Multimedia Systems: Video

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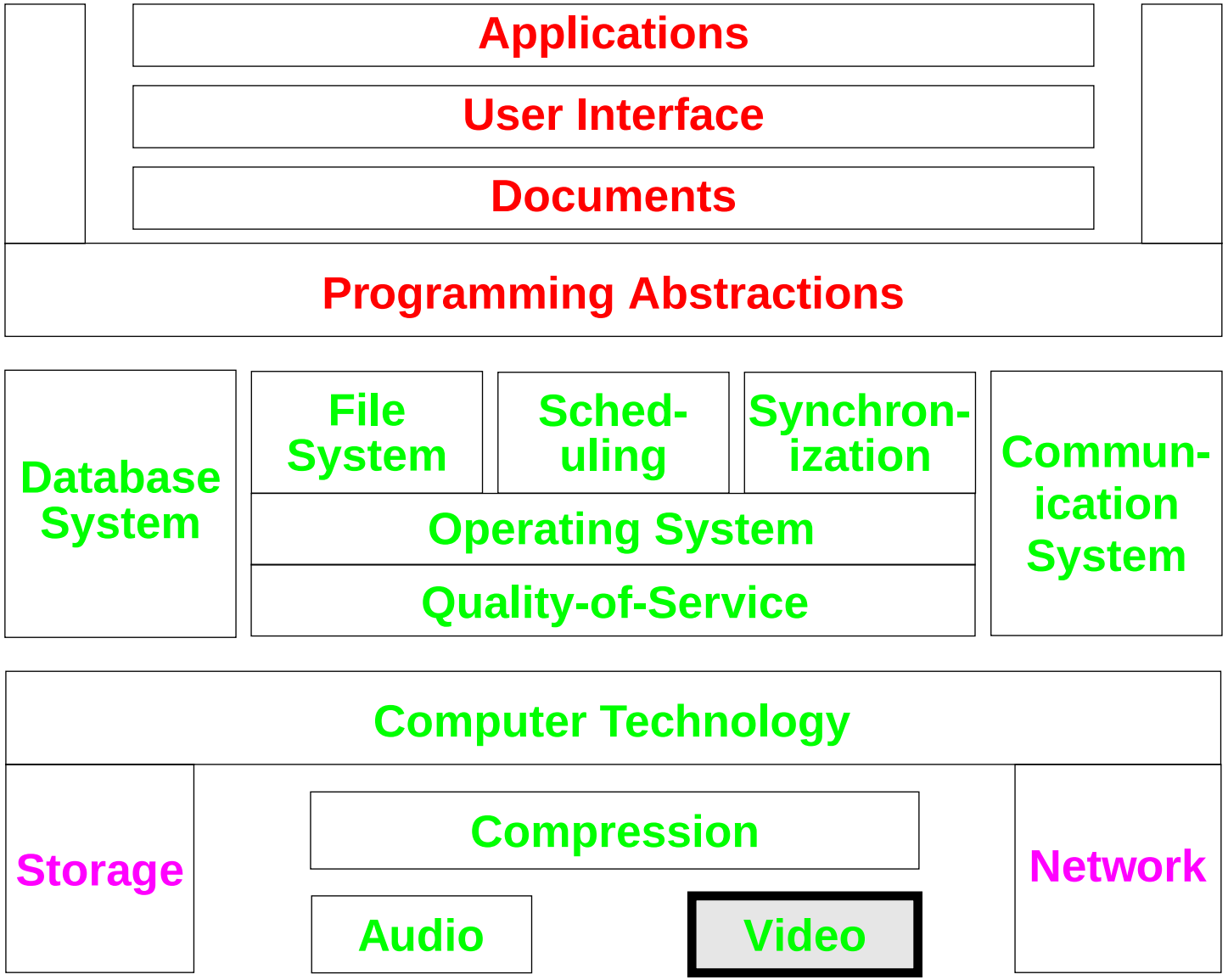
Applications
User Interface
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Programming Abstractions
Database System
File System
Sched-uling
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Operating System
Quality-of-Service
Commun-ication System
Computer Technology
Storage
Compression
Audio
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Network

Contents

1. Human Visual Perception

Specification of video systems determined by:

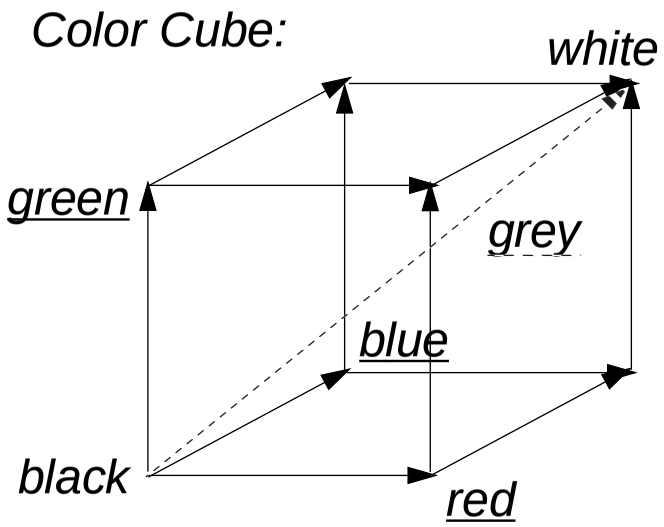
- Characteristics and limitations of human visual perception
- Human information processing

Each color defined by mix of primary colors:

- Red
- Green
- Blue

E.g. white is represented by:

- Red : green : blue = 100% : 100% : 100%



Brightness and Resolution

Perception of brightness:

- Higher than perception of color:
  - Especially high perception of bright edges
  - Perception decreases with brightness of surroundings
- Different perception of the primary colors
  - Relative brightness: green : red : blue = 59% : 30% : 11%

Spatial resolution (of single points) depends on:

- Picture size
- Viewing distance

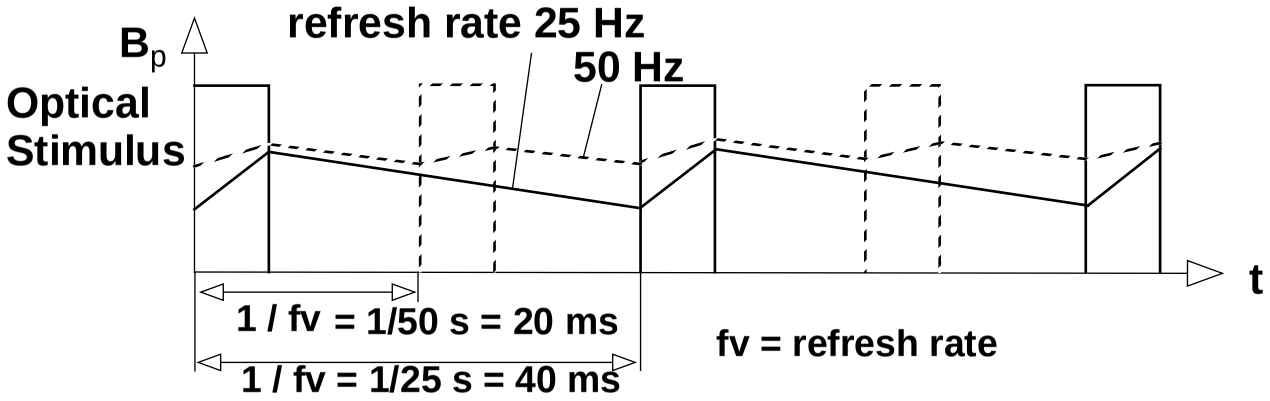
Temporal Resolution:

- Inertia of human eye
- Sequence of images (= „frames“):
  - No identification of single frames if refresh frequency high enough
  - Perception of 16 frames/s as continuous sequence

Flicker Effect

Flicker effect:

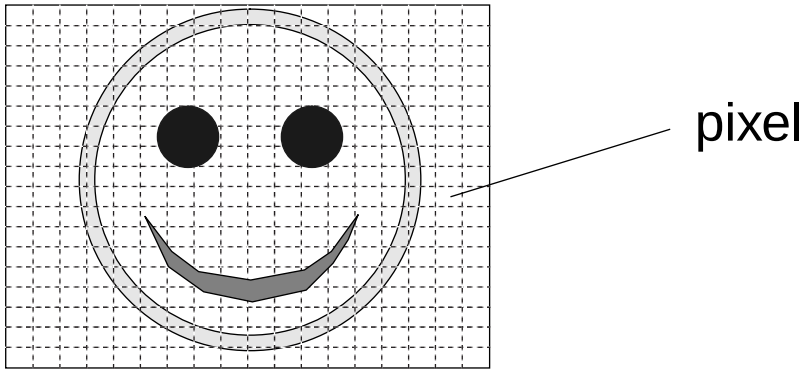
- Flicker perceived if refresh rate of screen too low
- Especially in large bright areas
- No flicker if refresh rate > 50/s



2. Coding and I/O

Representation of Images

Image is *rastered* for further processing



- Raster point = „picture element“ = *pixel*
- Raster:
  - Discretization of image into a number of pixels
  - Fixed number of rows and columns -> fixed number of pixels

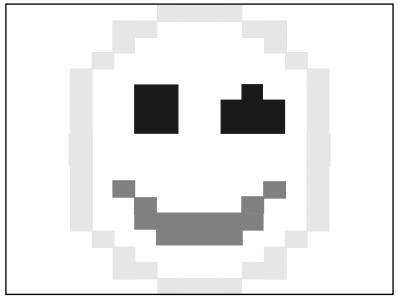
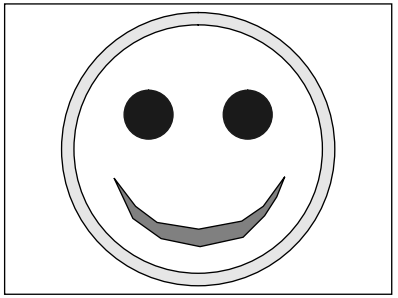
Storage / manipulation / transmission / display of an image are based on

- grey-scale or color values of its pixels

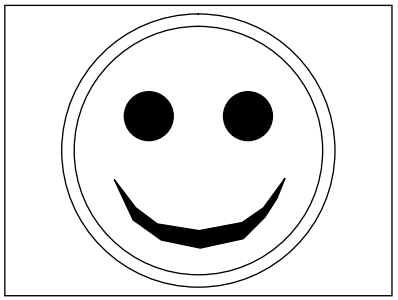
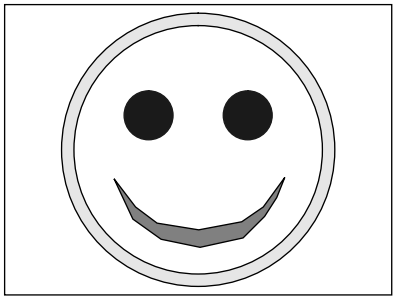
Image Quality

Quality of representation depends on:

- „Resolution“ = number of raster points

coarse:  fine: 

- „Color depth“ = number of bits per pixel

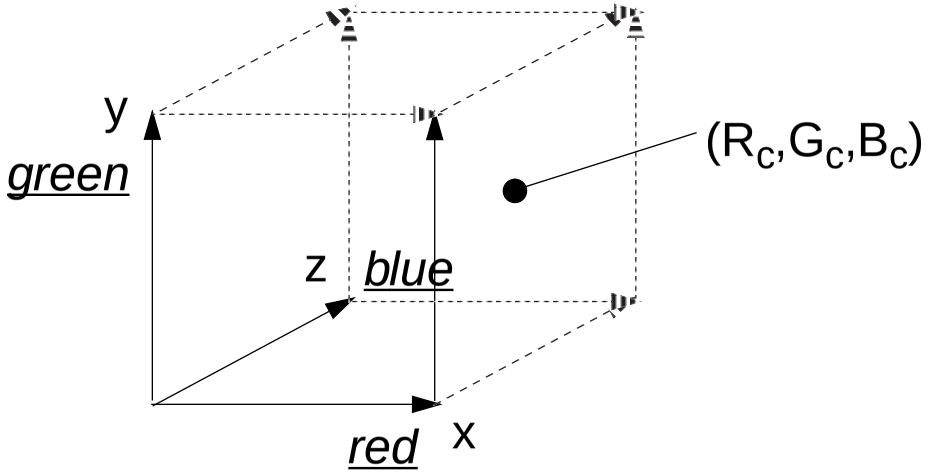
1 bit:  >2 bits: 

  - 1 bit = black / white information only
  - 15 bits = „high color“
  - 24 bits = „true color“

Color Coding: RGB

RGB color coding:

- Color code = coordinates of a point within the color cube



- Three independent components for red (R_c), green (G_c), and blue (B_c)
- I.e. code is a tripel (R_c,G_c,B_c),
  R_c, G_c, B_c being the contributions of the primary colors
- Number of bits per component determines color depth

Color Coding: Luminance/Chrominance Principle

Code consists of *luminance* and *chrominance* components:

- Luminance component: brightness of pixel
- Chrominance difference components: color of pixel
  - Hue: which color
  - Saturation: depth of color

Examples:

- YUV coding:
  - Y = 0.30R + 0.59G + 0.11B (luminance)
  - U = (B - Y) x 0.493 (chrominance 1)
  - V = (R-Y) x 0.877 (chrominance 2)
- YIQ coding:
  - Y = 0.30R + 0.59G + 0.11B (luminance)
  - I = 0.60R - 0.28G - 0.32B (chrominance 1)
  - Q = 0.21R - 052G + 0.31B (chrominance 2)

Color Coding: Luminance/Chrominance (cont.)

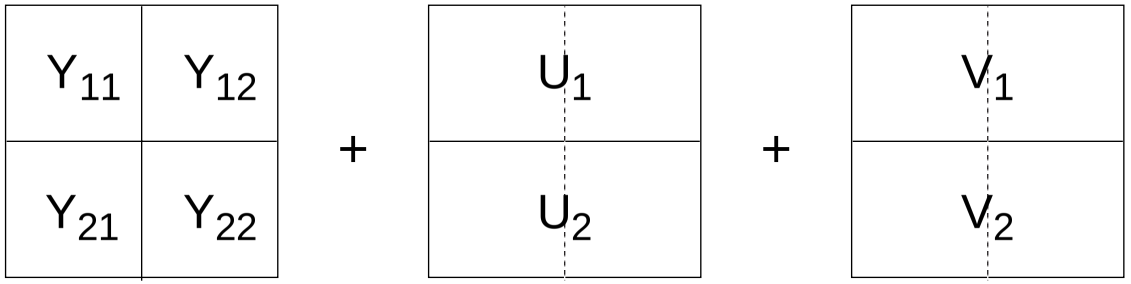
Different resolutions for luminance and chrominance possible:

- Luminance Y: high resolution
- Chrominance U, V: lower resolution

Examples:

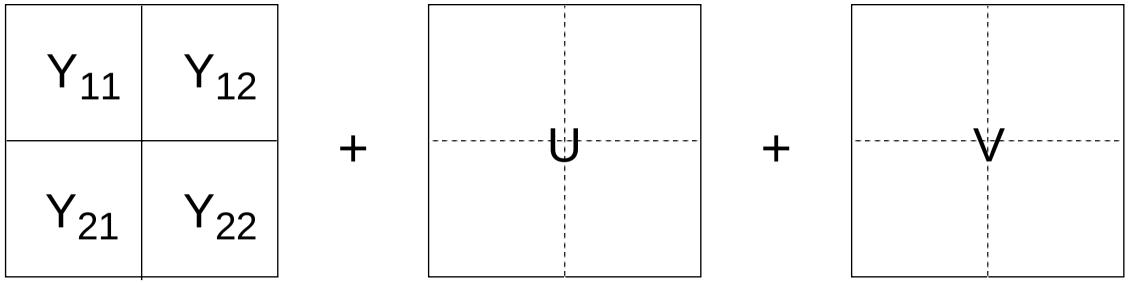
- 4:2:2: double resolution for luminance

Coding of four pixels:



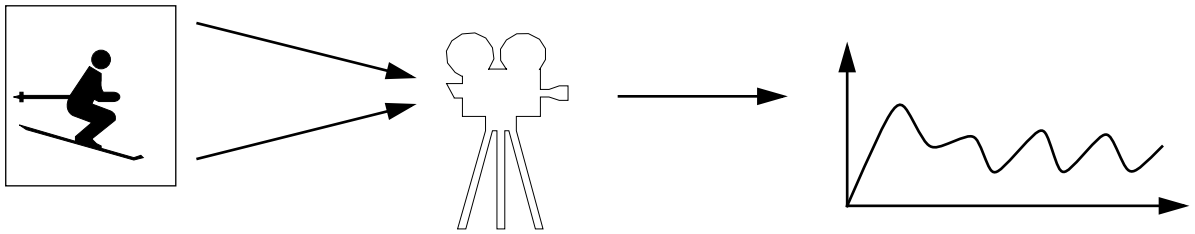
- 4:1:1: quadrupel resolution for luminance

Coding of four pixels:



Video I/O Devices: Camera

Transformation of a two-dimensional picture into a one-dimensional electrical signal



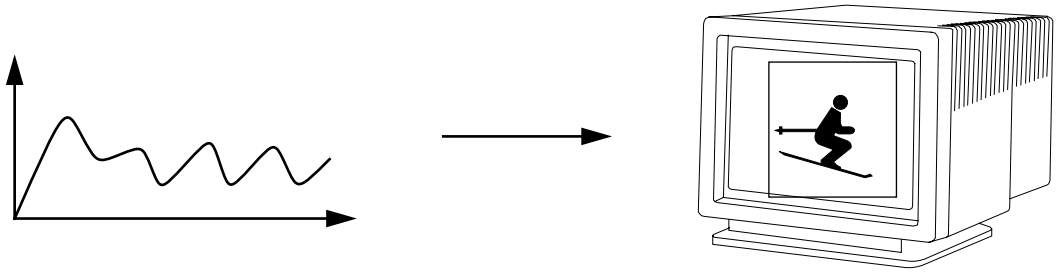
Principle of operation:

- Plate of photosensitive material
- Evolving of a charge in the material depending on amount of light at each spot
- Charge read out:
  - Emitting an electron beam onto the plate
  - Collecting generated signals

Video I/O Devices: Monitor

Cathode Ray Tube (CRT):

- Transformation of one-dimensional electrical signal into two-dimensional visual image



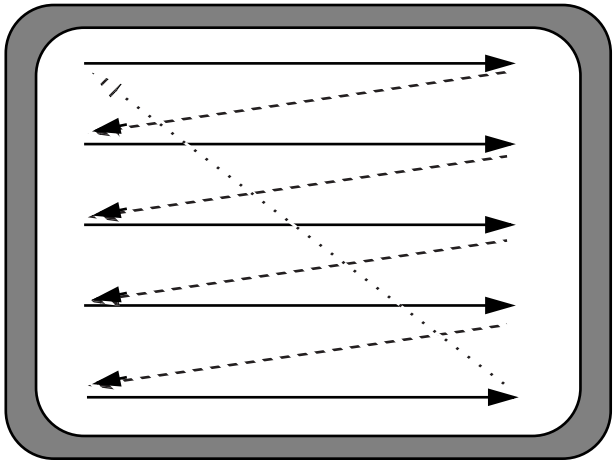
- Principle of operation:
  - Transformation of signal into electron emission of a cathode
  - Light emission in a layer of fluorescent material caused by electrons

Variants:

- Black-and-white:
  - Signal amplitude proportional to image brightness
- Color:
  - Signal includes brightness and color information (luminance and chrominance)

Scanning Principles

Scanning direction:



- Start at top left corner of image
- Horizontal and slowly vertical scanning

3. Black and White Television

Fundamentals

Aspect ratio:

- Width-to-Height ratio
- Television: 4 : 3
- Movies: 2 : 1

Vertical resolution:

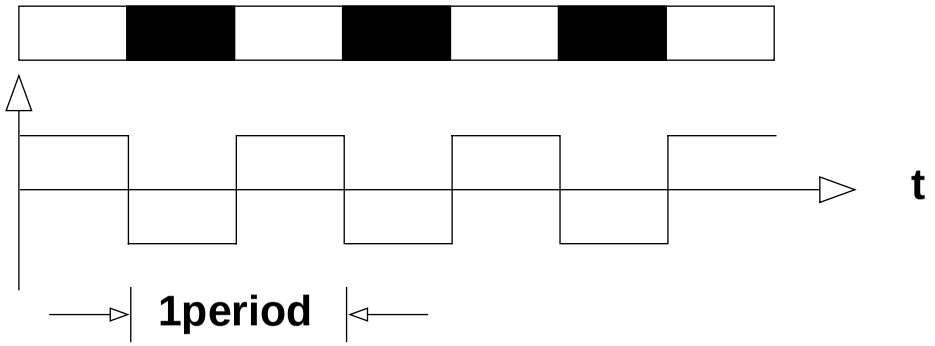
- Europe: 625 lines/frame
- Japan, USA: 525 lines/frame

Horizontal resolution:

- Sampling frequency: 13.5 MHz
- Scanning time / line: 64 µs
- hence: 864 pixels/line (in Europe)

Video Bandwidth

Max. number of black/white changes: 864 oscillations/line



Theoretical video bandwidth at least:

- 864/2 osc./line * 625 lines/frame * 25 frame/s = 6.75 MHz

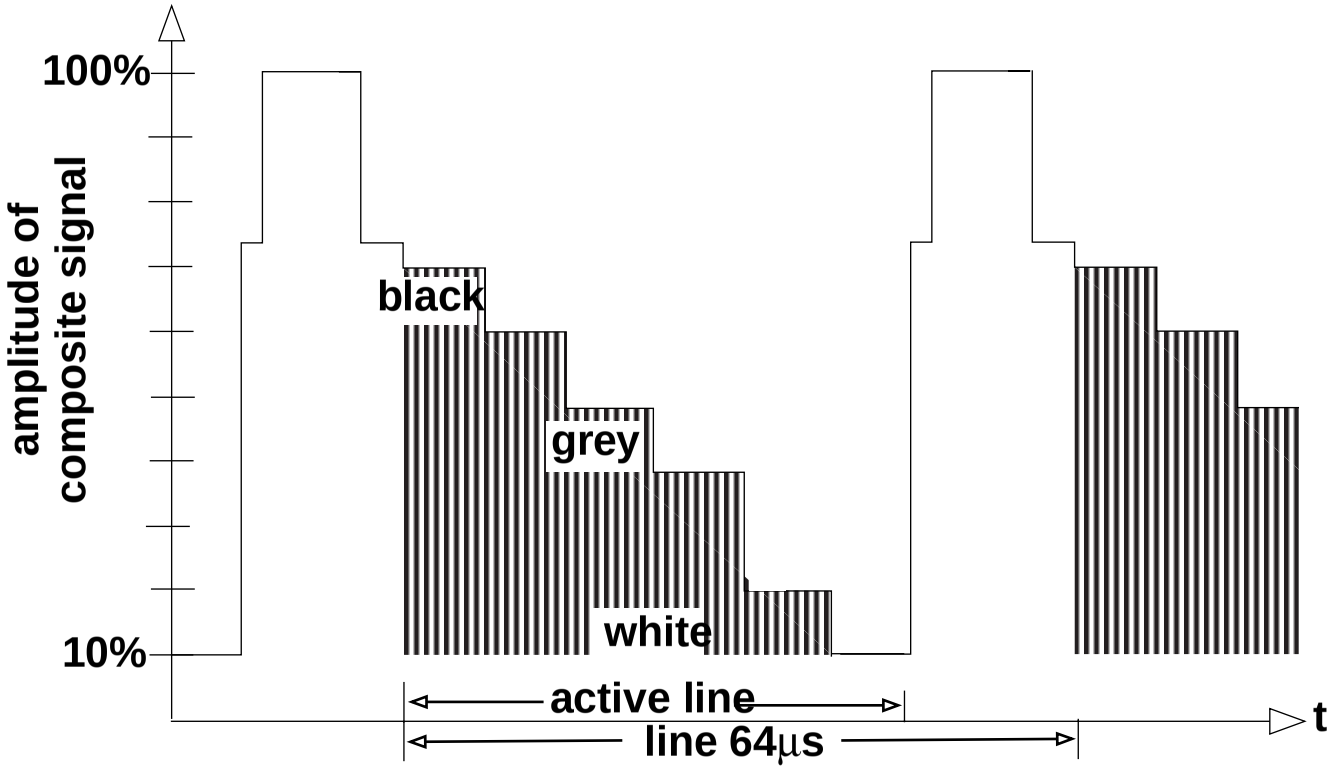
Video bandwidth for sufficient quality:

- 5.5 MHz
- or even only 5 MHz

Composite Signal

Composite signal:

- Image data
- Sampling data
- Synchronization data

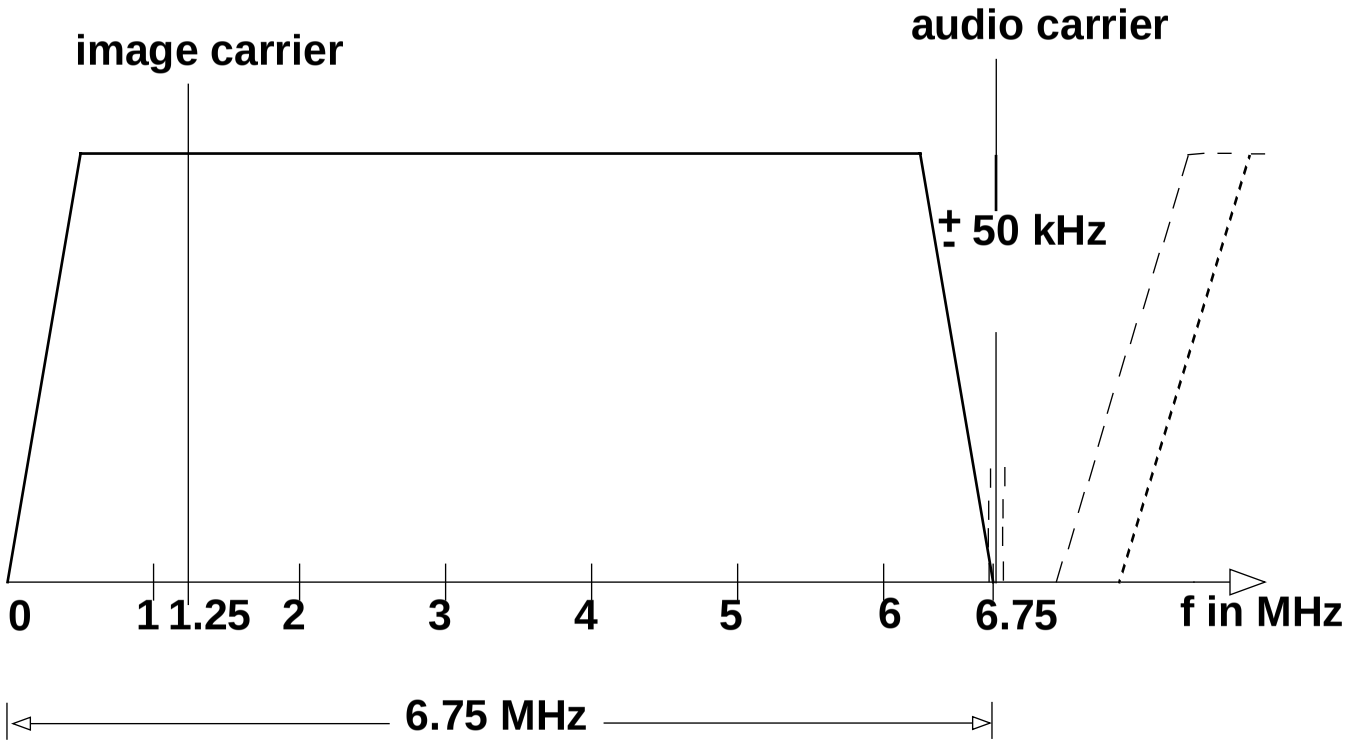


Composite Signal

Signal modulation:

- Amplitude modulation

Spectrum of composite signal:



4. Color Television

Color Fundamentals

Based on:

- Tri-stimulus theory of color reproduction
- Creation of colors by mixing light
- Additive primary system colors: red, green, blue

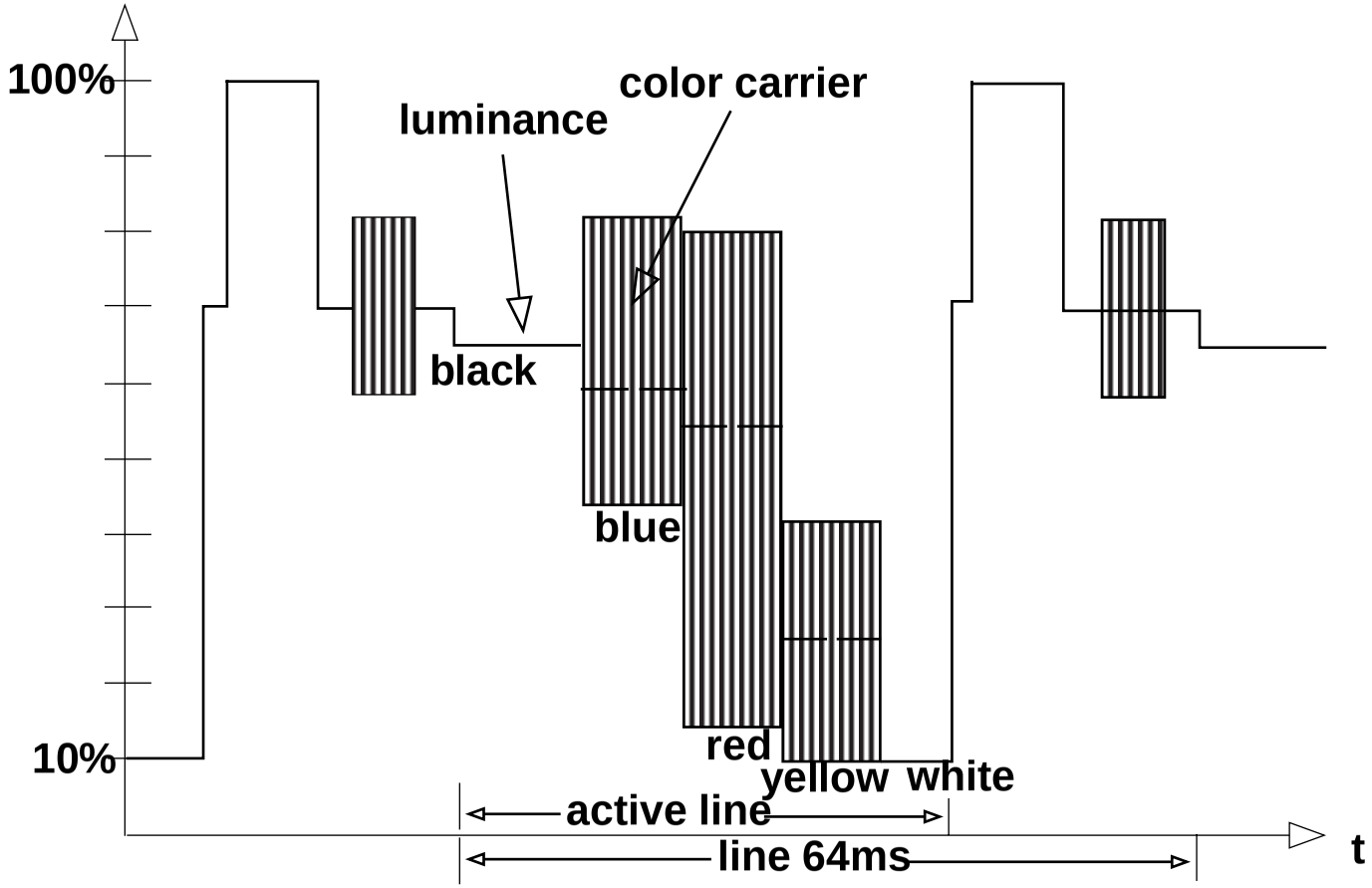
Tube:

- One beam for each color
- Sent through shadow mask onto screen:
  - 357 000 holes in shadow mask
    diameter: 0.35 mm
  - 1 071 000 color points
    diameter: 0.42 mm

Composite Coding

One signal:

- Transmission of luminance and chrominance over one channel
- „Composite Color Signal“



Frequency Interleaving

Requirement for composite signal:

- Reduction of interference
  between luminance and chrominance components

Technique: „Frequency Interleaving“

- Luminance signal:
  - Using full bandwidth
- Chrominance signals:
  - Reduced by factor 2 to 4 as:
    - Human eye more sensitive for brightness information
    - Easier recognition of bright edges
  - On high frequency subcarrier

5. Television Standards

Overview of Color TV Standards

standard	lines	pixels/ line	frames/ sec	coding	modul- ation
NTSC	525	700	30	YIQ	AM
Secam	625	864	25	YUV (seq. trans- mission)	FM
PAL	625	864	25	YUV (2-phase signal)	AM

6. High Definition Television (HDTV)

Overview of First Initiative

Resolution/image size:

- Viewing distance: 2-3 m
- Horizontal viewing angle: 45°
- Aspect ratio: 16:9
- Vertical resolution:1150 visible lines/frame
- Horizontal resolution: 1900 pixels/line

Sharpness:

- Twice the conventional TV resolution
- Bandwidth = 30 MHz (Steinmetz/Nahrstedt, p. 95)

Flicker:

- Receiver display refresh rate: about 100 Hz

7. Digital Television & Digital Video Broadcasting

Signal Digitalization

1995: DVB Digital Video Broadcasting

1982: CCIR international digital television standard

Combined Digitalization of composite black/white signal:

- Video bandwidth: 2 * 5 MHz * 8 bit = 80 Mbit/s
  - 5 MHz = bandwidth of B/W TV signal

Combined Digitalization of composite color signal:

- Lower interference with color carrier
- Requires even-numbered multiple frequency of the color carrier
- Sampling frequency: 4 * frequency of color carrier
- Data rate: 4 * 4.43 MHz * 8 bit = 141.8 Mbit/s
  - 4.43 MHz = frequency of color carrier

Drawbacks of Combined Digitalization

Interference between luminance and chrominance data

Digitalization technique depends on TV standard

No adaptation of:

- Sampling frequency to bandwidth of single components
- Data reduction to characteristics of single components

Component Coding: Fundamentals

Separate digitalization of single components:

- Multiplexing of digitized signals

Sampling frequency:

- Luminance: 13.5 MHz
- Chrominance: 6.75 MHz

8 bit uniform quantization:

- Data rate: (13.5 MHz + 2 * 6.75 MHz) * 8 bit = 216 Mbit/s

Vertical resolution: 625 lines/frame

Horizontal resolution:

- Luminance: 864 pixels/line (visible: 720 pixels)
- Chrominance: 432 pixels/line (visible: 360 pixels)

Frame rate: 25 frames/s

Component Coding: Drawback

High data rate

Hence: definition of substandards

- Lower data rates
- Lower sampling frequencies

		substandard 1	substandard 2	substandard 3
sampling frequency	luminance	11.25 MHz (5/6 of standard)	10.125 MHz (3/4 of standard)	9 MHz (2/3 of standard)
	chrominance	5.625 MHz (5/6 of standard)	3.375 MHz (1/2 of standard)	2.25 MHz (1/3 of standard)
data rate		$180*10^6$ bit/s	$135*10^6$ bit/s	$108*10^6$ bit/s

8. Video Techniques for Computer Systems

Fundamentals

Goals:

- Integration of digital video into computer systems
- Random access editing
- Interactivity
- Image processing
- Integration into computer documents
- Storage on different media
- Transmission over computer networks

Conversion of analogue video signal to digital format

Requires display refresh rate of at least 70 Hz

Digital Video

Puts demands on:

- Storage
- Transmission
- Throughput
- Display

Solved by:

- Restricting the color domain:
  - Color represented by fewer bits
  - Using color look up tables (CLUT)
    - CLUT holds 256 (e.g.) different 24-bit RGB values
    - Pixel code is 8-bit (e.g.) index into CLUT
- Compression
- Specialized hardware