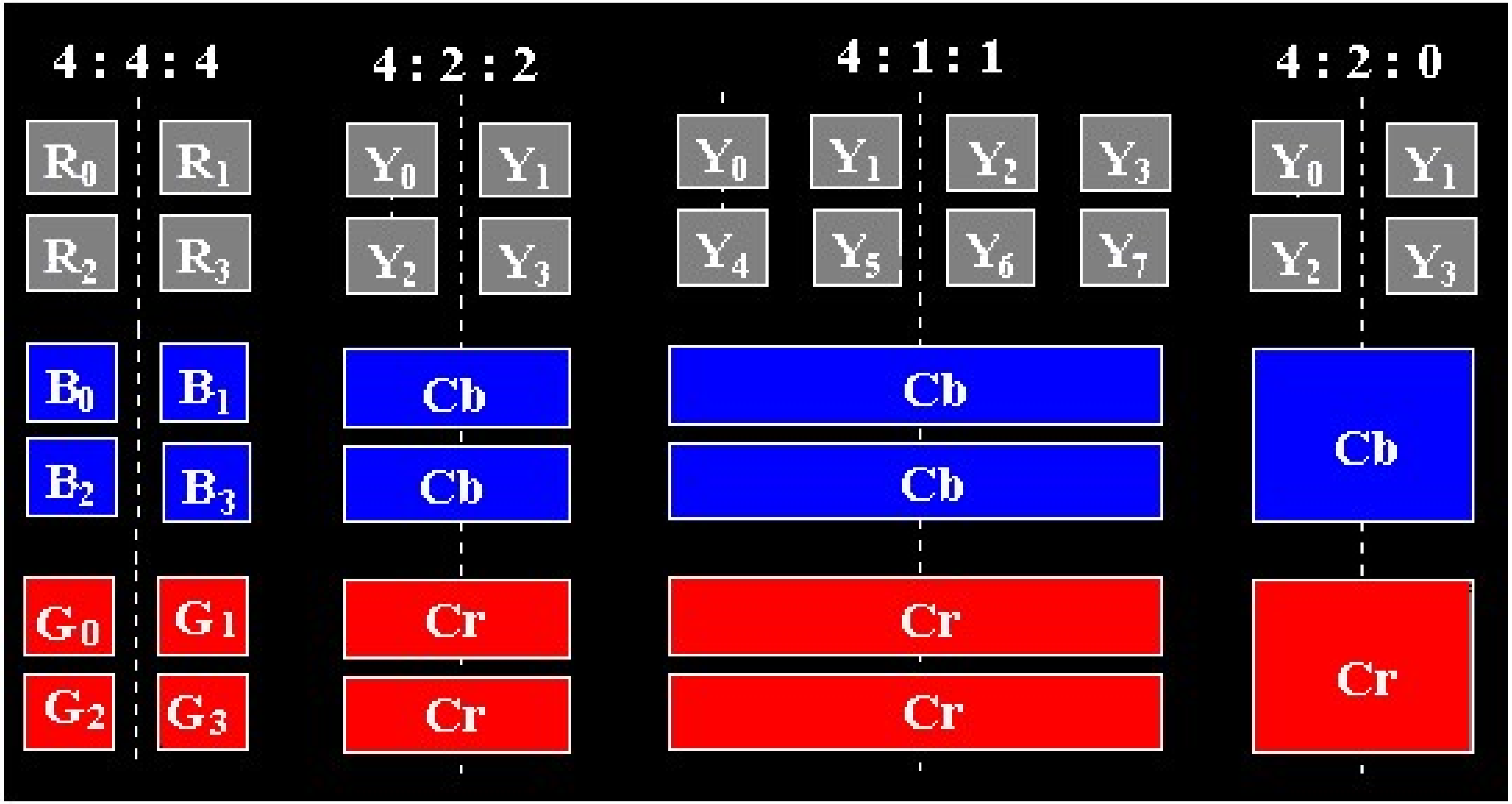
3.2 Chroma subsampling

- Human vision : color with less resolution than Black and White – different Schemes

- Per four original pixels, how many pixel values really sent?
  - 4:4:4 indicates no subsampling
  - 4:2:2 indicates horizontal subsampling of Cb and Cr with factor 2
  - 4:1:1 indicates horizontal subsampling of Cb and Cr with factor 4
  - 4:2:0 indicates horizontal and vertical subsampling of Cb and Cr with factor 2 respectively

- 4:2:0 scheme generally used in JPEG and MPEG

3.2 Chroma Subsampling



3.3 Digital video CCIR standard

- CCIR is the Consultative Committee for International Radio, and one of the most important standards it has produced is CCIR-601, for component digital video.
- CCIR-601 : one important standard for component digital video, further become ITU-R-601 standard
- For NTSC standard：
  - 525 lines； 858 pixels/line （where, 720 is visible） ；
  - 4:2:2 scheme；
  - One pixel -- two bytes
- CCIR 601 （NTSC） date rate：
  - $525 \times 858 \times 30 \times 2\text{bytes} \times 8\text{bits/byte} \approx 216\text{Mbps}$

3.3 Digital video CCIR standard

Digital video Specification

	CCIR 601 525/60 NTSC	CCIR 601 625/50 PAL/SECAM	CIF	QCIF
Luminance resolution	720 x 480	720 x 576	352 x 288	176 x 144
Chrominance resolution	360 x 480	360 x 576	176 x 144	88 x 72
Colour Subsampling	4:2:2	4:2:2	4:2:0	4:2:0
Fields/sec	60	50	30	30
Interlaced	Yes	Yes	No	No

3.4 CIF standard

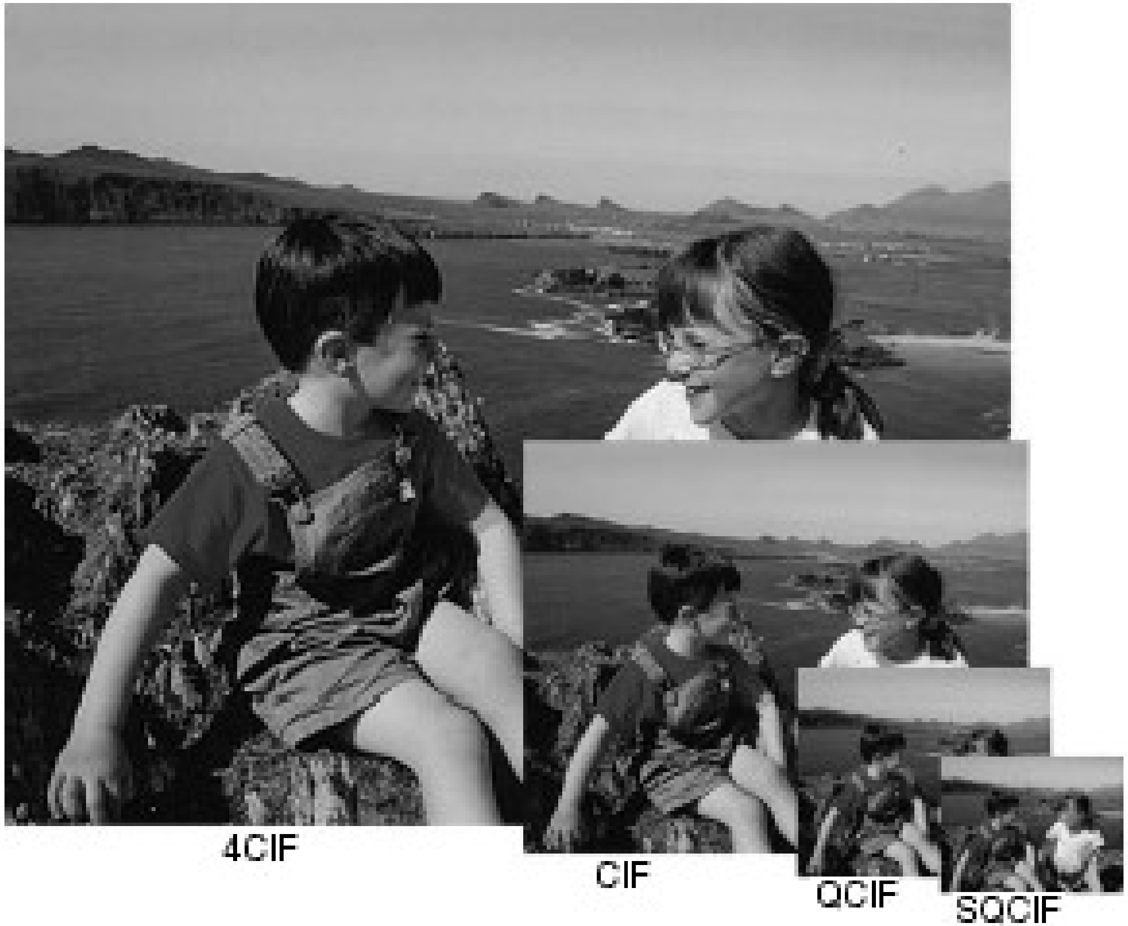
- CIF -- Common Intermediate Format
  - Specified by CCITT; Superseded by ITU-T
- The idea of CIF: a format for lower bitrate, with the same quality as VHS
- QCIF -- Quartar-CIF， more lower bitrate
- The resolution of CIF/QCIF can be divided by 8 or 16
  - Convenient for block-based video coding in H.261、H.263

3.4 CIF standard

	CIF		QCIF		SQCIF	
	lines/frame	Pixel/line	lines/frame	pixel/line	lines/frame	pixel/line
Luminance(Y)	288	360(352)	144	180(176)	96	128
Chrominance(Cb)	144	180(176)	72	90(88)	48	64
Chrominance(Cr)	144	180(176)	72	90(88)	48	64

3.4 CIF Standard

- 4CIF、
  CIF、
  QCIF
  and SQCIF



CIF : 4:2:0
scheme

3.5 HDTV (High Definition TV)

- The main thrust of **HDTV** (High Definition TV) is not to increase the "definition" in each unit area, but rather to increase the visual field especially in its width.

  (a) The first generation of HDTV was based on an analog technology developed by Sony and NHK in Japan in the late 1970s.

  (b) MUSE (MUltiple sub-Nyquist Sampling Encoding) was an improved NHK HDTV with hybrid analog/digital technologies that was put in use in the 1990s. It has 1,125 scan lines, interlaced (60 fields per second), and 16:9 aspect ratio.

  (c) Since uncompressed HDTV will easily demand more than 20 MHz bandwidth, which will not fit in the current 6 MHz or 8 MHz channels, various compression techniques are being investigated.

  (d) It is also anticipated that high quality HDTV signals will be transmitted using more than one channel even after compression.

3.5 HDTV (High Definition TV)

- A brief history of HDTV evolution:

  (a) In 1987, the FCC decided that HDTV standards must be compatible with the existing NTSC standard and be confined to the existing VHF (Very High Frequency) and UHF (Ultra High Frequency) bands.

  (b) In 1990, the FCC announced a very different initiative, i.e., its preference for a full-resolution HDTV, and it was decided that HDTV would be simultaneously broadcast with the existing NTSC TV and eventually replace it.

  (c) Witnessing a boom of proposals for digital HDTV, the FCC made a key decision to go all-digital in 1993. A “grand alliance” was formed that included four main proposals, by General Instruments, MIT, Zenith, and AT&T, and by Thomson, Philips, Sarnoff and others.

  (d) This eventually led to the formation of the ATSC (Advanced Television Systems Committee) — responsible for the standard for TV broadcasting of HDTV.

  (e) In 1995 the U.S. FCC Advisory Committee on Advanced Television Service recommended that the ATSC Digital Television Standard be adopted.

3.5 HDTV (High Definition TV)

- The standard supports video scanning formats shown in Table 5.4. In the table, "I" mean interlaced scan and "P" means progressive (non-interlaced) scan.

Table 5.4: Advanced Digital TV formats supported by ATSC

# 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

3.5 HDTV (High Definition TV)

- The salient difference between conventional TV and HDTV:

  (a) HDTV has a much wider aspect ratio of 16:9 instead of 4:3.

  (b) HDTV moves toward progressive (non-interlaced) scan. The rationale is that interlacing introduces serrated edges to moving objects and flickers along horizontal edges.

3.5 HDTV (High Definition TV)

– HDTV: Example

3.5 HDTV (High Definition TV)

- The FCC has planned to replace all analog broadcast services with digital TV broadcasting by the year 2009. The services provided will include:
  - **SDTV (Standard Definition TV)**: the current NTSC TV or higher.
  - **EDTV (Enhanced Definition TV)**: 480 active lines or higher, i.e., the third and fourth rows in Table 5.4.
  - **HDTV (High Definition TV)**: 720 active lines or higher.

The End

Thanks！

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