VIDEO CODING TECHNOLOGIES

Martina Eckert
Universidad Politécnica de Madrid
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Image signals, analog video signals, standards and recommendations, characterization, parameters

TOPIC 2: DIGITIZING PROCESS

Capture, sampling, quantizing, interpolation and reconstruction, standardization

TOPIC 3: IMAGE AND VIDEO COMPRESSION SYSTEMS

Still image compression (redundancy, coding , transform, quantizing, JPEG), video compression (predictive coding, hybrid model, MPEG, H.26x)

TOPIC 4: ADVANCED VIDEO CODING

History, MPEG-4 AVC/H.264, MPEG-4 Visual

POSSIBLE SCHEDULE

Fr	19	T1			
Mon	22	T1	Mon	6	LAB 3-1
Mon	22	T1,T2/LAB 1 home	Mon	6	T3-inter
Tue	23	T2	Tue	7	T3-inter
Wed	24	T2	Wed	8	T3-inter
Fr	26	T2	Fr	10	T3-inter
Mon	29	LAB 2	Mon	13	LAB 3-2
Mon	29	T3-intra	Mon	13	T4
Tue	30	T3-intra	Tue	14	T4
Wed	1	T3-intra	Wed	15	T4
Fr	3	T3-intra	Fr	17	exam

TOPIC 1
BASIC CHARACTERISTICS OF IMAGE AND VIDEO SIGNALS

1.1. Image signals

1.2. Analog video signals, standards and recommendations

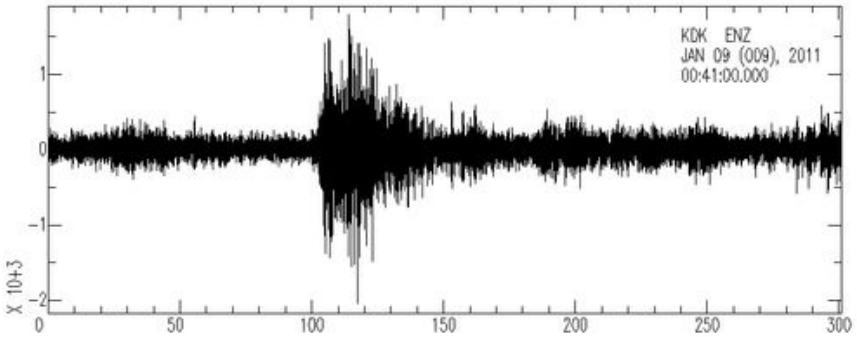
1.3. Characterization, Parameters

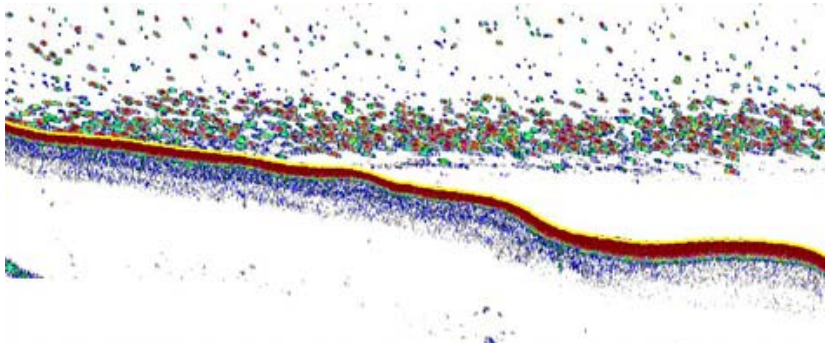
1.1 IMAGE SIGNALS

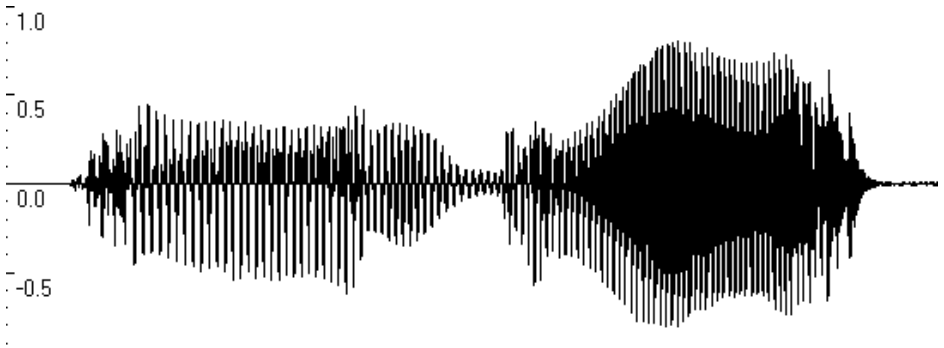
- General aspects about signals
- **Analogue** image and video signals
  - **Image formation**
  - Brightness
  - **Synchronisms,** periods of **Active Video** and **Blanking**
  - Color image signal
    - RGB image
    - Component image
    - Gamma correction

¿WHAT IS A SIGNAL?

- Time varying magnitude in some medium:
  - Interpreted as information
  - Used to transmit information







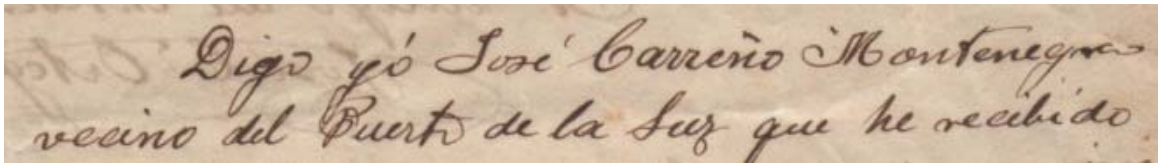
ANALOGUE IMAGE AND VIDEO SIGNALS

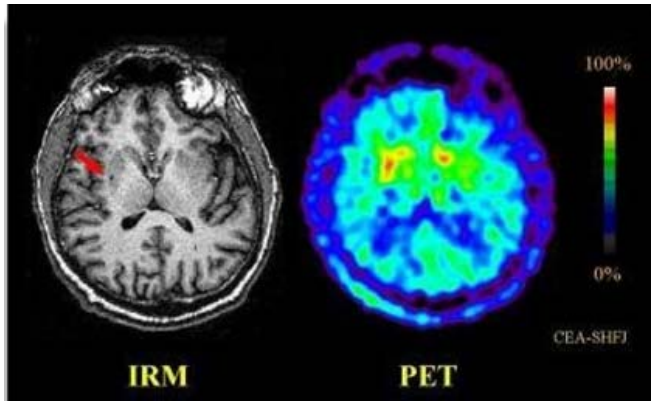
- Analogue Signal
  - **Information varies continuously with the signal value**: signal level ↔ information value
- Image: **bi-dimensional signal**, **variation** of a **magnitude** over a surface: **i(x,y)**
- Video signal: image signal which **additionally varies over time: v(x,y,t)**

Spatial dimensions: x and y

Time: t

EXAMPLES OF IMAGE SIGNALS





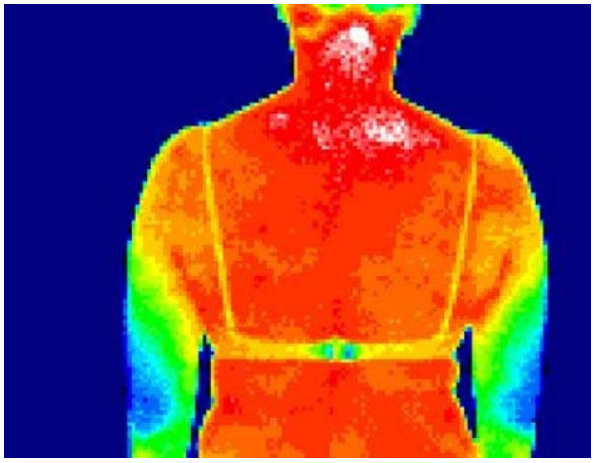
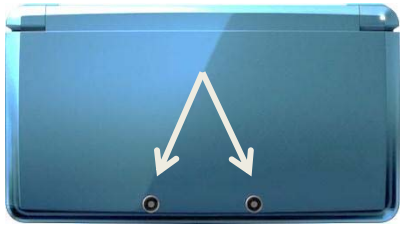


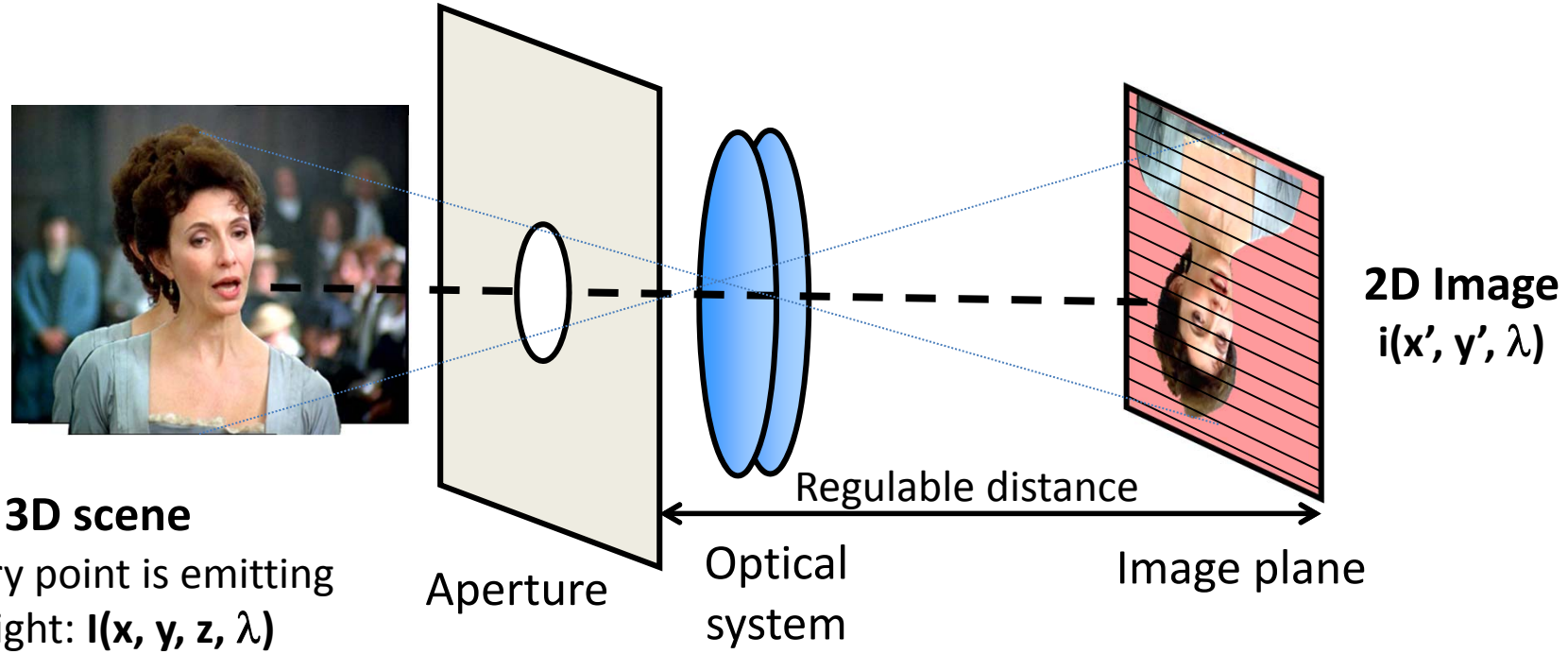
IMAGE FORMATION (I)

- Projection that registers a magnitude over a surface
- Different processes according to signal types
  - **Camera**: capture of visible light images **I(λ)**
    - Luminance is a function of wavelength



Others:

IMAGE FORMATION(II) **CAMERA**



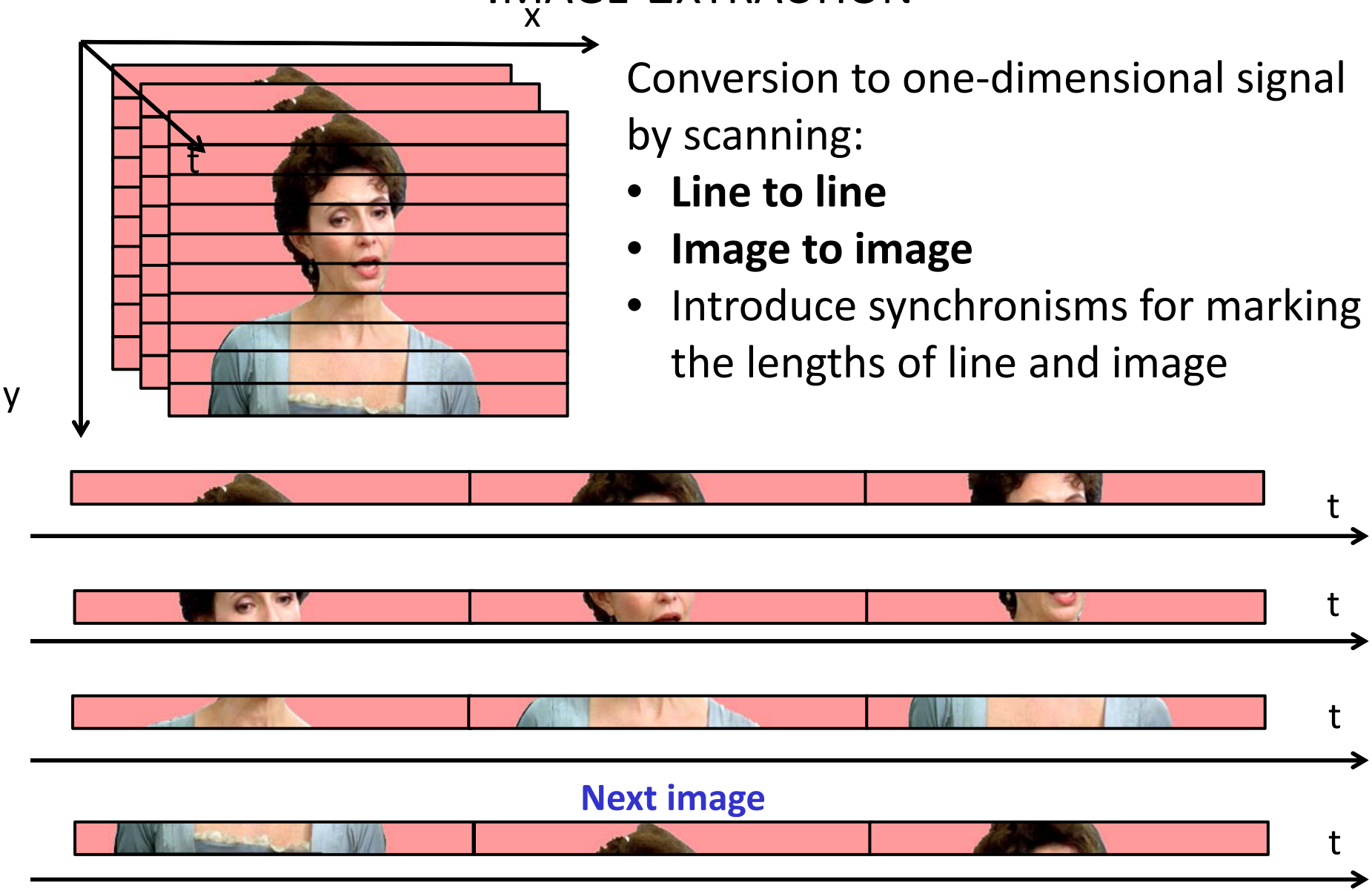
Objectives:

- **Focused image**: every 3D point → point in 2D image
- **Sufficient light**: relative to sensibility to luminance energy

IMAGE FORMATION (III)

- **Projection** of the 3D world to a 2D image
- **Limited to** rectangles
- **Representation** of **I(λ) is** also **limited**
- The signal has to be **serialized to extract it**, using the limitations of the human visual system:
  - Sampling in time and image frequency: **visual memory**
  - Line sampling: limitation of the **visual sharpness**

IMAGE EXTRACTION



Conversion to one-dimensional signal by scanning:

- **Line to line**
- **Image to image**
- Introduce synchronisms for marking the lengths of line and image

BRIGHTNESS SIGNAL (LUMINANCE)

- **Electrical charge is proportional ≈ to luminance**
  Light intensity of radiation **I(λ)**:

$$Y = k \cdot \int S(\lambda) \cdot I(\lambda)\, \mathrm{d}\, \lambda$$

$S(\lambda)$ ideal photonic response of HVS

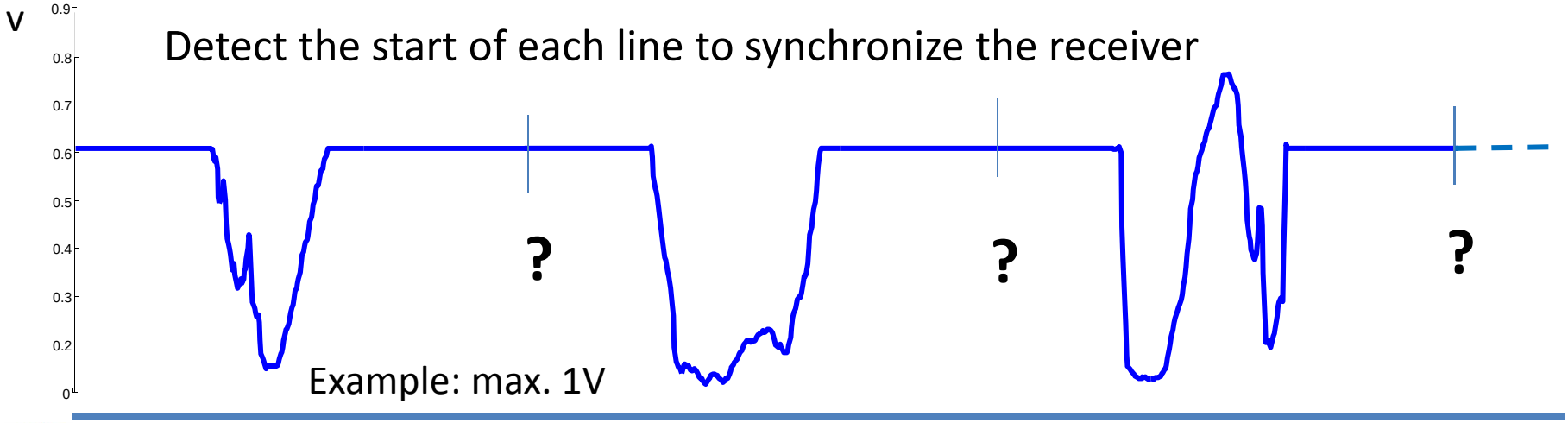
- In every sensitive point of the surface **Y(x,y)**
- **Range**: **minimum= 0, maximum** depends on the sensor and its conditions
- **Normalized range**: 0 to maximum brightness 1

EXTRACTION OF LUMINANCE IMAGE

Charge ≈ brightness

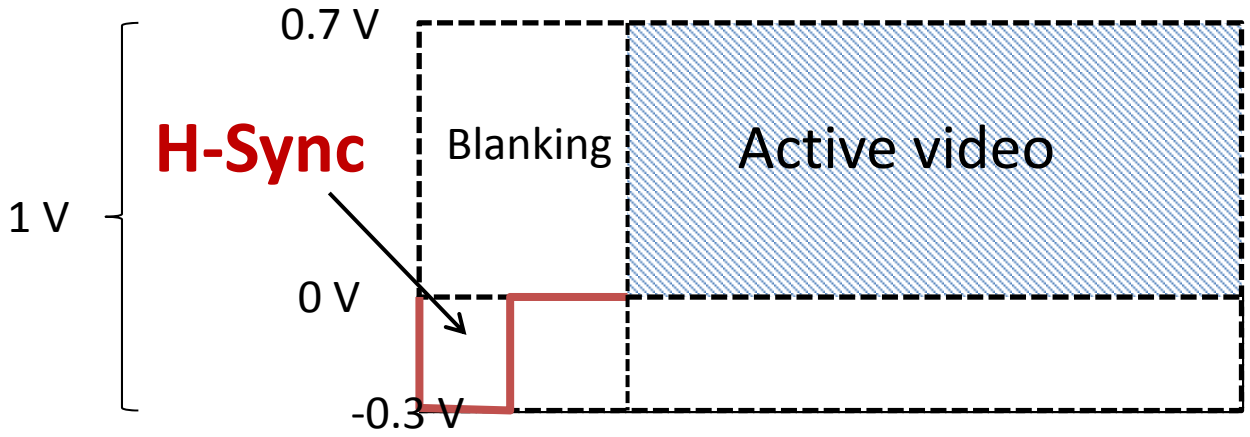
Tension signal ≈ Charge

Called: **simple video-frequency-signal**



HORIZONTAL SYNCHRONISM

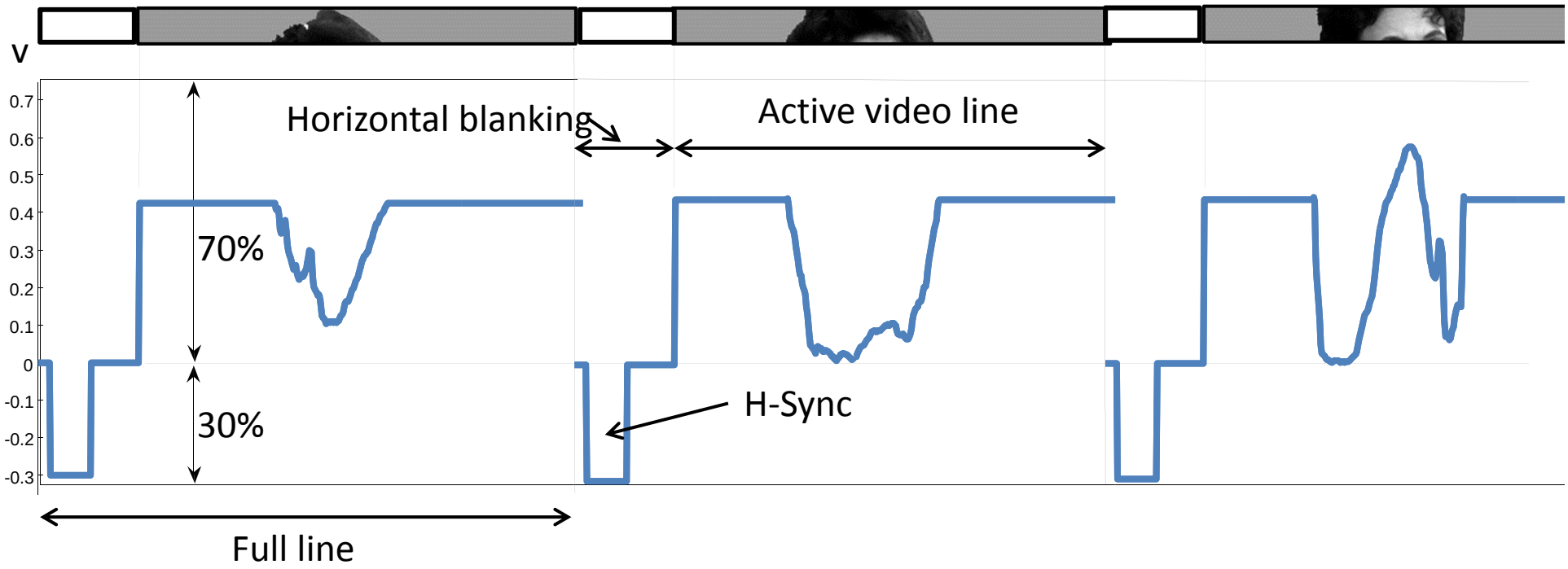
- A special signal indicates the start of line:
- Different to luminance signal: negative pulse called **Horizontal synchronization pulse (H-Sync)**
- Blanking period: no video signal
- Voltage range (1V): sync: 0.3 to 0 V, video signal: 0 to 0.7 V



Recommendation: ITU-R BT.470

COMPOSED VIDEO SIGNAL

Sync plus active video



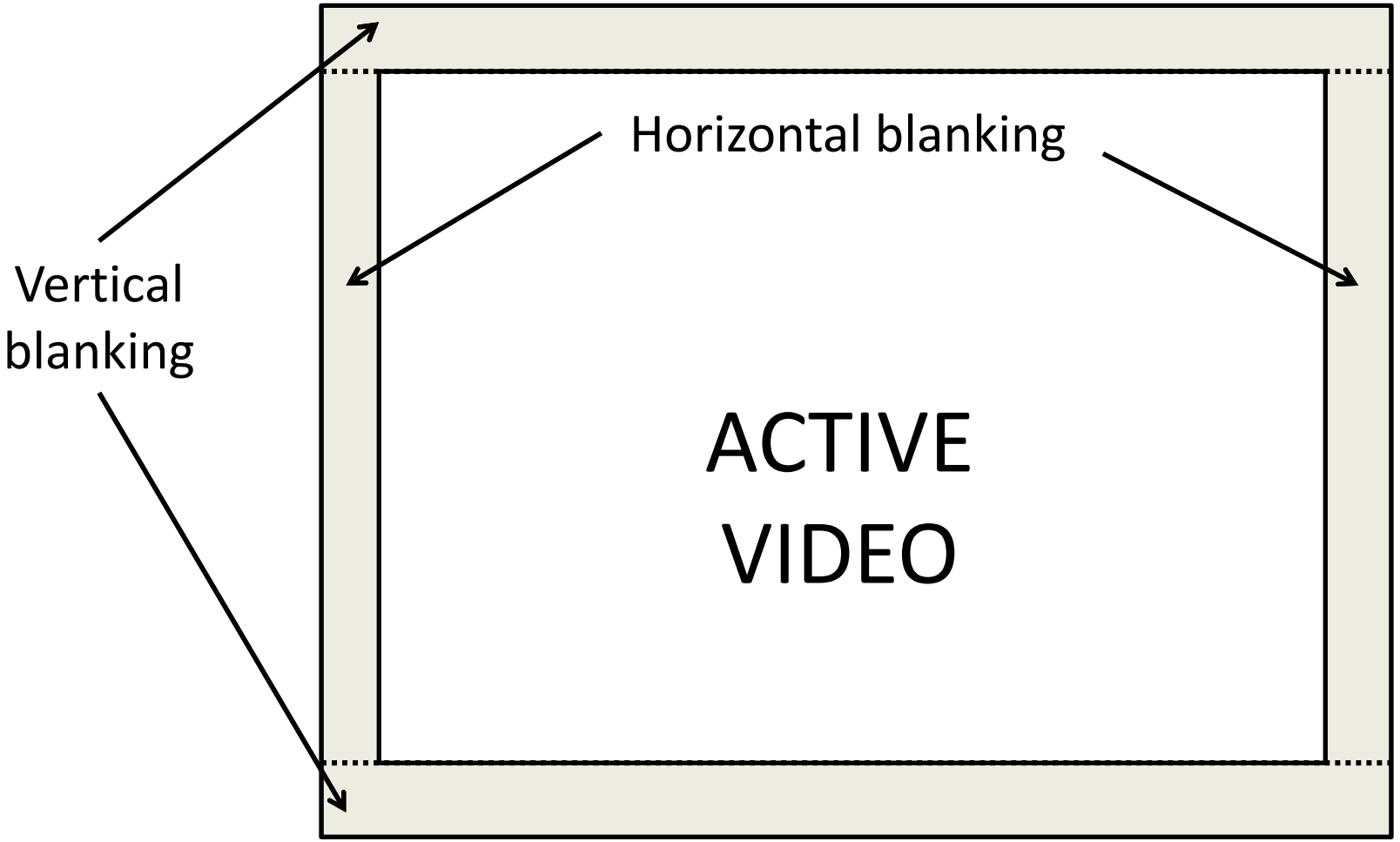
V-Sync (vertical synchronism) to indicate the end of image:

no video signal during some lines = **vertical blanking**

INTERVALS OF BLANKING AND ACTIVE VIDEO

- Origin in imperfections in circuits and CRT (Cathode ray tubes) :
  - horizontal and vertical blanking
- In each line:
  - Period of **horizontal blanking** containing syncs and more
  - Period of **active line**: video signal
- In each field (interlaced)
  - Period of vertical blanking: multiple blank lines with syncs
  - Lines containing video signal

INTERVALS OF BLANKING AND ACTIVE VIDEO (II)



+ Interlaced

COLOR IMAGE SIGNAL: RGB-COMPONENTS

- Camera obtains in each point: **color components with respect to primary colors:**
  - **Normalized:** between 0 and 1 (0 - 0.7 V)
- The components are obtained by weighted primary functions:

$$R = \int I(\lambda) \cdot R(\lambda) \cdot d\lambda$$

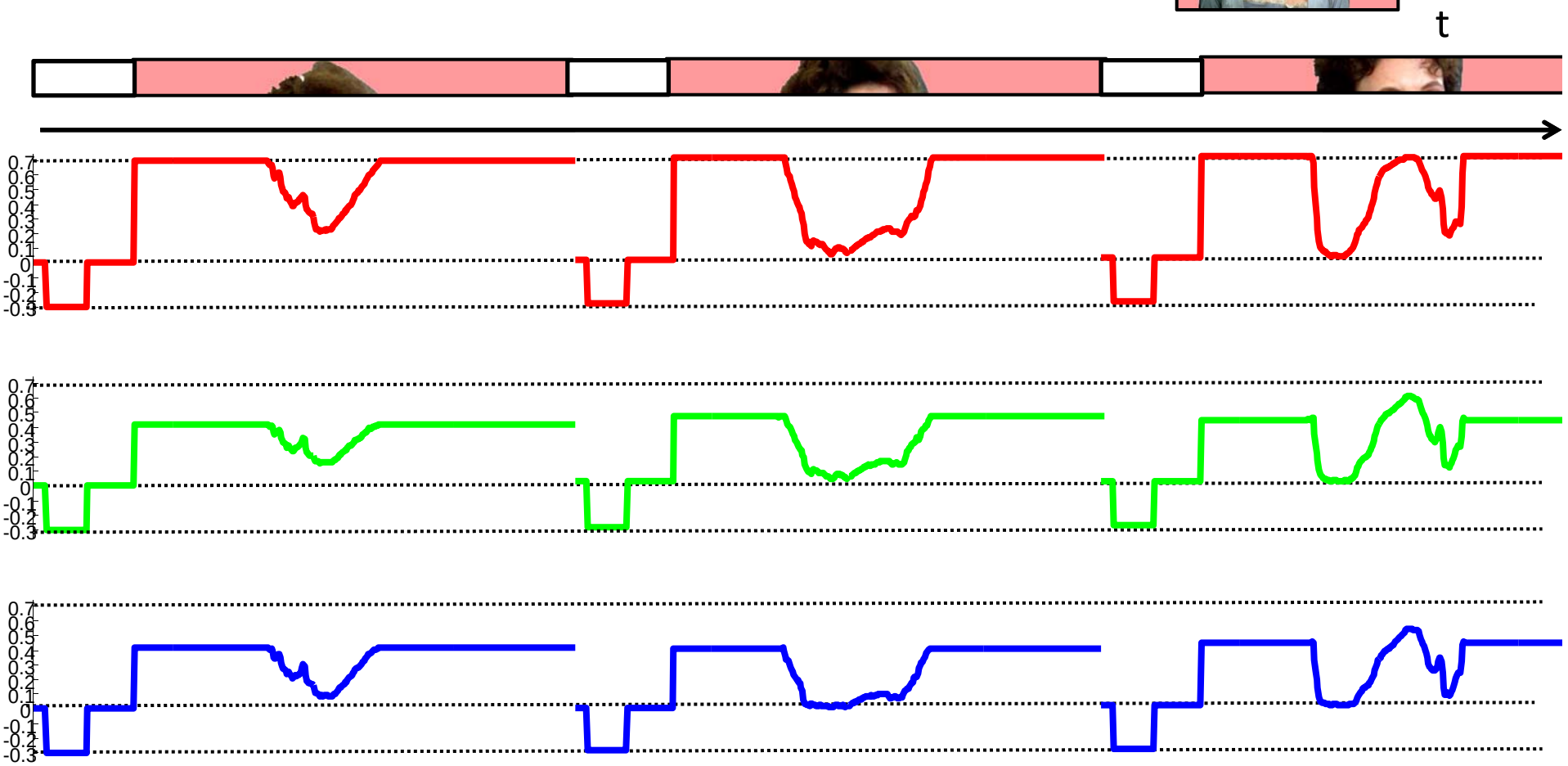
$$G = \int I(\lambda) \cdot G(\lambda) \cdot d\lambda$$

$$B = \int I(\lambda) \cdot B(\lambda) \cdot d\lambda$$

- Individual signals **R**, **G** and **B**: if they are **equal** they compose a **reference white**

EXTRACTION OF RGB-IMAGE

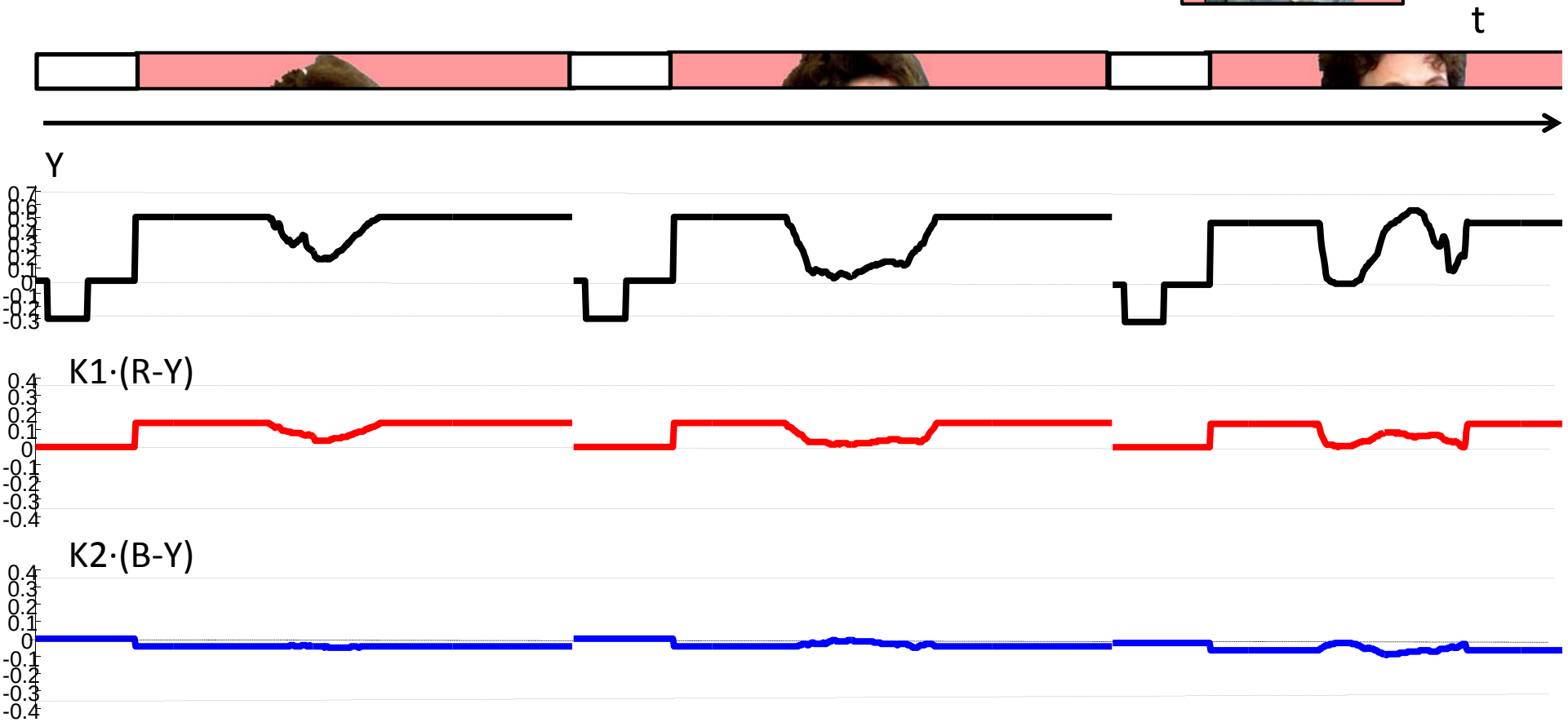
Observe the correlation!



COLOR IMAGE SIGNAL : YP_BP_R-COMPONENTS

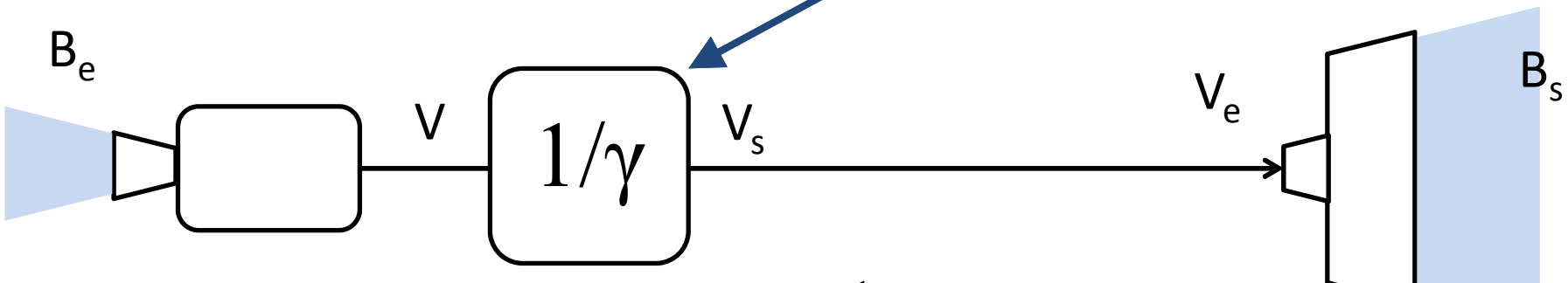
- Components **RGB** are transformed into signals:
  - **Y**: brightness = **Luma**
  - **P_b = B-Y** and **P_r = R-Y**: color differences = **Croma**
    - Are outweighed for grey values (no color!)
    - Have positive and negative values
    - Depend on the system
- Introduced for **compatibility reasons** to BW-TV
- Today maintained because **Y** carries more **information** than the color difference signals

YP_BP_R-COMPONENT SIGNAL

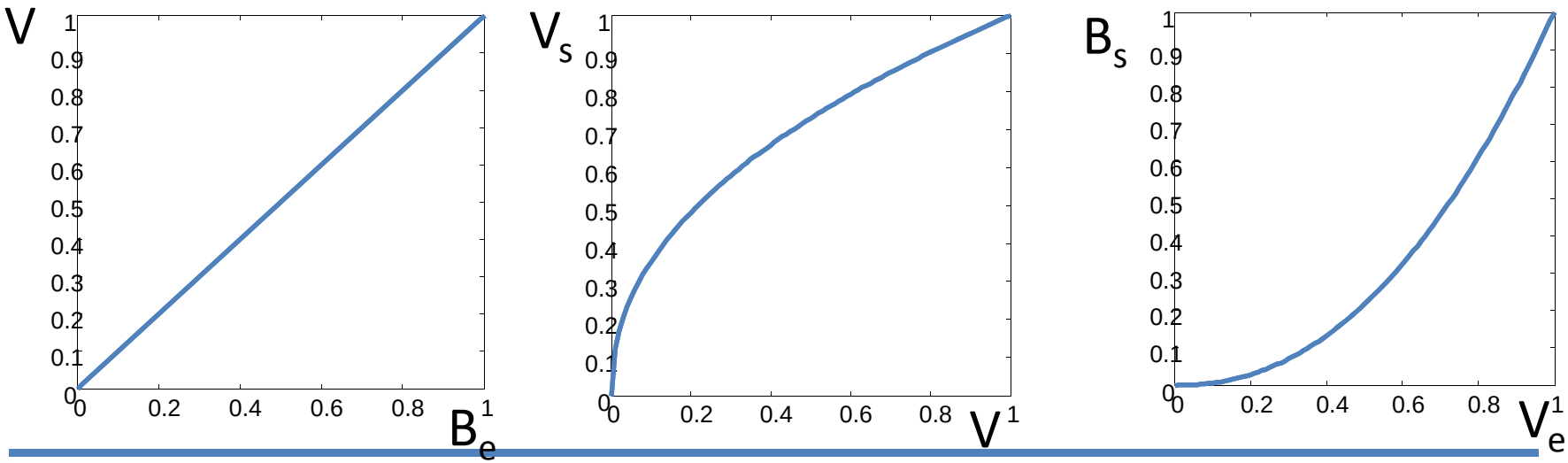


GAMMA CORRECTION

$\gamma=2,2$



$$V = K \cdot B_e \qquad V_s = K \cdot (V)^{\frac{1}{\gamma}} \qquad B_s = K \cdot (V_e)^{\gamma}$$



1.2 ANALOG VIDEO SIGNALS STANDARDS AND RECOMMENDATIONS

- Organisms
  - ITU-R: **International Telecommunication Union**, Sector Radio communications
  - EBU: **European Broadcasting Union**
  - SMPTE: **Society of Motion Picture & Television Engineers**
  - ISO: International Organization of Standardization

1.2 ANALOG VIDEO SIGNALS STANDARDS AND RECOMMENDATIONS

Unión Internacional de Telecomunicaciones

International Telecommunication Union

ITU-R: International Telecommunication Union

http://www.itu.int

- RECOMMENDATION ITU-R BT.470: "**Conventional analogue television systems" (PAL, SECAM, NTSC)**
  http://www.itu.int/rec/R-REC-BT.470-7-200502-I/en
- RECOMMENDATION ITU-R BT.471: "Nomenclature and **description of color bar signals**"
  http://www.itu.int/rec/R-REC-BT.471/en

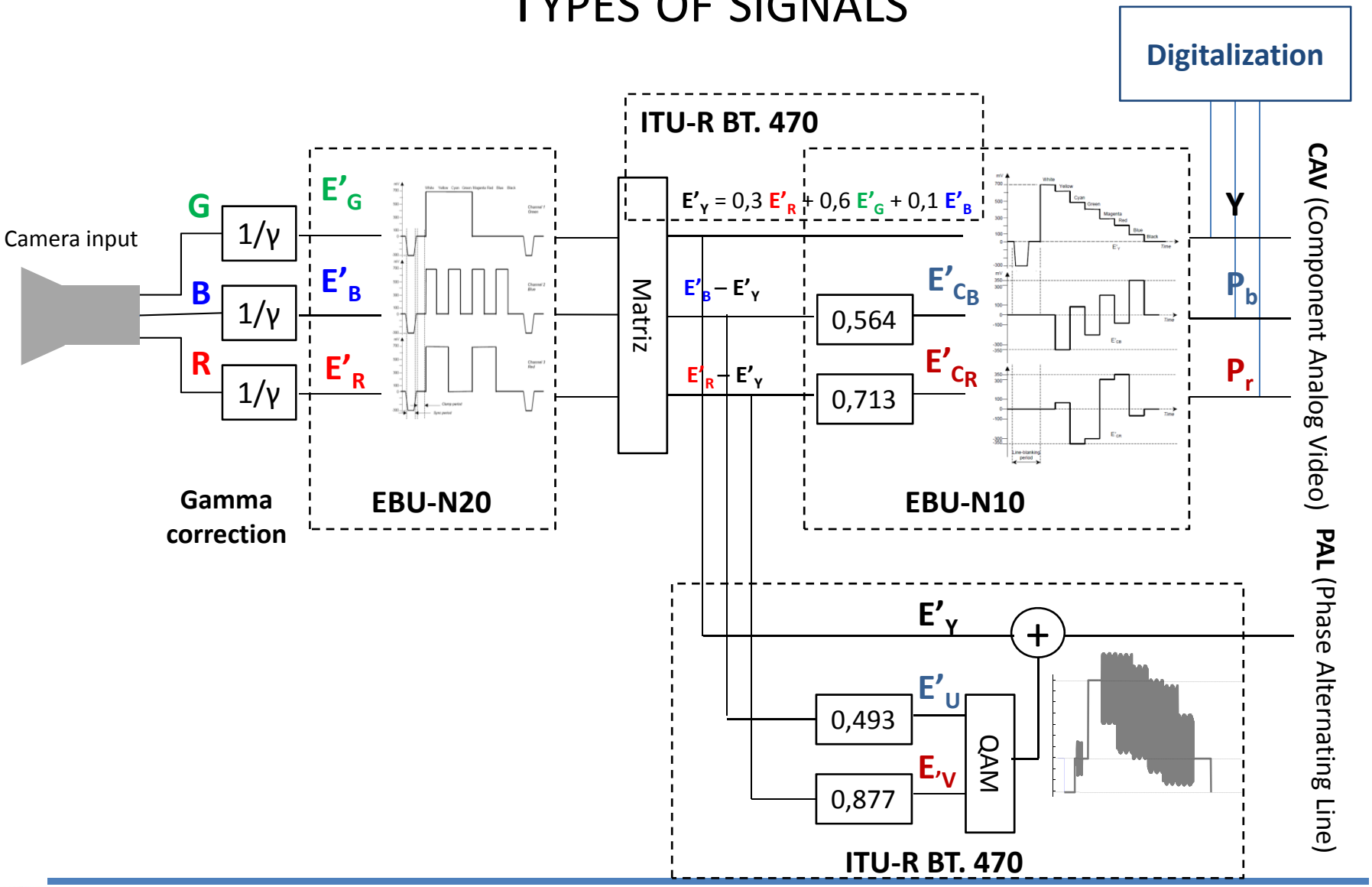
1.2 ANALOG VIDEO SIGNALS STANDARDS AND RECOMMENDATIONS

EBU: European Broadcasting Union

http://www.ebu.ch/

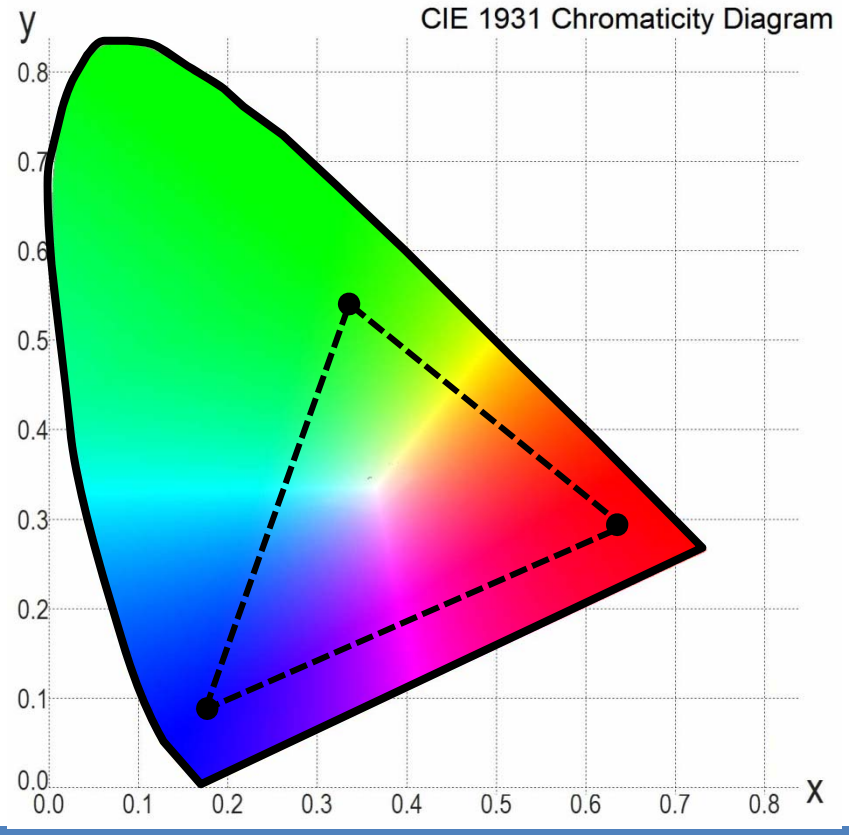
- EBU Technical Standard N10-1998: "Parallel interface for **analogue component video signals"**
- EBU Technical Standard N20-1998: "Parallel interface for **analogue component video signals in GRB form**"

TYPES OF SIGNALS



SATURATION OF COLOR IN TV

- 100 % saturated color: pure spectral
- A TV set cannot represent pure spectral colors, only a combination of the primaries: interior triangle RGB



Redefinition for TV:
Triangle of primaries

SATURATION OF COLOR IN TV (II)

- Measure:

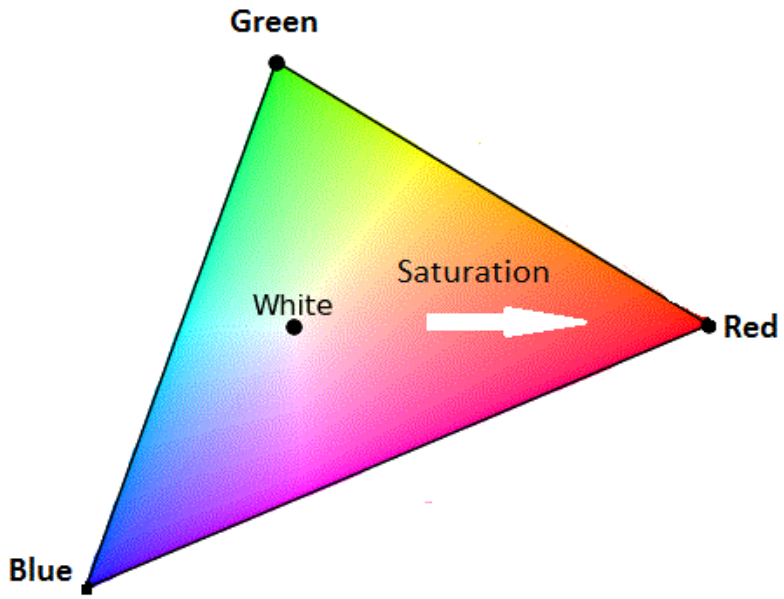
$$S = \frac{\max(R, G, B) - \min(R, G, B)}{\max(R, G, B)}$$

- 100 % saturated color:
  - One or two components are 0
- Color with saturation < 100 % (C):
  - Mixture (Sum) of 100% saturated C_S and Grey G:

$$C = C_S + G$$

AMPLITUDE OF COLOR IN TV

- Amplitude **A = max(R,G,B)**
- If **R=G=B**: grey values with 0 saturation
- The vivid colors are more saturated



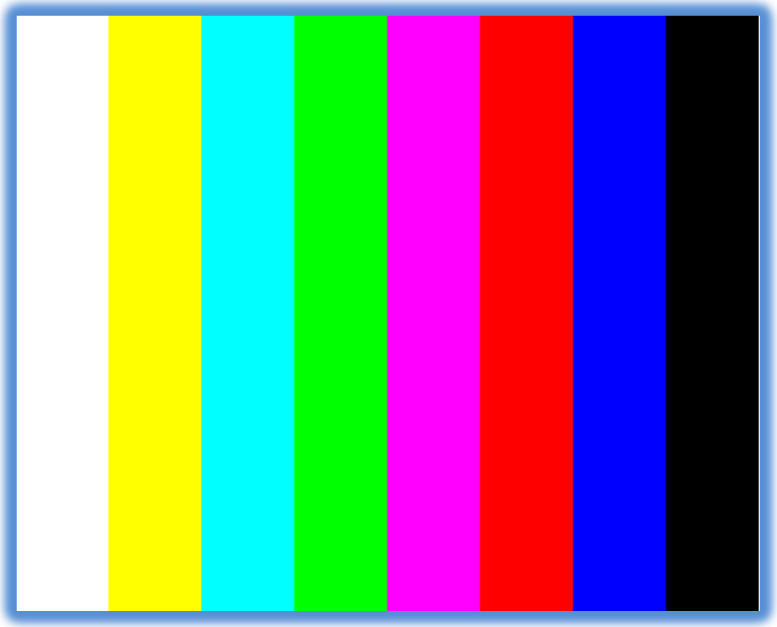
ACTIVITY A1.1

a) A color **C** has the following components: **R=0.8, G=1, B=0.2**. Calculate amplitude **A** and saturation **S**.

b) Decompose **C** (not 100% saturated) into the sum of a 100% saturated Color plus Grey: **C=Cs+G**.

COLOR BARS

- 8 vertical parts:
  - White
  - G, R, B primaries
  - Complements
    Y, Cy, Mag
  - Black
  - Descending luminance



- With maximum saturation and amplitude:
  S=A=1 maximum values of Y, (R-Y) and (B-Y)

RGB

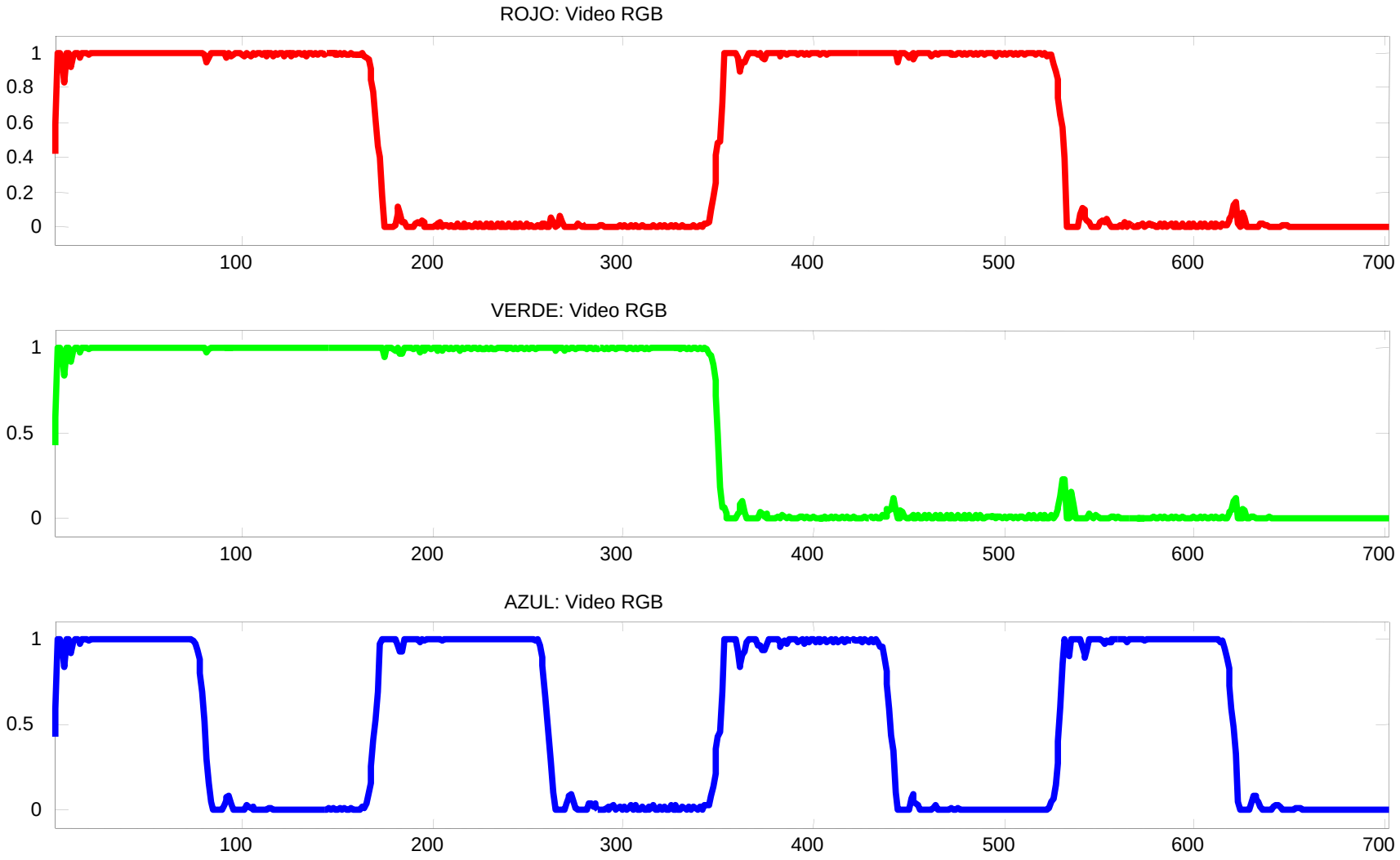
COMPOSITION OF COLOR BARS

Maximum amplitude and saturation

Compo-nent	White	Yellow	Cyan	Green	Ma-genta	Red	Blue	Black
R	1	1	0	0	1	1	0	0
G	1	1	1	1	0	0	0	0
B	1	0	1	0	1	0	1	0

RGB

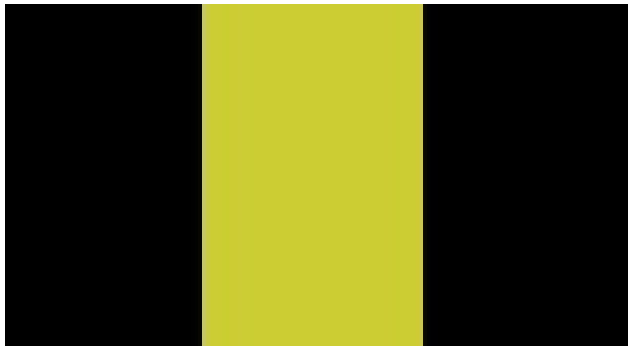
RGB SIGNAL IN COLOR BARS



RGB

ACTIVITY A1.2

The following signal consists in 2 black stripes and one of color X (third part of the image). X is a yellow with R=B, Saturation S=75% and Amplitude A=80%



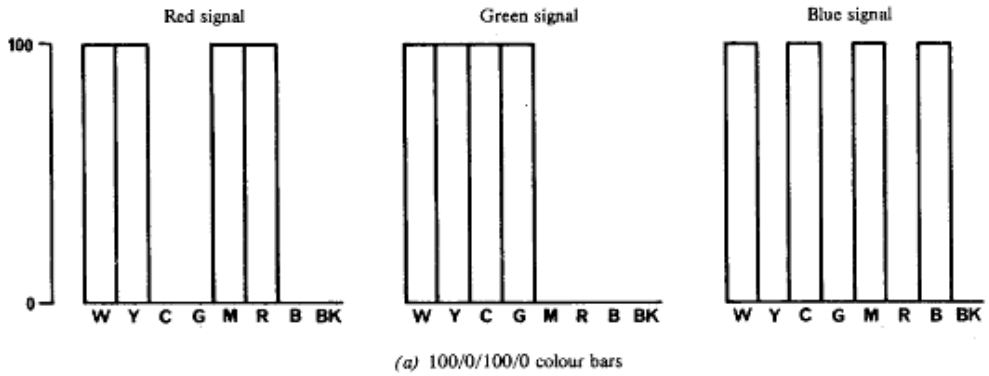
a) Calculate the components R, G, B of color X

b) Trace the lines of the three components

COLOR BAR SIGNAL: **RECOMMENDATION BT.471**

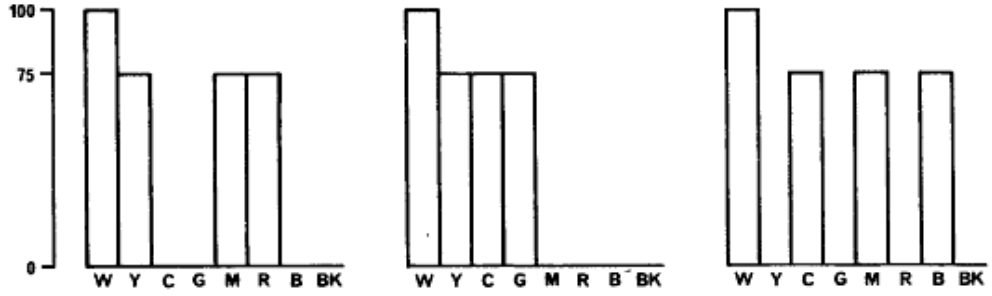
- Nomenclature of color bars:
  max white/min white/max color/min color
- 4 example signals with 100% and 75% color amplitude

(a) 100/0/100/0



(a) 100/0/100/0 colour bars

(b) 100/0/75/0



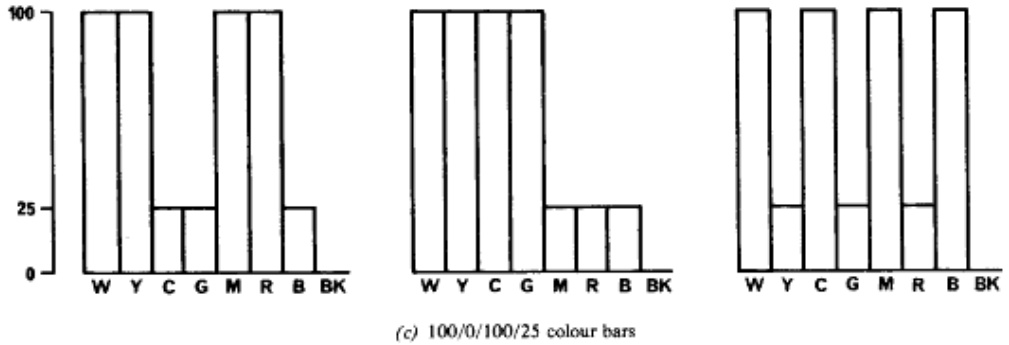
(b) 100/0/75/0 colour bars

RGB

COLOR BAR SIGNAL: **RECOMMENDATION BT.471** (II)

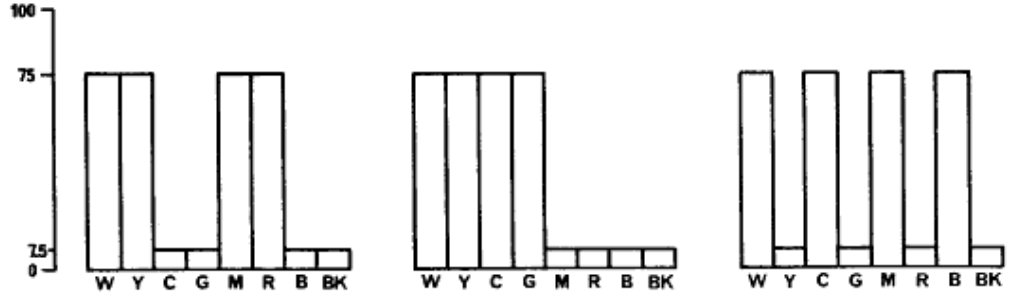
- Nomenclature of color bars:
  max white/min white/max color/min color
- 4 example signals with 100% and 75% color amplitude

(c) 100/0/100/25



(c) 100/0/100/25 colour bars

(d) 75/7.5/75/7.5



(d) 75/7.5/75/7.5 colour bars

RGB

ACTIVITY A1.3

From a hypothetical color bar signal:

100/15/90/10

Calculate the values of the normalized RGB components between 0 and 1 and mark the names of the resulting colors:

Compo-nent	White							
R								
G								
B								

RGB

ACTIVITY A1.3

From a hypothetical color bar signal:

100/15/90/10

Calculate the values of the normalized RGB components between 0 and 1 and mark the names of the resulting colors:

Compo-nent	White	**Light yellow**	Light cyan	Light green	**Light magenta**	Light red	**Light blue**	Grey
R	**1**	**0.9**	0.1	0.1	**0.9**	**0.9**	0.1	0.15
G	**1**	**0.9**	**0.9**	**0.9**	0.1	0.1	0.1	0.15
B	**1**	0.1	**0.9**	0.1	**0.9**	0.1	**0.9**	0.15

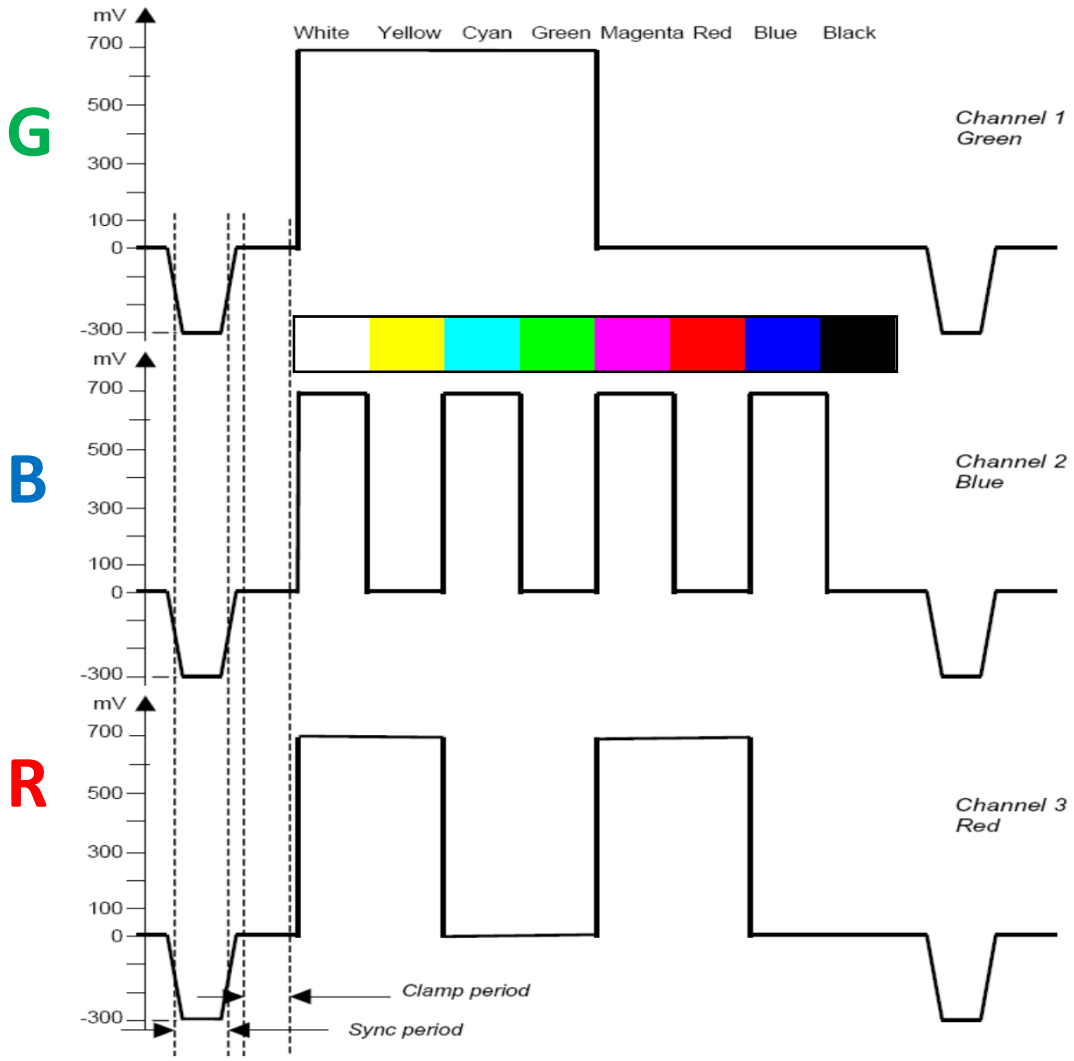
RGB

SEÑAL RGB: EBU TECHNICAL STANDARD N20-1998

RGB bars:
100/0/100/0

"Parallel interface for analogue component video signals in GRB form"

Video: 0 to 0.7 V
Synchronisms: -0.3 to 0 V



RGB

COMPONENT SIGNAL: **RECOMMENDATION BT.470**

E': Primary colors **gamma-corrected** and **normalized** (0 to 1V):

R, G, B ➔ E_R', E_G', E_B'

Calculate **luminance Y** from E_R', E_G', E_B':

$$Y = E_Y = 0.299 \cdot E'_R + 0.587 \cdot E'_G + 0.114 \cdot E'_B$$

Calculate **color differences**:

$$Cr = 0.713 \cdot \left(E'_R - Y\right)$$

$$Cb = 0.564 \cdot \left(E'_B - Y\right)$$

Y: 0 - 1V
- signal: 0 to 700 mV
- syncs: 0.3V

Cr,Cb: -0.35 to 0.35V
(EBU N-10)

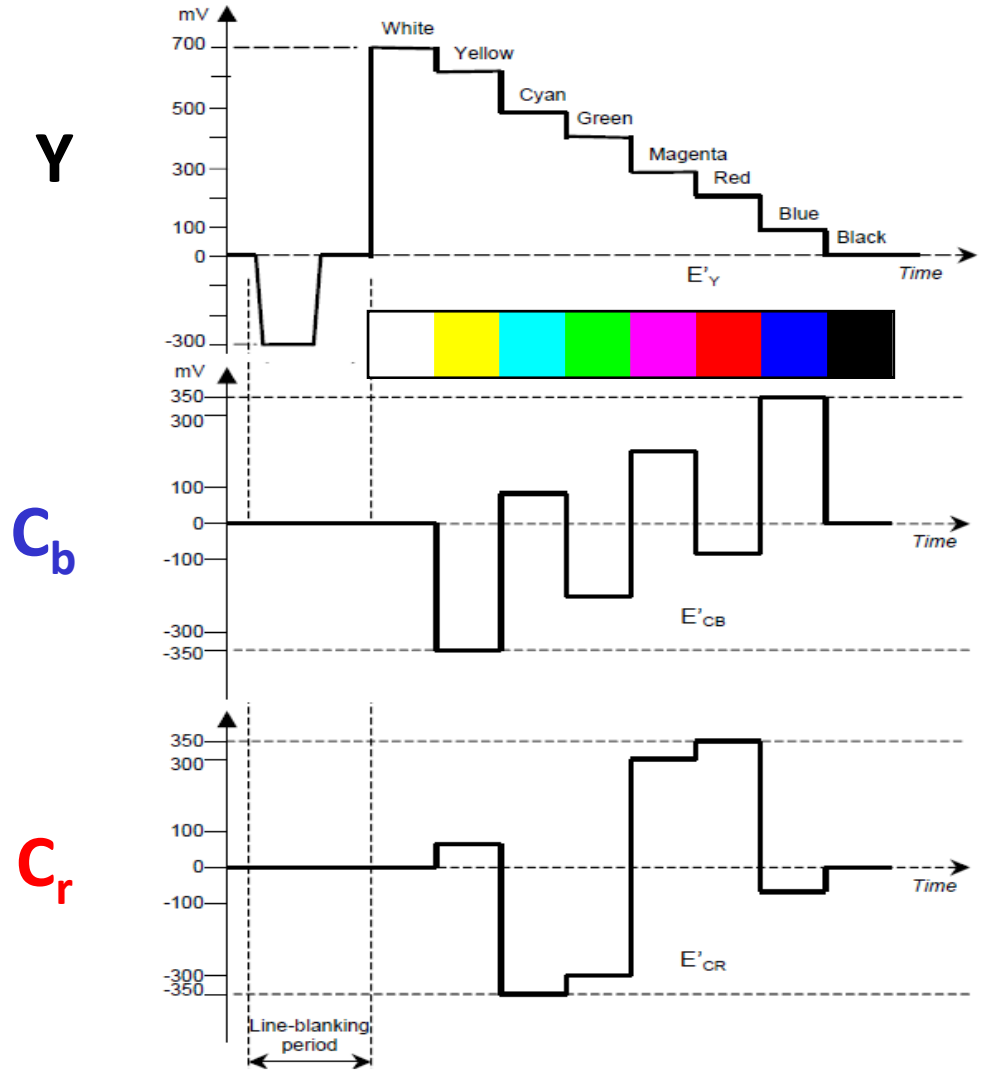
YCbCr

EBU TECHNICAL STANDARD **N10-1998**

RGB bars:
100/0/100/0

"Parallel interface for analogue component video signals"

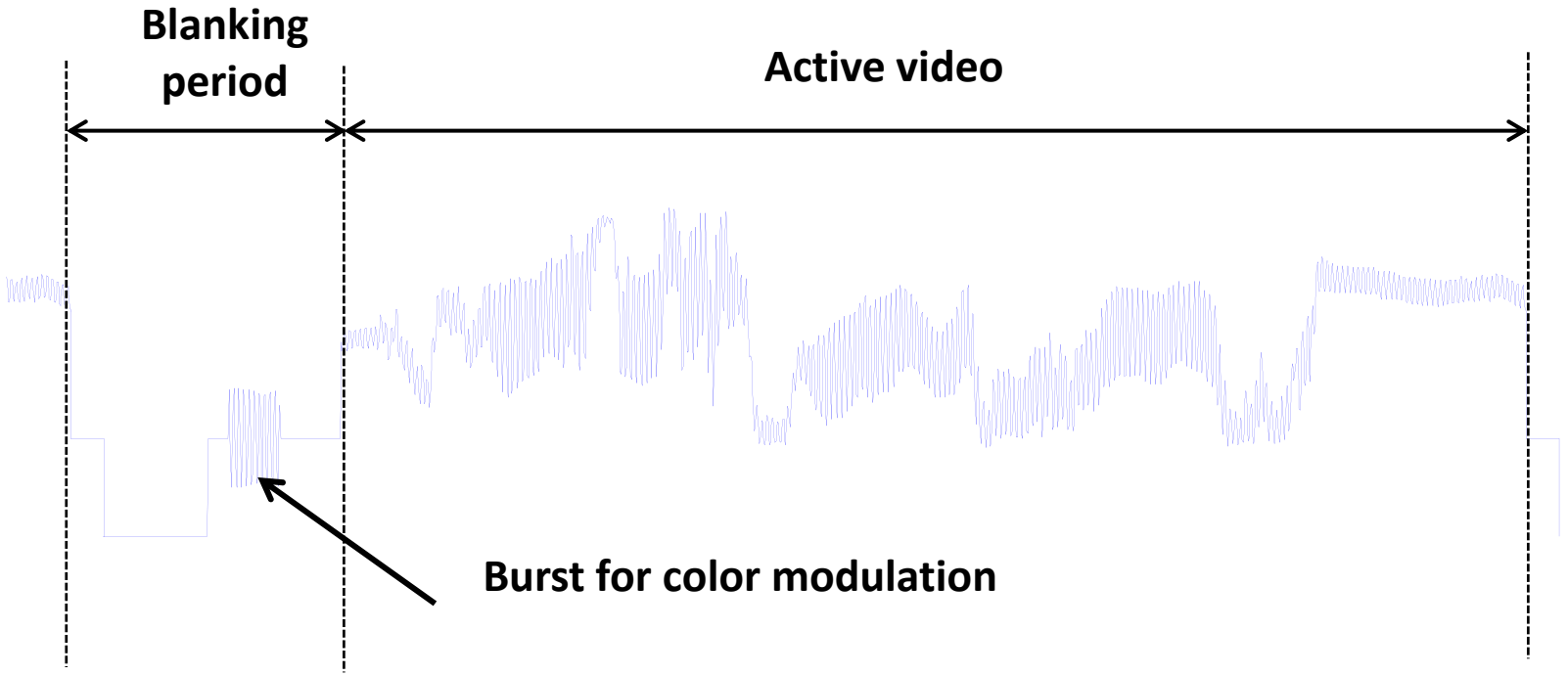
Y: 0 to 0.7V
Cb, Cr: -0.35 to 0.35V
Syncs: -0.3 to 0V



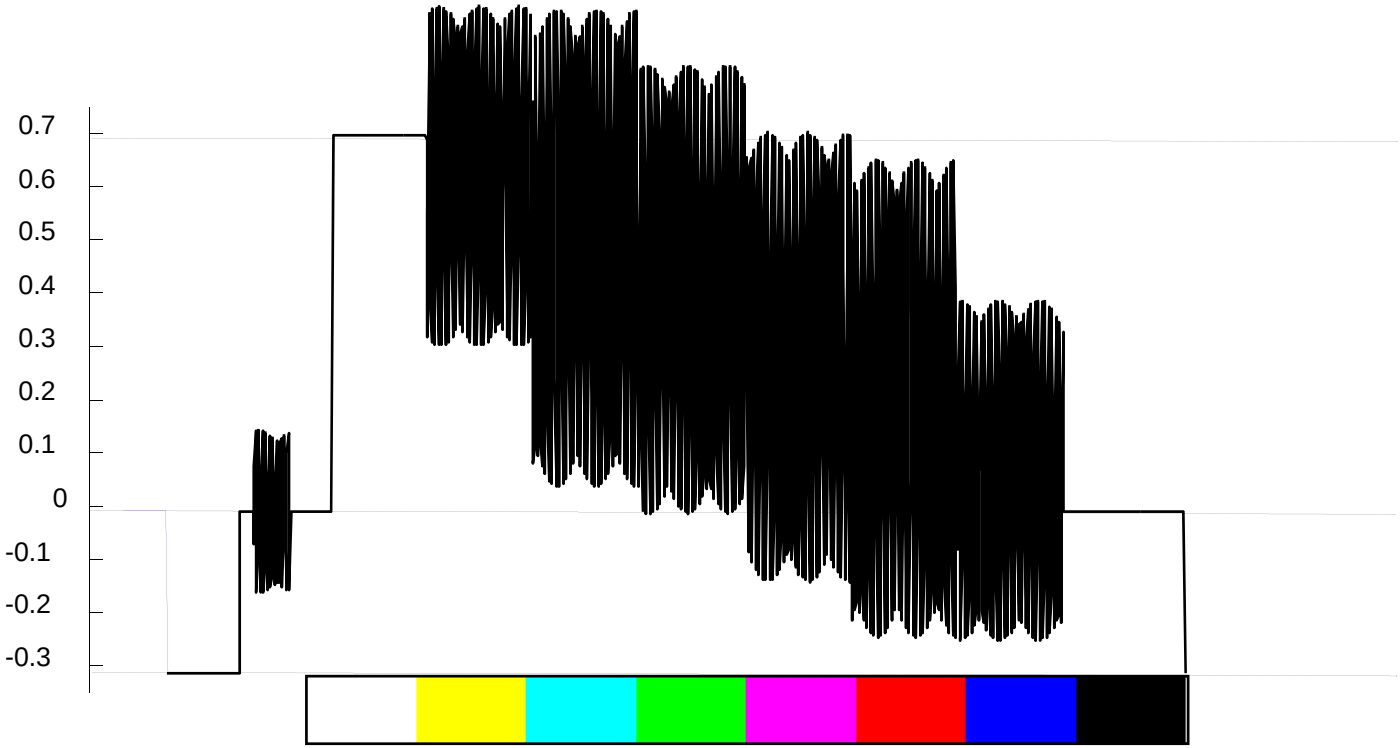
YCbCr

COMPOSITE VIDEO: IN EXTINCTION

- Luminance in mean value of signal
- Chrominance signal added: color differences modulated over amplitude and phase of a porting frequency



UIT-R BT.470: PAL, SECAM, NTSC



Limitations:

- Amplitude and phase are “fragile”
- Confusion luma/chroma

1.3 CHARACTERIZATION, PARAMETER

- Image adjustments: **Contrast**, **Brightness**, **Saturation**
- **Aspect ratio**
- **Image frequency** and **number of lines**
- **Structure**: temporization, synchronisms, interlaced
  - **Standard definition**: Recommendation **ITU-R BT.470**
  - **Analogue high definition**: Recommendation **ITU-R BT.709**
  - Other formats
- **Quality**: Bandwidth, resolution, color bar adjustment
- **Limitations** of analogue signals

IMAGE ADJUSTMENTS

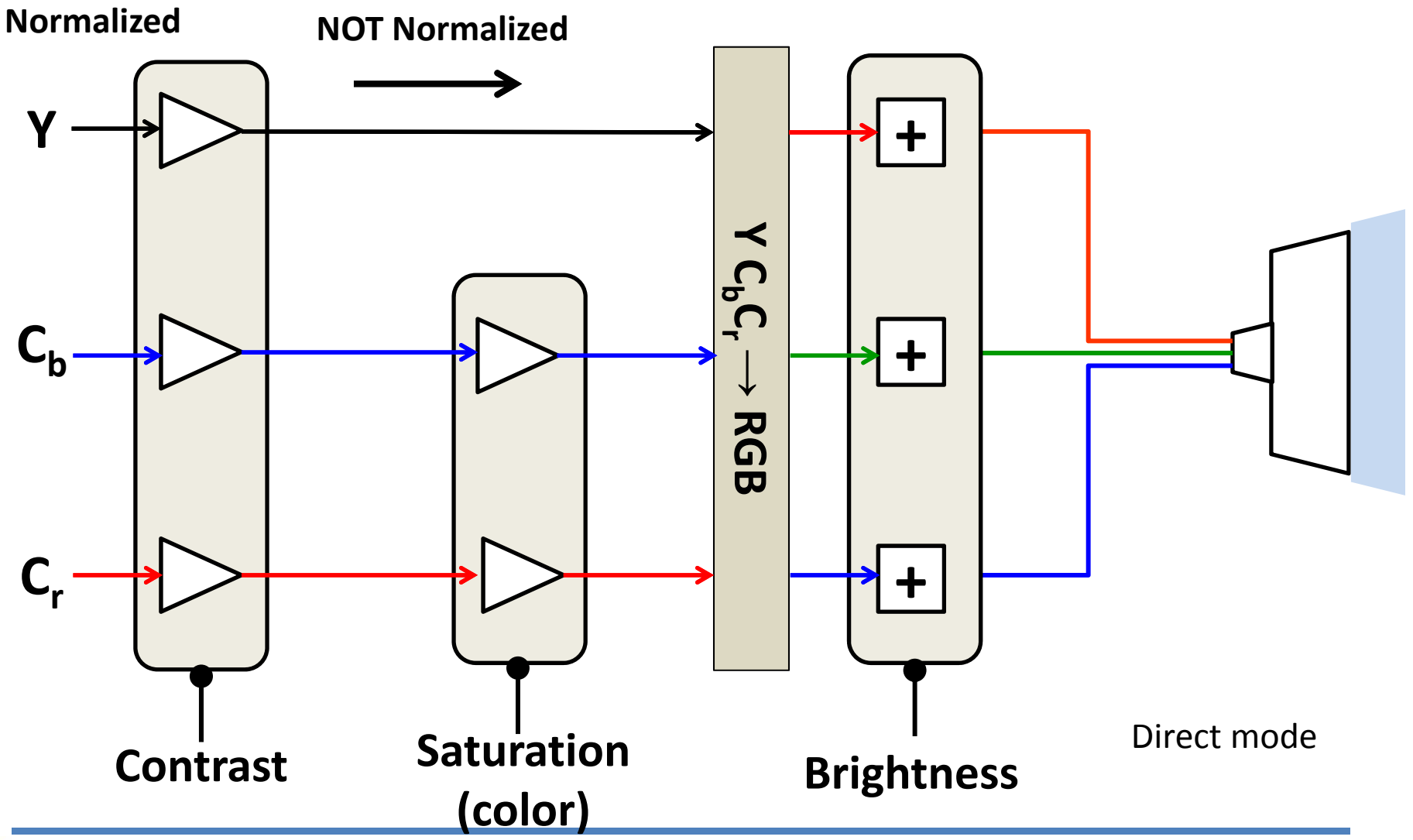
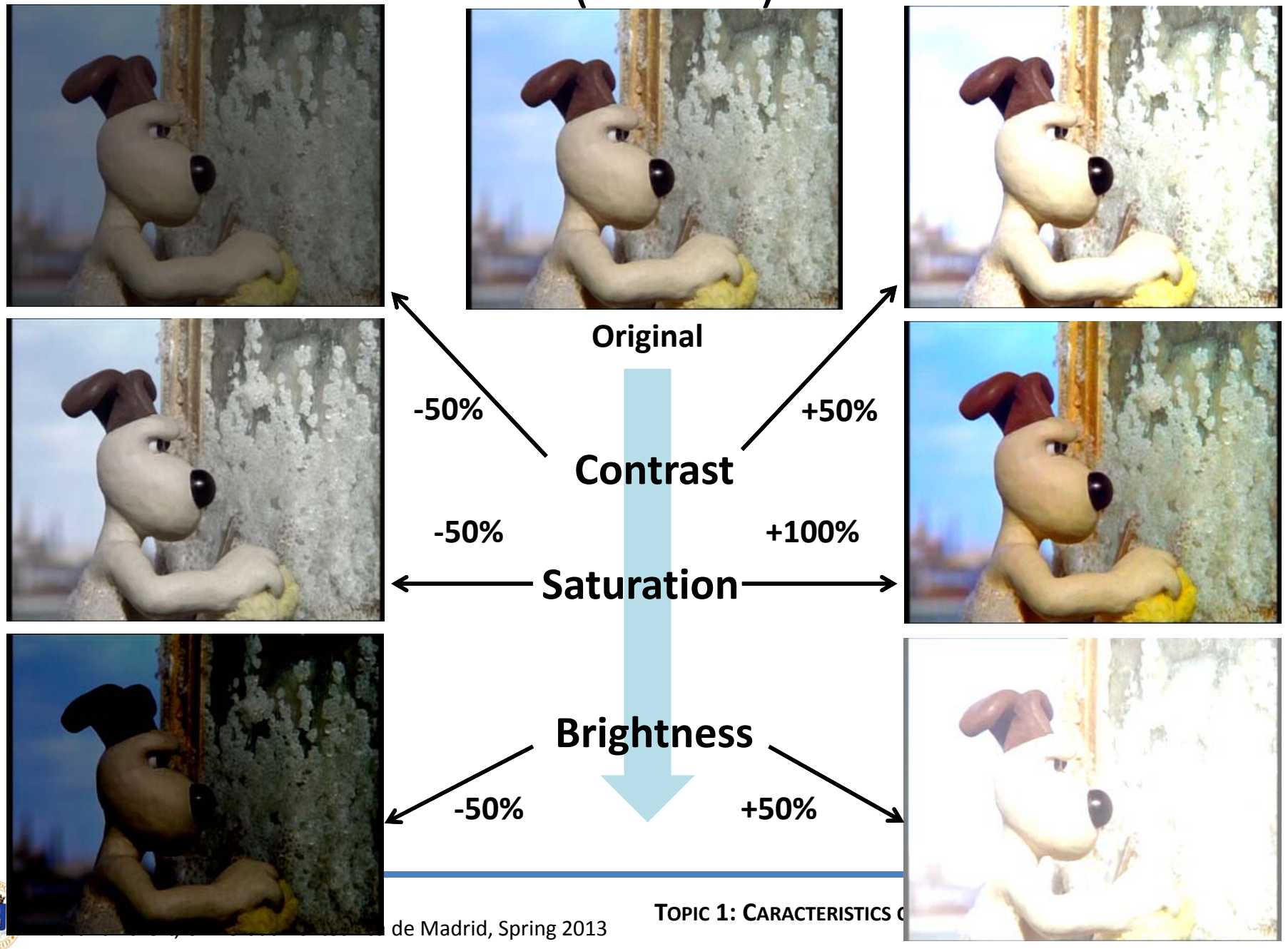
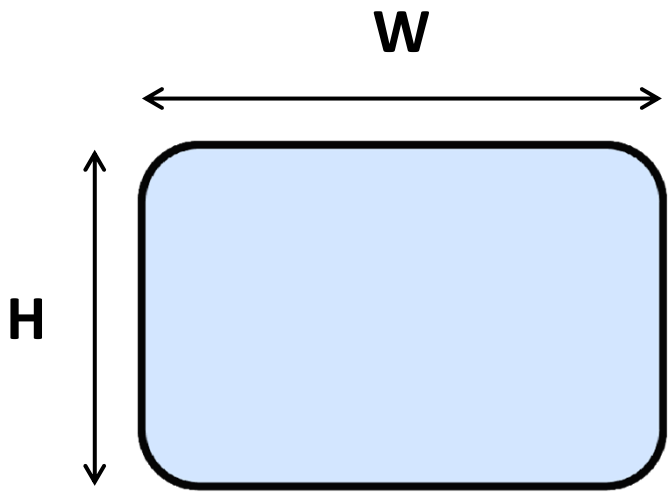


IMAGE ADJUSTMENTS (EFFECTS)



ASPECT RATIO OF THE IMAGE

- Representing the image the aspect ratio has to be maintained



Coefficient between width (W) and height (H) of image display

$$Z = \frac{W}{H}$$

4:3 or 16:9 for Standard Definition (SDTV),
16:9 for High Definition (HDTV)

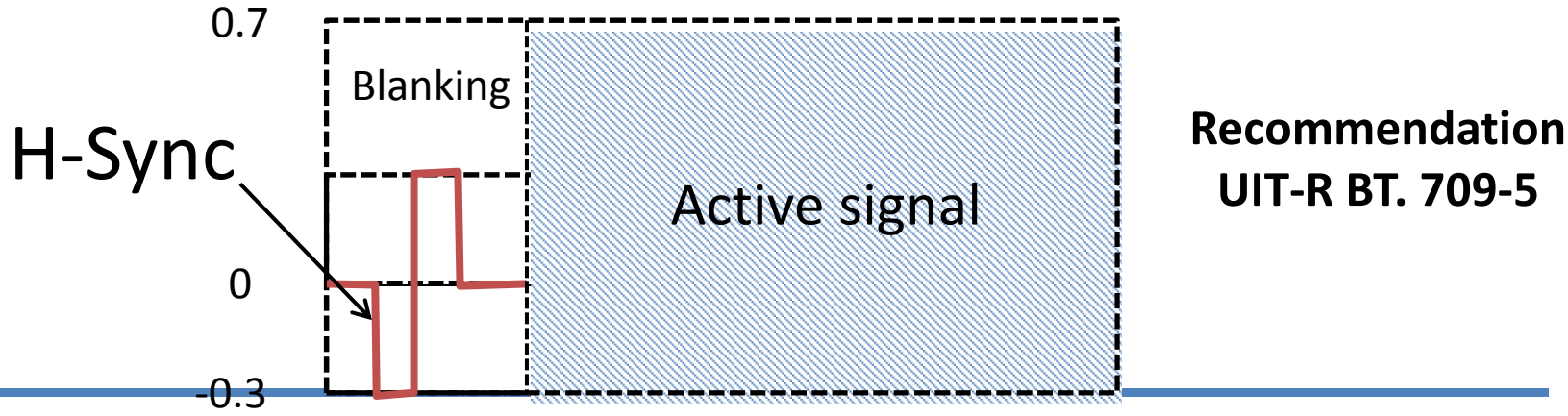
Display Aspect Ratio

FRAME FREQUENCY AND NUMBER OF LINES

- Two families of SDTV:
  - PAL, SECAM: 625 lines, 25 frames/second
    - 312,5 lines per field (interlaced)
    - 575 active lines (video) + 50 blanking lines
    - Line frequency fh=625·25 = 15625 lines/s
    - Line period Th = 64 μs (52+12 μs)
  - NTSC: 525 lines, 30 frames/second
    - 262,5 lines per field (interlaced)
    - 483 active lines (video) + 42 blanking lines
    - Line frequency fh=525·30 = 15750 lines/s
    - Line period Th = 63.5 μs (55.2+8.3 μs)

SISTEMAS DE ALTA DEFINICIÓN (HDTV)

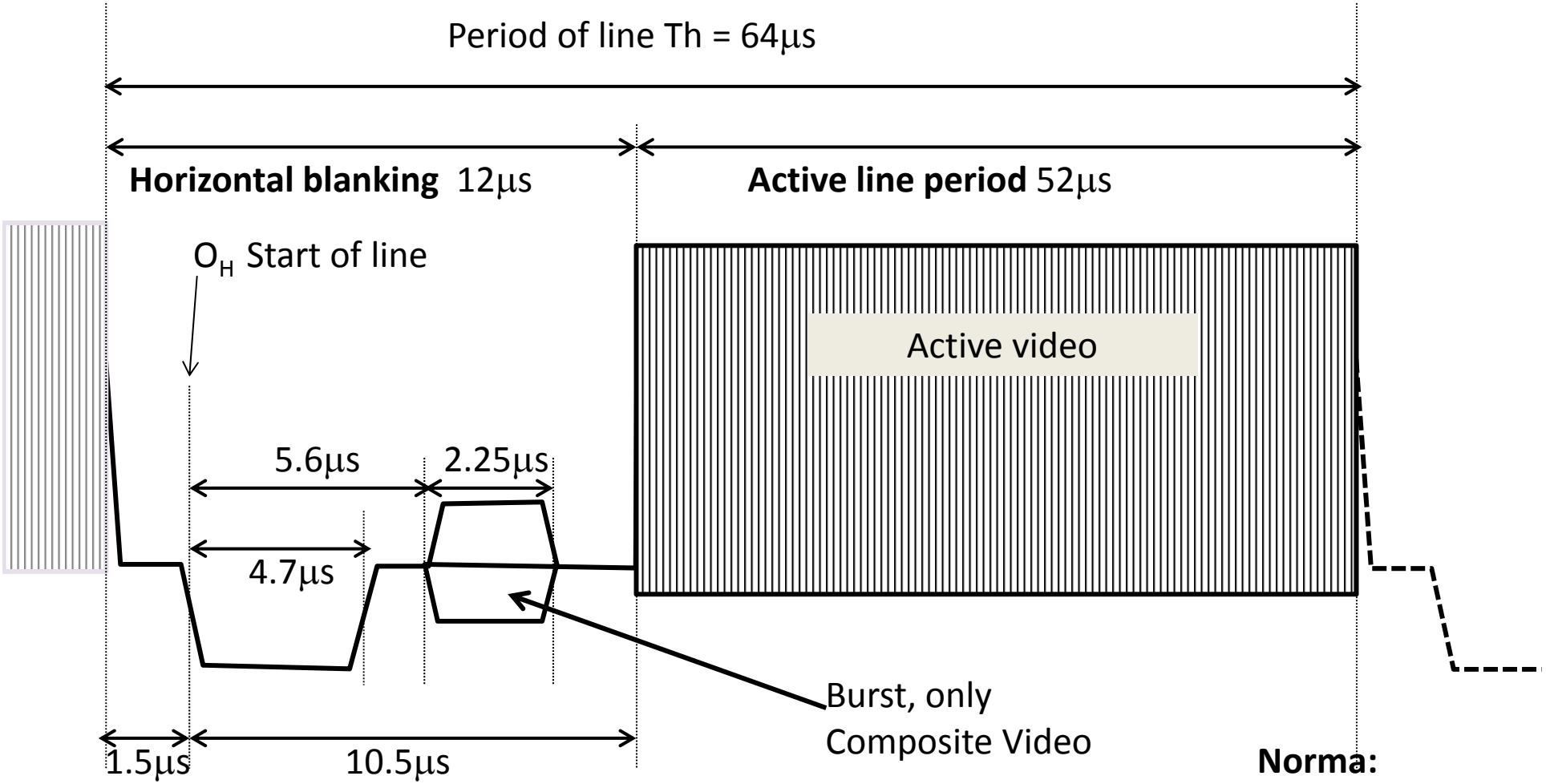
- American system:
  - 1125 lines, 1035 active video
  - 30 frames per second, interlaced
- European system:
  - 1250 lines, 1152 active image: 576 per frame
  - 25 frames per second, interlaced
  - Each line 32 μs: 26 μs active video+ 6 μs blanking



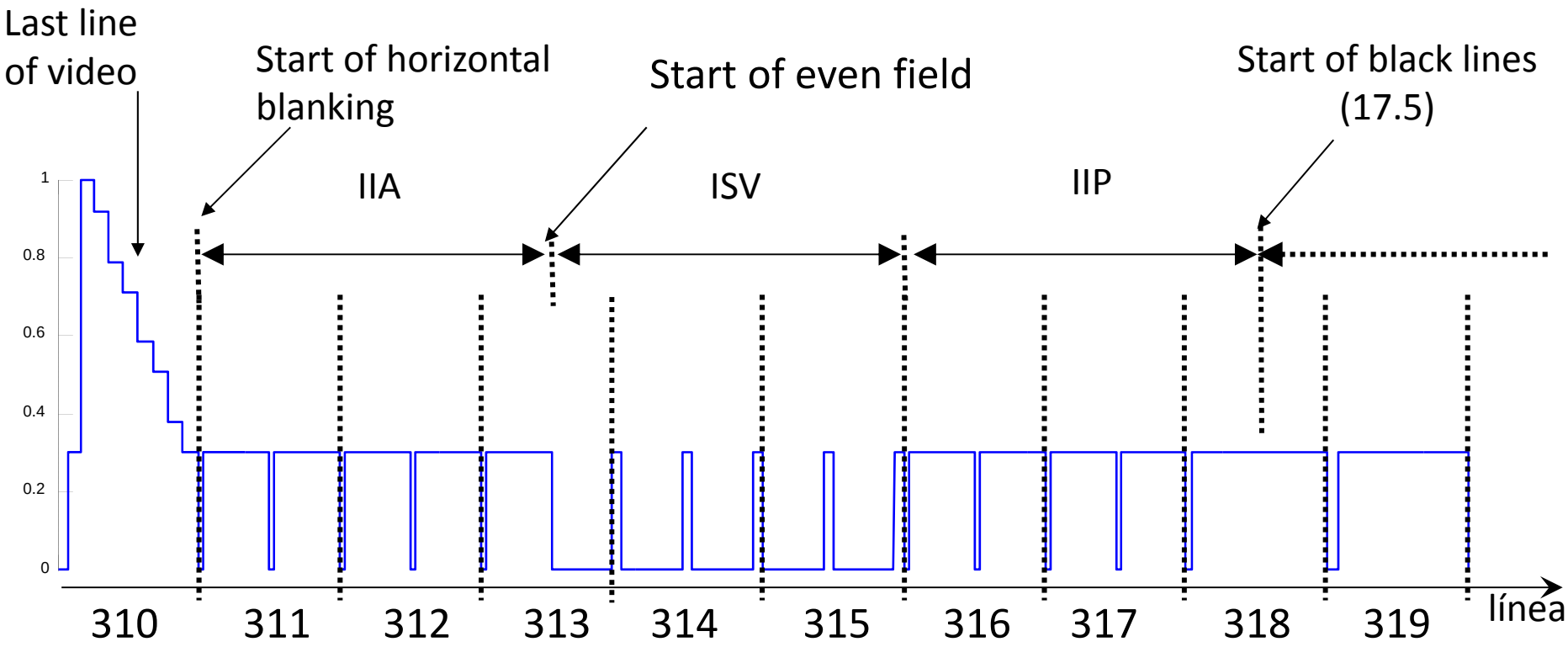
INTERLACED VIDEO

- Process of information reduction based on limitations of human visual system
- Alternative line transmission (even and odd image lines)
- Half of bandwidth saved and transmitted information reduced
- Vertical resolution is reduced and artifacts appear

TEMPORIZATION OF SYNCHRONISMS AND BLANKING



BLANKING AND VERTICAL SYNCHRONISM



25 lines without video per field: 50 per frame
312.5 with video per field: 575 per frame

Recommendation: UIT-R BT.470

Standard definition

SIGNAL STRUCTURE (STANDARD DEFINITION)

- Field 1 (odd): 312.5 lines:
  - Line 1 to half of 23: vertical blanking
  - Lines 23 to 310: active video
  - Lines 311 to half of 313: vertical blanking
- Field 2 (even); 312.5 lines:
  - Half of line 313 to 335: vertical blanking
  - Lines 336 to half of 623: active video
  - Lines of half of 623 to 625: vertical blanking

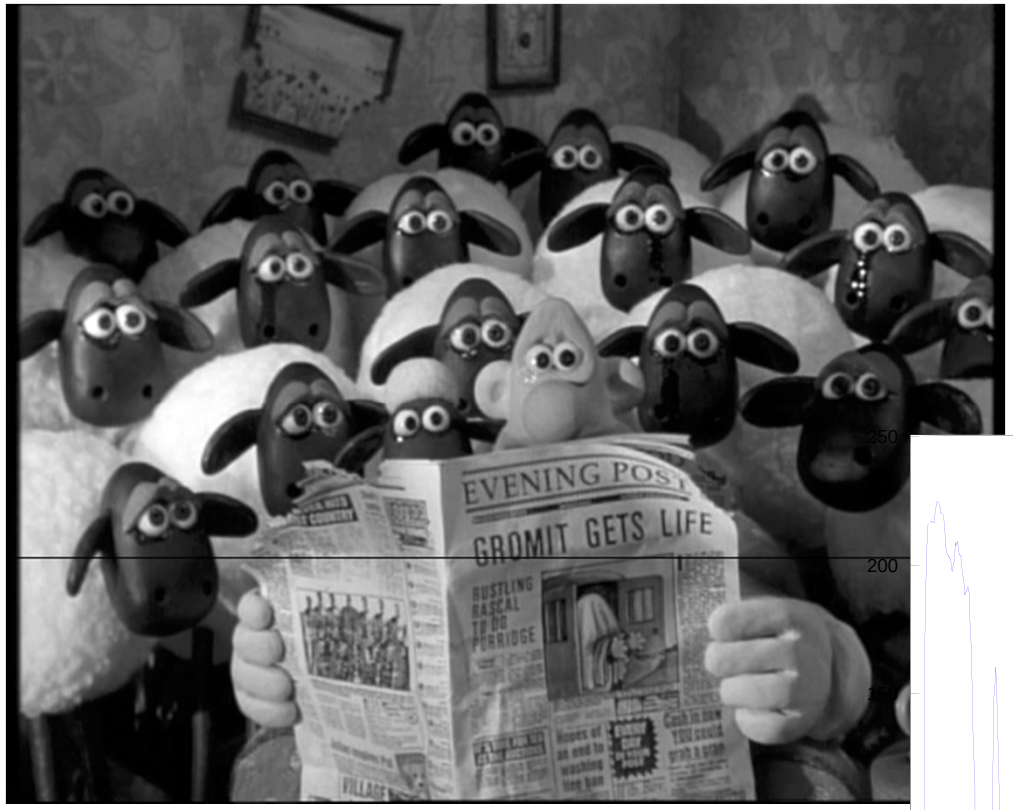
MORE FORMATS

Format	Aplication
QCIF (quarter common intermediate format)	Visual telefony with small bandwidth
CIF (common intermediate format)	Videoconference with higher quality
SIF (standard intermediate format)	30 frames per second
ITU 472	Digital TV with redused resolution (videoconference)
ITU 601	Digital TV with studio quality
EDTV (enhanced definition TV) O **EQTV** (enhanced quality TV)	Progressive HDTV signals with higher aspect ratio (PAL plus)
HD-1440	TV with high resolution (HDTV, high definition TV) doble resolution than SDTV
HD-I	Interlaced HDTV format with improved aspect ratiocon
HD-P	Progressive and 60 frames per second

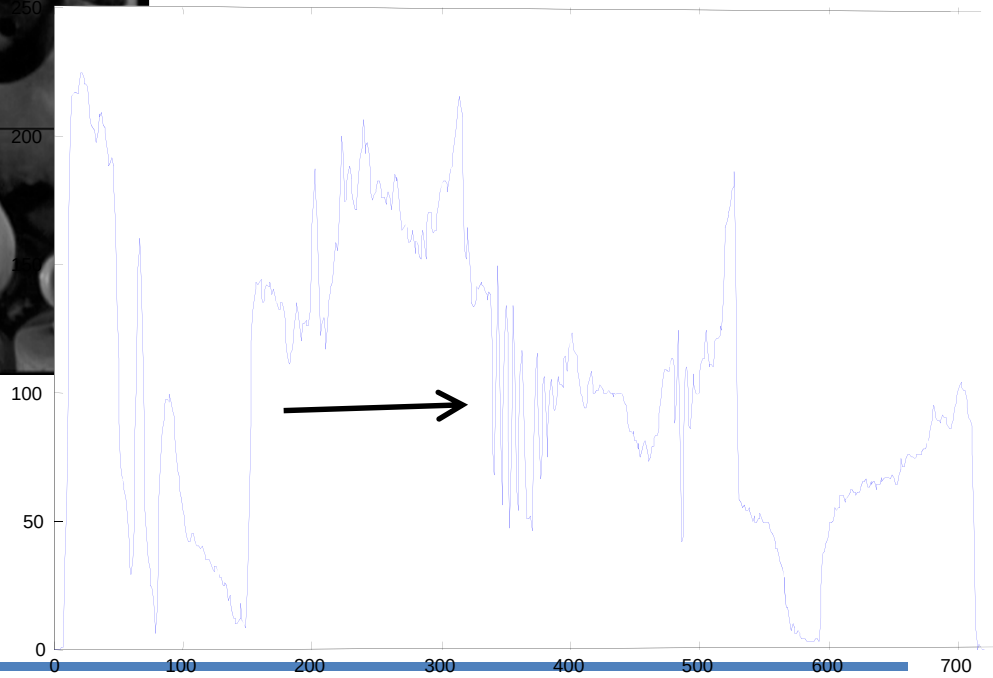
BANDWIDTH OF VIDEO SIGNALS

- High frequency signal due to serialization of values and synchronisms in one dimension
- Limitation in frequencies leads to less details: loss of horizontal resolution
- Standard definition:
  - Luma at least **6 MHz**, chroma **3 MHz**
- High definition:
  - Luma at least 30MHz, chroma 15MHz

BANDWIDTH



Much higher in High Definition Video

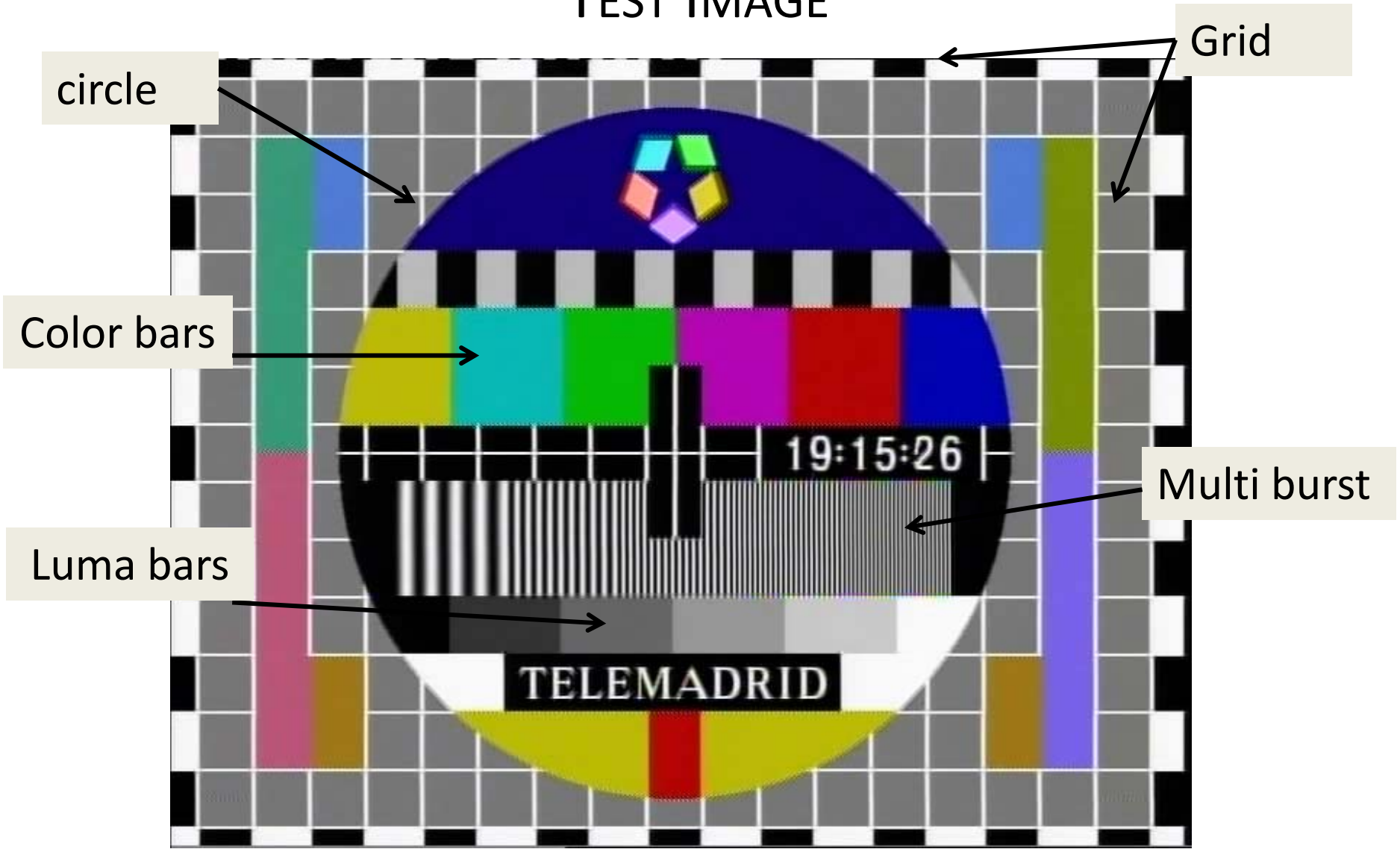


Faster variation of signal where more details are

VERTICAL RESOLUTION

- Depend on active lines
- In interlaced systems the real vertical resolution is less:
  - Degradation of vertical resolution due to interlaced signals (Kell effect). The level of detail is reduced by factor 0.65: the effective vertical resolution is 0.65*number of active lines
    - European TV: 575·0.65 = 374

TEST IMAGE


Grid
circle
Color bars
19:15:26
Multi burst
Luma bars
TELEMADRID

LIMITATIONS OF ANALOGUE SIGNALS I

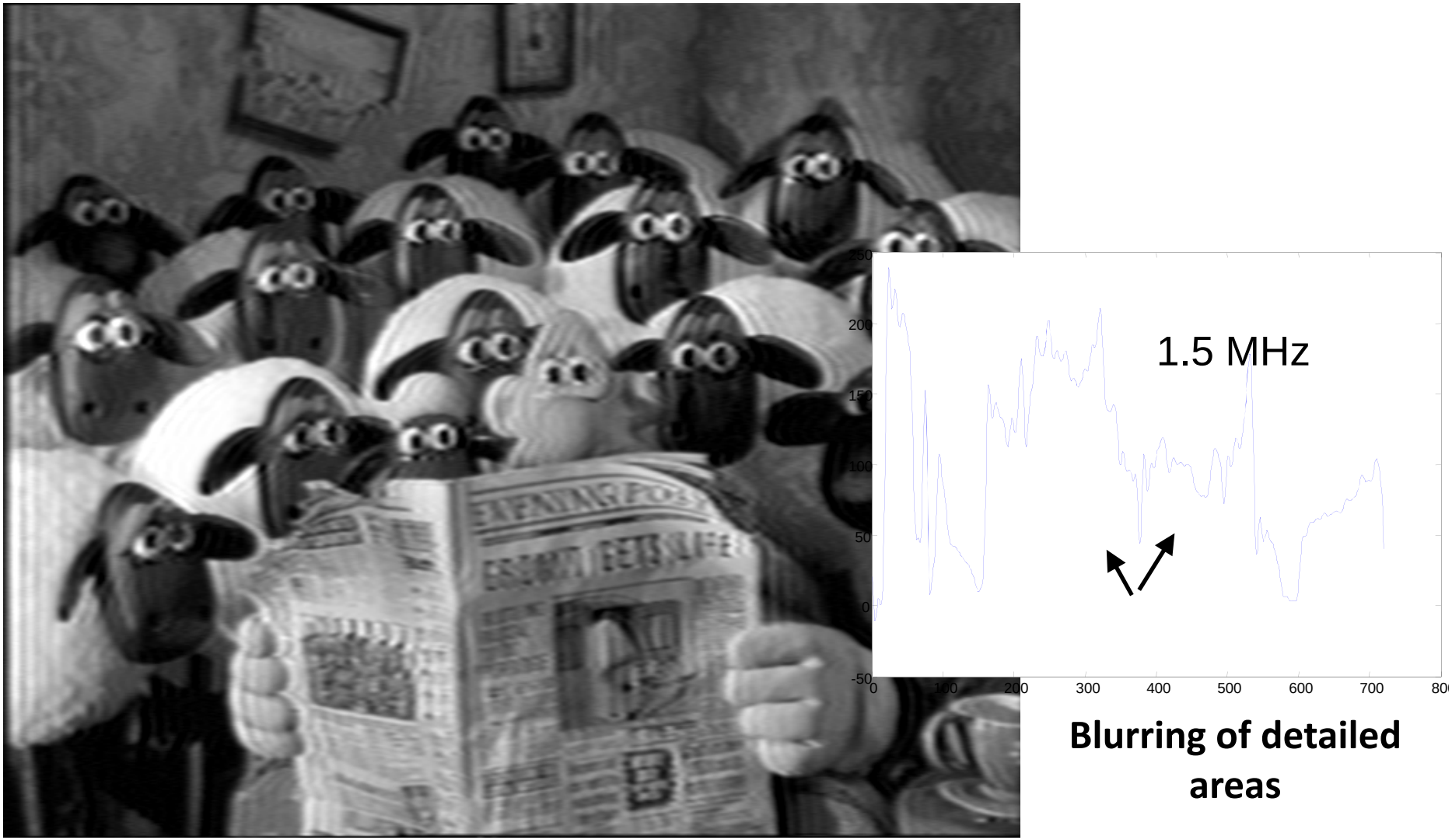
- Perturbations:
  - Noise, distortion, crosstalk, intermodulation, interferences
- Information carries:
  - Signal values → information values + electrical noise

NOISE

INTERFERENCE

COMPOSITE VIDEO

LOSS OF BANDWIDTH, DISTORSIONS



Blurring of detailed areas