ANALOGUE TELEVISION

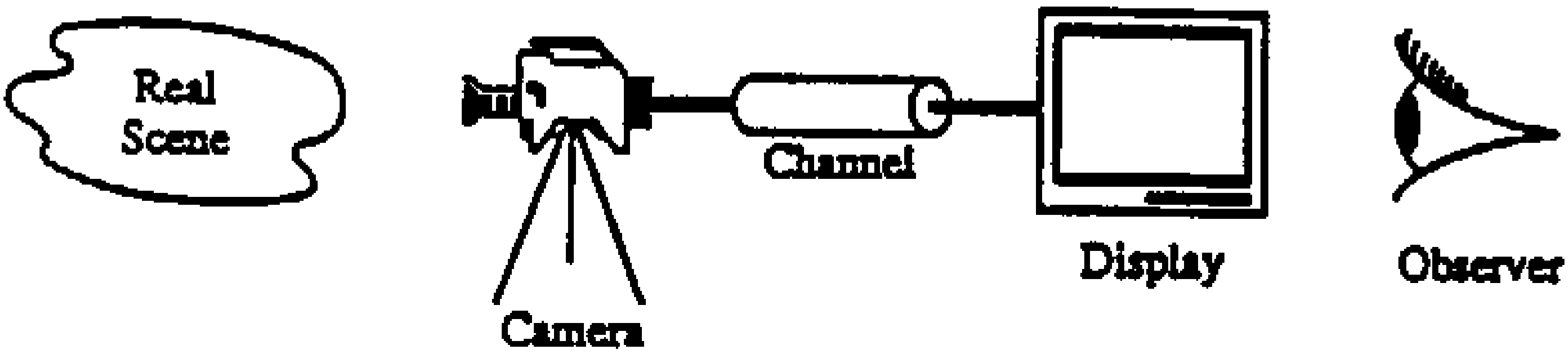
Fernando Pereira

Instituto Superior Técnico

The box that changed the World … or

A picture is worth a thousand words !

Television: the Objective

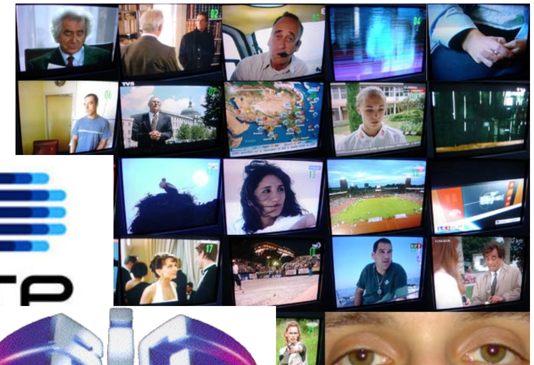


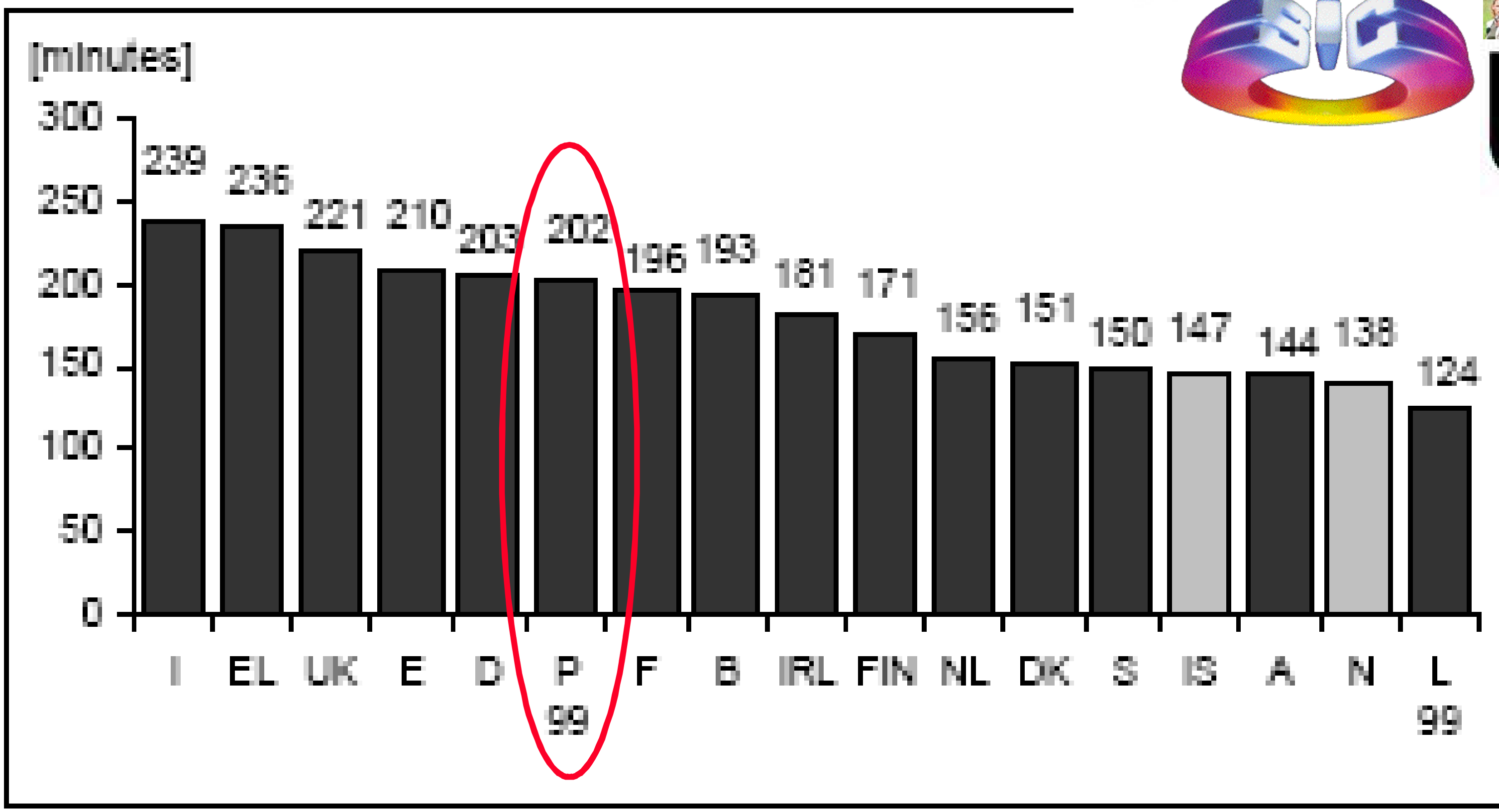
Transference at distance of audiovisual information using electrical/optical signals where many users (?) simultaneously (?) consume the same content.

The Final Target: Telepresence

Growing sensation of immersion

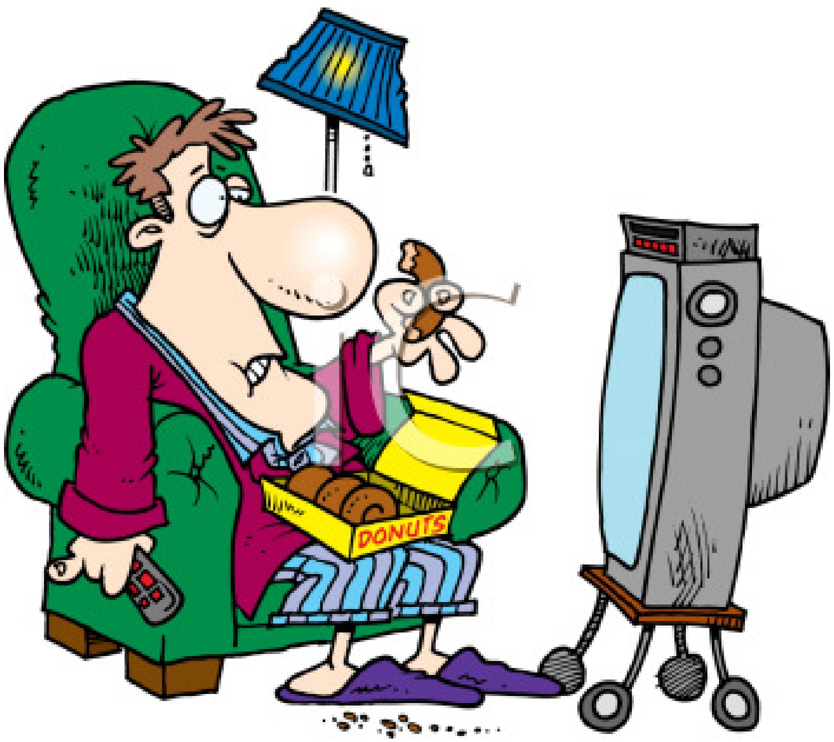
Minutes of TV per Day …

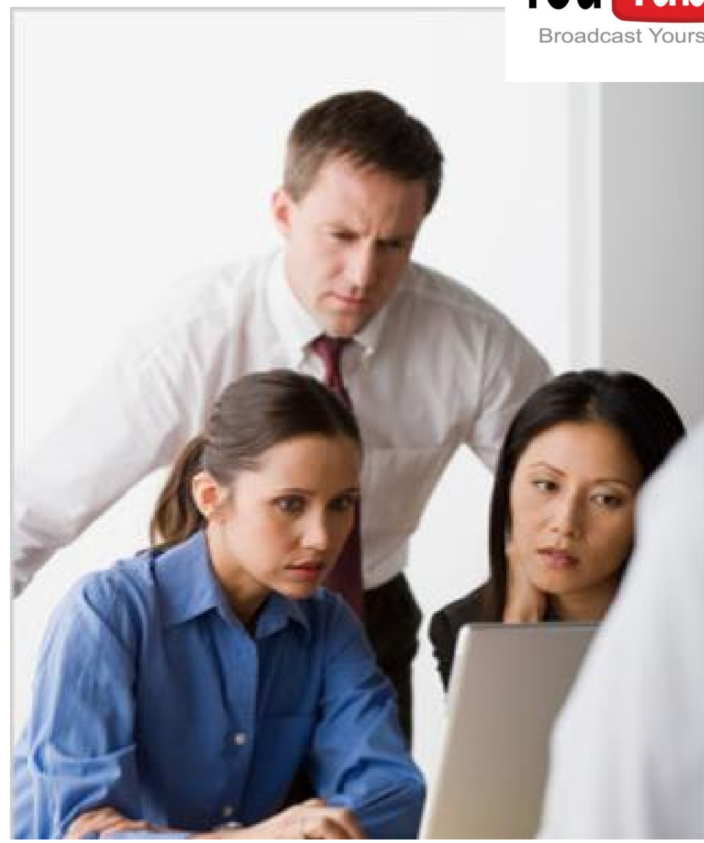




Year 2000

Lean Backward versus Lean Forward





History of Television: First Phase

- 1925 - John Baird shows the possibility to transmit shapes of simple objects.
- 1926 - John Baird shows the first monochrome TV system.
- 1928 - John Baird shows the first colour TV system.
- 1929 - Bell Labs show the first colour TV system where colours are transmitted in parallel.
- 1936 – Olympic Games in Berlin – First TV transmission with great power.
- 1937 – France, UK, Germany and USA start regular services of monochrome TV (low definition).
- 1941 – FCC (USA) standardizes the monochrome TV system with 525 lines.
- 1951 - CCIR does not reach agreement on a single standard for monochrome TV systems.
- 1951/52 – Starts in Europe the monochrome TV system with 625 lines.
- 1953 - FCC (USA) standardizes the NTSC TV colour system.
- March 1957 – Starting in Portugal of monochrome TV regular transmissions.
- 1957 – Crowning of Queen Elisabeth II – First European direct transmission.
- 1960 – In Germany, appears the PAL TV colour system.
- 1960 – In France, appears the SECAM TV colour system.
- 1964 – Olympic Games in Tokyo – First satellite direct transmission of monochrome TV.

History of Television: Second Phase

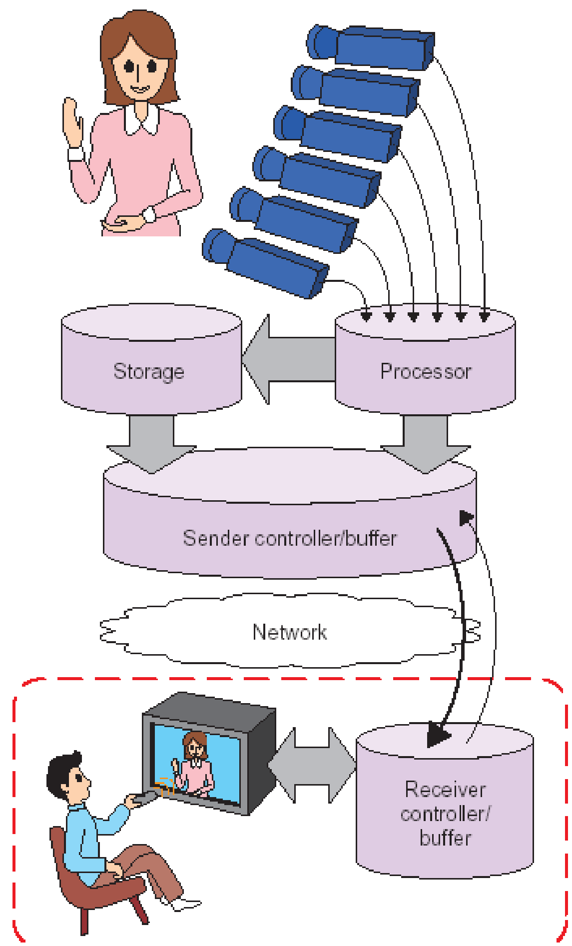
- 1970 – Start in Japan the studies towards high definition TV.
- 1977 – Allocation by WARC of 27 MHz channels for satellite TV.
- March 1980 – Starting in Portugal of colour TV (PAL) regular transmissions.
- 1981 – First public demonstration of the Japanese high definition TV system - MUSE.
- 1983 – Specification in Europe of the MAC system for satellite TV transmissions.
- 1985 – Europe decides to develop its own high definition TV system (HD-MAC) in reaction to the Japanese system (MUSE).
- 1986 – First MUSE prototype for the MUSE high definition TV system.
- 1988 – Olympic Games in Seoul – Direct satellite transmission with the MUSE system.
- 1989 – Starting in Japan of high definition (MUSE) regular transmissions.
- 1990 – Football World Cup in Italy – First demonstration of the European high definition system (HD-MAC).
- 1992- Olympic Games in Barcelona – Large scale demonstration of the HD-MAC system.
- 1993 – USA select the first TV system fully digital.
- 1993 – Digital TV gains supporters … digital TV technology develops very quickly …
- 1993 - MPEG-2 standard is finished.
- 1998 - DVB develops technical specifications complementing the MPEG-2 standard for a full digital TV chain.
- 200X –TV digital grows in many forms, cable, cupper wires (ADSL), IPTV, DVB-H, …

Classification of Television Systems

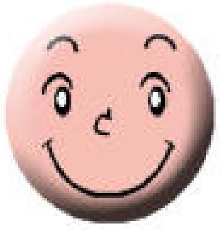
✶ **Type of information**
- Black and white (Y)
- Colour (YUV)
- Stereo (2 × YUV)
- Multiview (N × YUV)

✶ **Image definition**
- Low definition, < 300-400 lines/image
- Medium definition, ≈ 500-600 lines/image
- High definition, > 1000 lines/image

✶ **Transmission**
- Radio (terrestrial)
- Cable
- Satellite
- Telephone line (XDSL)
- Mobile (UMTS)



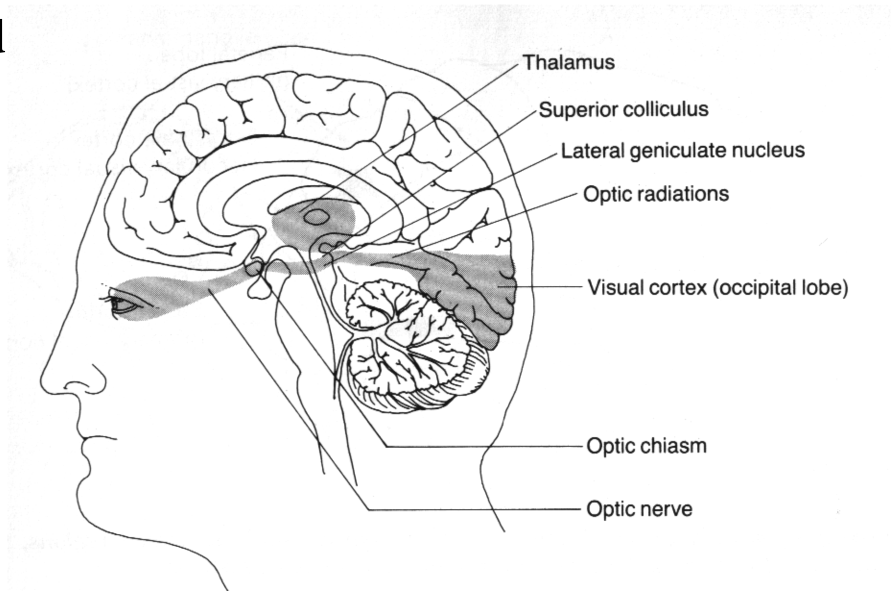
We, the Users …



It is important to remind that audiovisual communication services must, above everything, satisfy the final user needs !

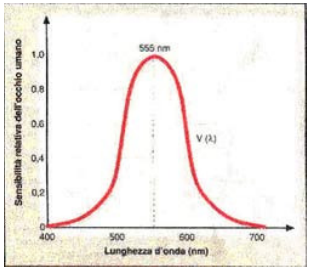
It is essential to take into account the characteristics of the Human Visual and Auditory Systems, notably for video data:

- The limited capacity to see spatial detail
- The conditions under which it reaches the ‘illusion of motion’
- The lower sensibility to color in comparison with luminance/brightness



MONOCHROME TELEVISION

What do we See in TV ? … Luminance



- The luminous flux radiated by a luminous source with a power spectrum $G(\lambda)$ is given by:

$$\Phi = k \int G(\lambda)\, y(\lambda)\, d\lambda \quad \text{[lm or lumen]} \quad \text{with } k = 680 \text{ lm/W}$$

where $y(\lambda)$ is the average sensibility function of the human eye

- The way the radiated power is distributed by the various directions is given by the luminous intensity:

$$J_L = d\Phi / d\Omega \quad \text{[lm/sr or vela (cd)]}$$

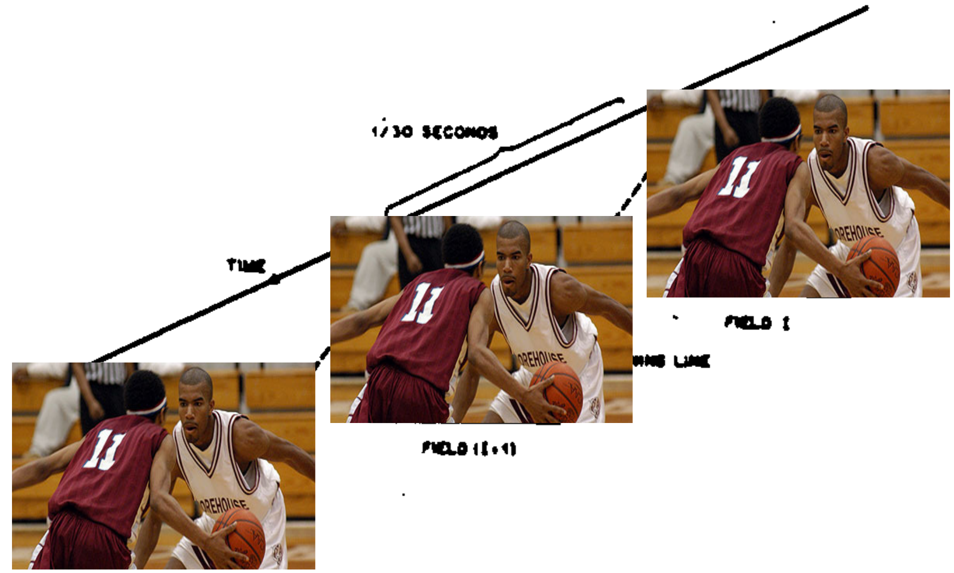
- In television, the relevant quantity is the luminance of a surface element dS when it is observed with an angle θ such that the surface orthogonal to the observation direction is dS_n

$$Y = dJ_L / dS_n \quad [\text{lm/sr/m}^2]$$

which corresponds to the luminous flux, per solid angle, per unit of area.

Illusion of Motion: Temporal Resolution

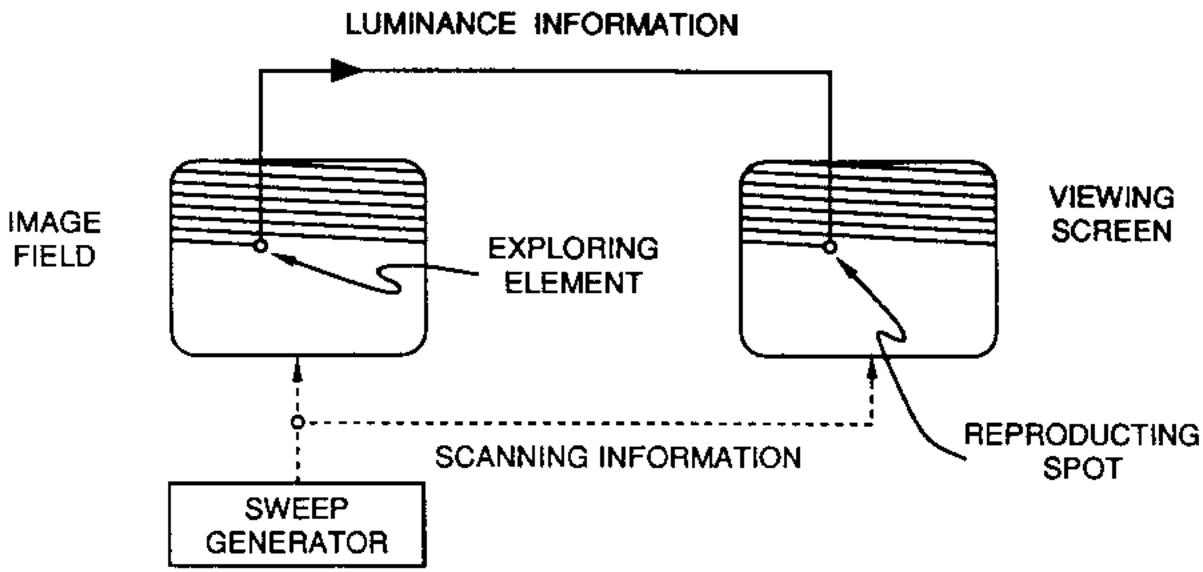
- Visual information corresponds to a time varying 3D signal which has to be transformed into a time varying 1D signal to be transmitted using the available channels.
- At the reception, the information is visualized in a 2D space resulting from the projection (during acquisition) into the camera plane.
- The 2D signal is sampled in time at a rate that guarantees the illusion of motion; this illusion improves with the image rate.



Experience shows that it is possible to get a good illusion of motion up from 16-18 image/s, depending on the image content.

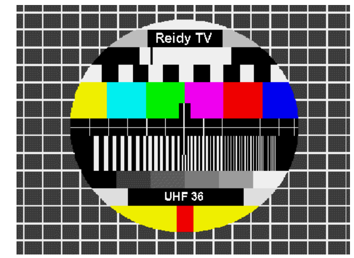
For CRT TV, the frame rate is 25 Hz (Europe) and 30 Hz (US and Japan) due to the electromagnetic interference with the electric network at 50/60 Hz.

From 2D to 1D: the Scanning Process



- The transformation of the 2D signal in the camera plan into a 1D signal to be transmitted is made through a line scanning process of the image, from top to bottom and left to right (such as when reading a book).
- The scanning sequence is *a priori* determined and, thus, it is known by the sender and the receiver.
- Initially, as there were no memory capabilities available, the acquisition, transmission and visualization processes were practically simultaneous.

Visual Acuity versus Number of Lines



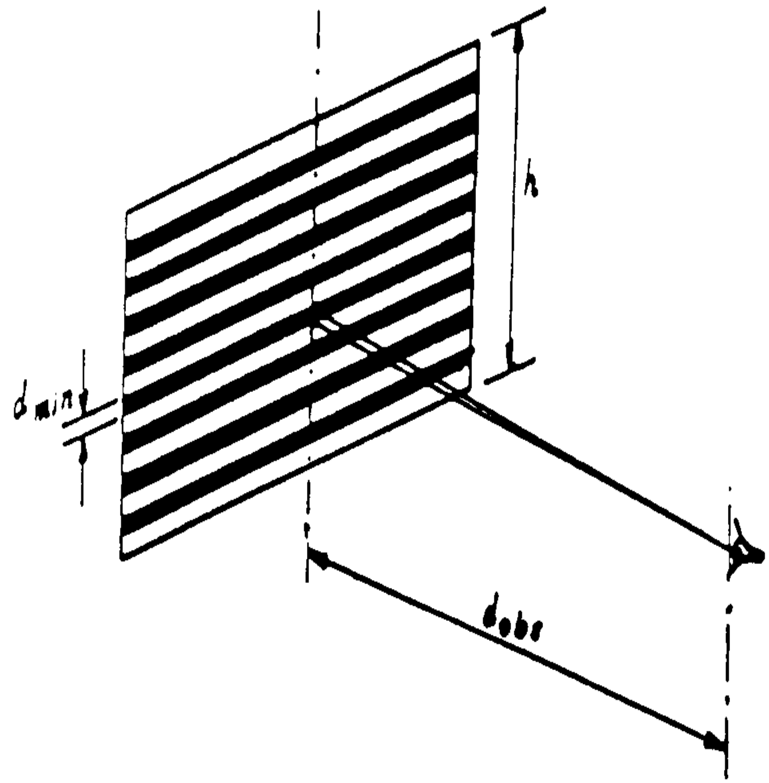
- Visual acuity regards the eye capability of distinguishing (resolving) spatial detail; it is measured with the help of special images called *Foucault bars images*.

- The visual acuity determines the minimum number of lines in the image in order the user located at a certain distance does not 'see' the lines and gains the sensation of spatial continuity.

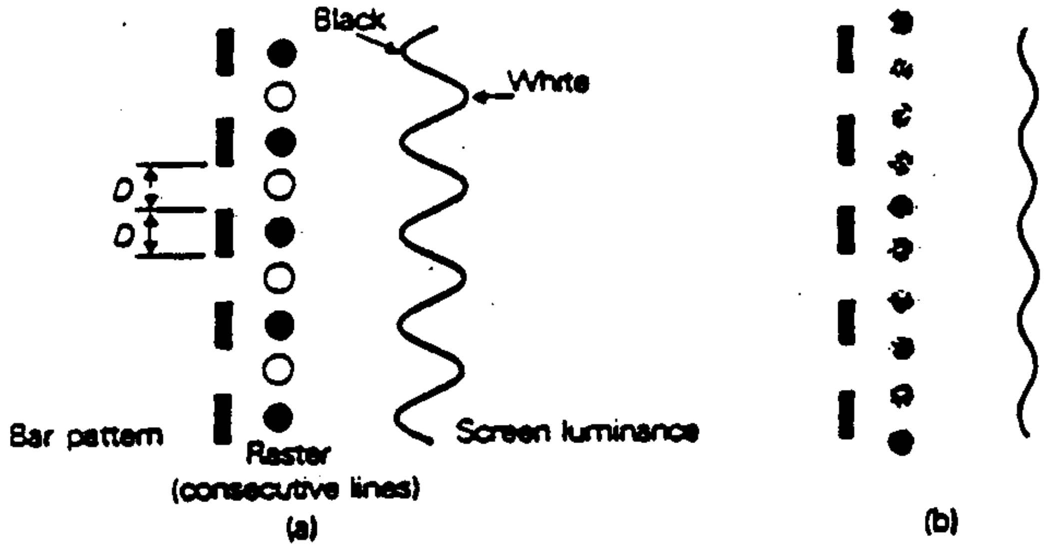
- The maximum number of lines that the Human Visual System manages to distinguish in a Foucault bars image is given by

$$N_{max} \sim 3400\ h\ /\ d_{obs}$$

for $d_{obs}/h \sim 8$, $N_{max} \sim 425$ lines.



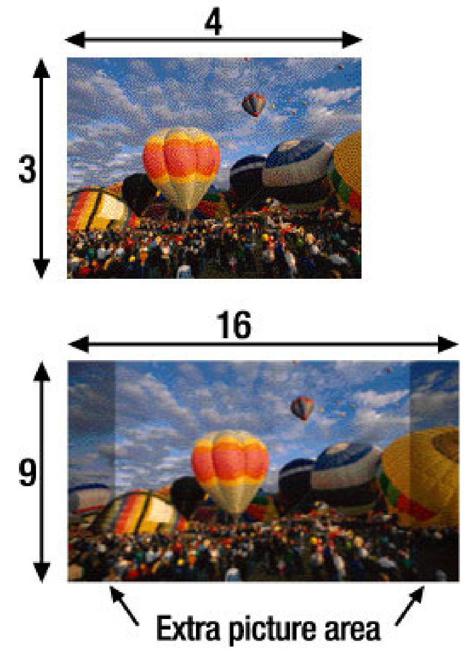
The Kell Factor: Why and Impact …



The phenomena associated to the Kell factor only happens for the vertical direction because this is where the visual information is discretized.

- Kell factor is a parameter used to determine the effective resolution of a discrete display device.
- If a horizontal line in a Foucault bars image were to fall exactly between two adjacent scan lines, it would not show well.
- The empirically determined relationship between the number of visually resolvable lines and the number of scan lines is called the Kell factor and is about 0.7.
- This means the number of scan lines must be $(N_{max} / 0.7) \sim (3400\ h / d_{obs} / 0.7) \sim 600$

The 2D Image …



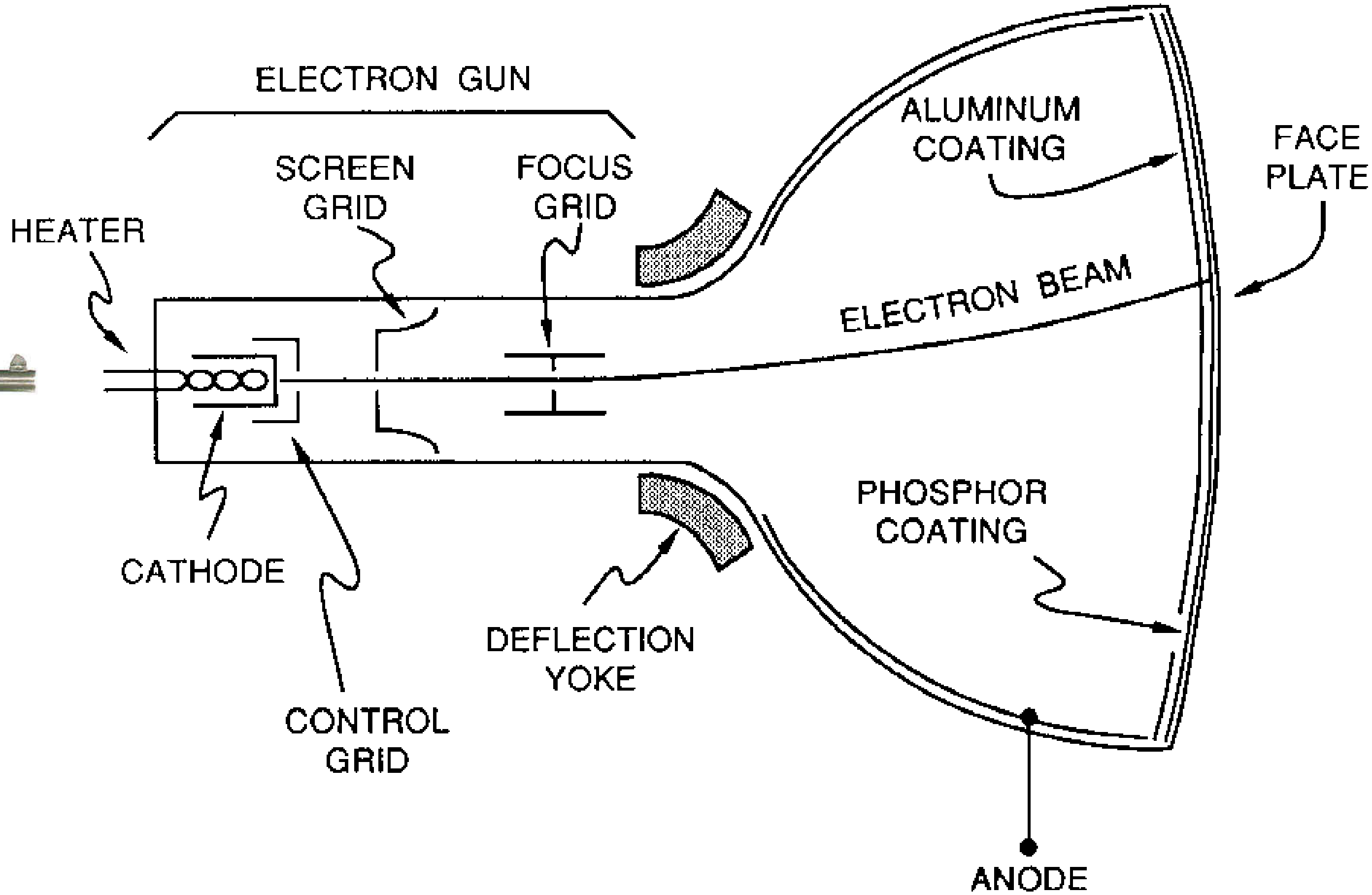
The 2D image is characterized by:

- ✶ **Number of lines/image** – Depends on the visual acuity and the Kell factor.
- ✶ **Aspect ratio** – To give the user a more intense sensation of involvement, the image is longer in the horizontal direction since this is the 'format' of our eyes and most real life action is performed along the horizontal axis (4/3 ⇒ 16/9)
- ✶ **Number of image elements/line** – For equal vertical and horizontal pixel densities, it depends on the number of lines/image and the aspect ratio.

Cathodic Ray Tubes (CRT): the First Displays

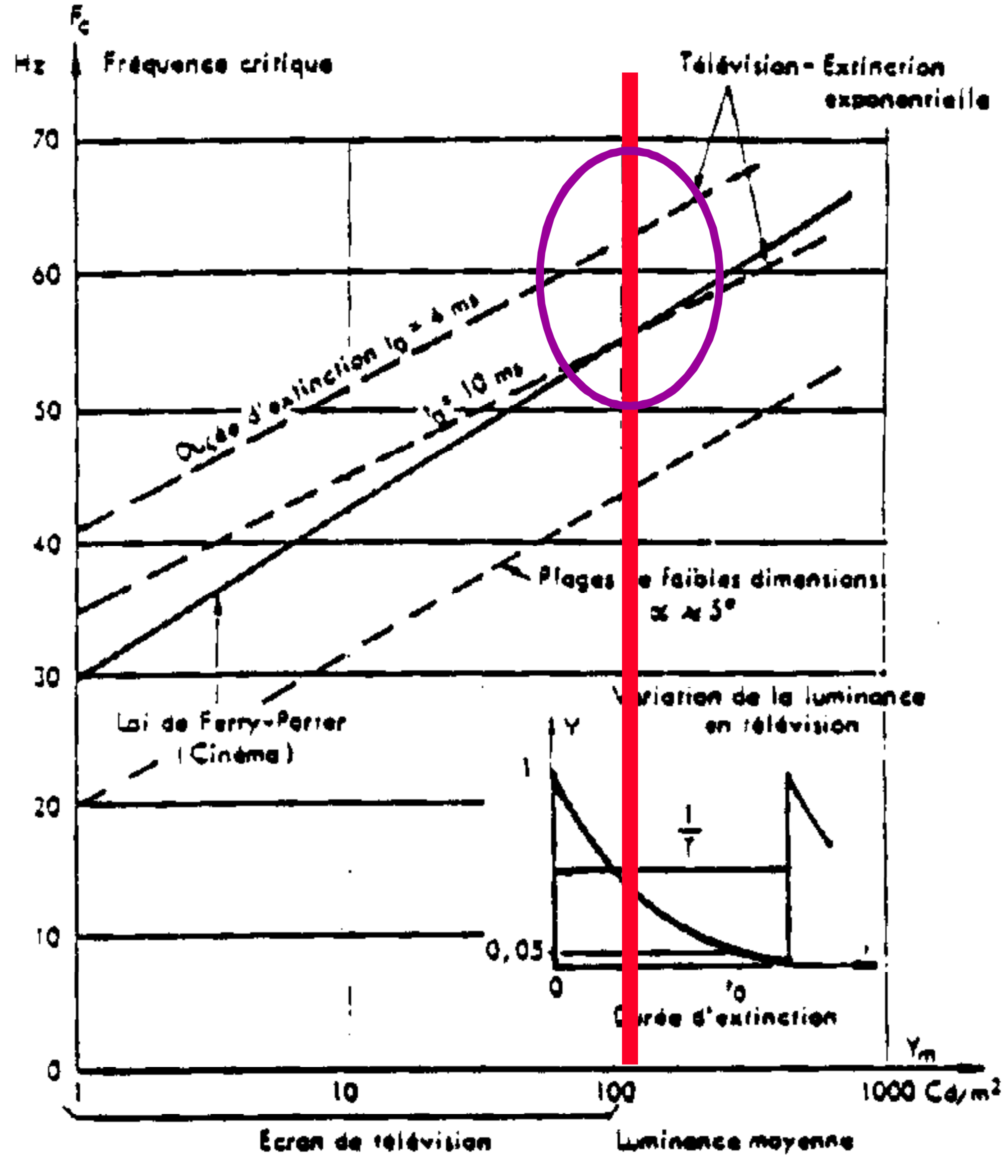
- **The cathode ray tube (CRT) is a vacuum tube containing an electron gun (a source of electrons) and a fluorescent screen, with internal or external means to accelerate and deflect the electron beam, used to create images in the form of light emitted from the fluorescent screen.**
- **The image may represent electrical waveforms (oscilloscope), pictures (television, computer monitor), radar targets and others.**
- **The CRT uses an evacuated glass envelope which is large, deep, heavy, and relatively fragile.**

Image Synthesis in a Cathodic Ray Tube (CRT)

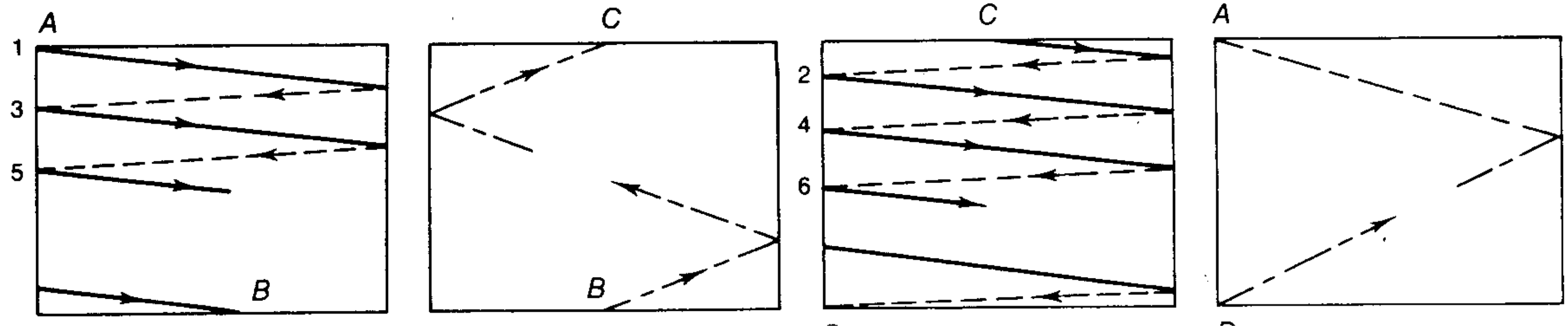


Flicker

- Flicker mandates the use of a image rate significantly higher than the rate necessary for the illusion of motion.
- For Cathode Ray Tubes (CRTs), the luminance variation in time is exponentially decreasing, with time constants between 3 and 5 ms.



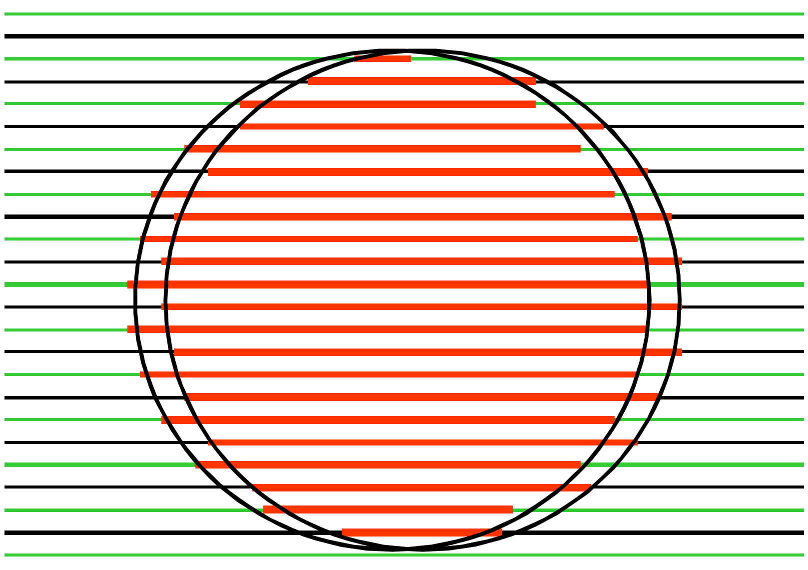
Against Flicker, Interlacing …



- In order to have each zone of the image enough refreshed, each image is represented as 2 fields (this means two half-images): <u>one with the odd and another with the even lines.</u>

- Interlacing resolves the flicker problem avoiding to increase the signal bandwidth by simply doubling the number of images/second.

1 frame **2 fields**



field 1
+
field 2
=
complete frame

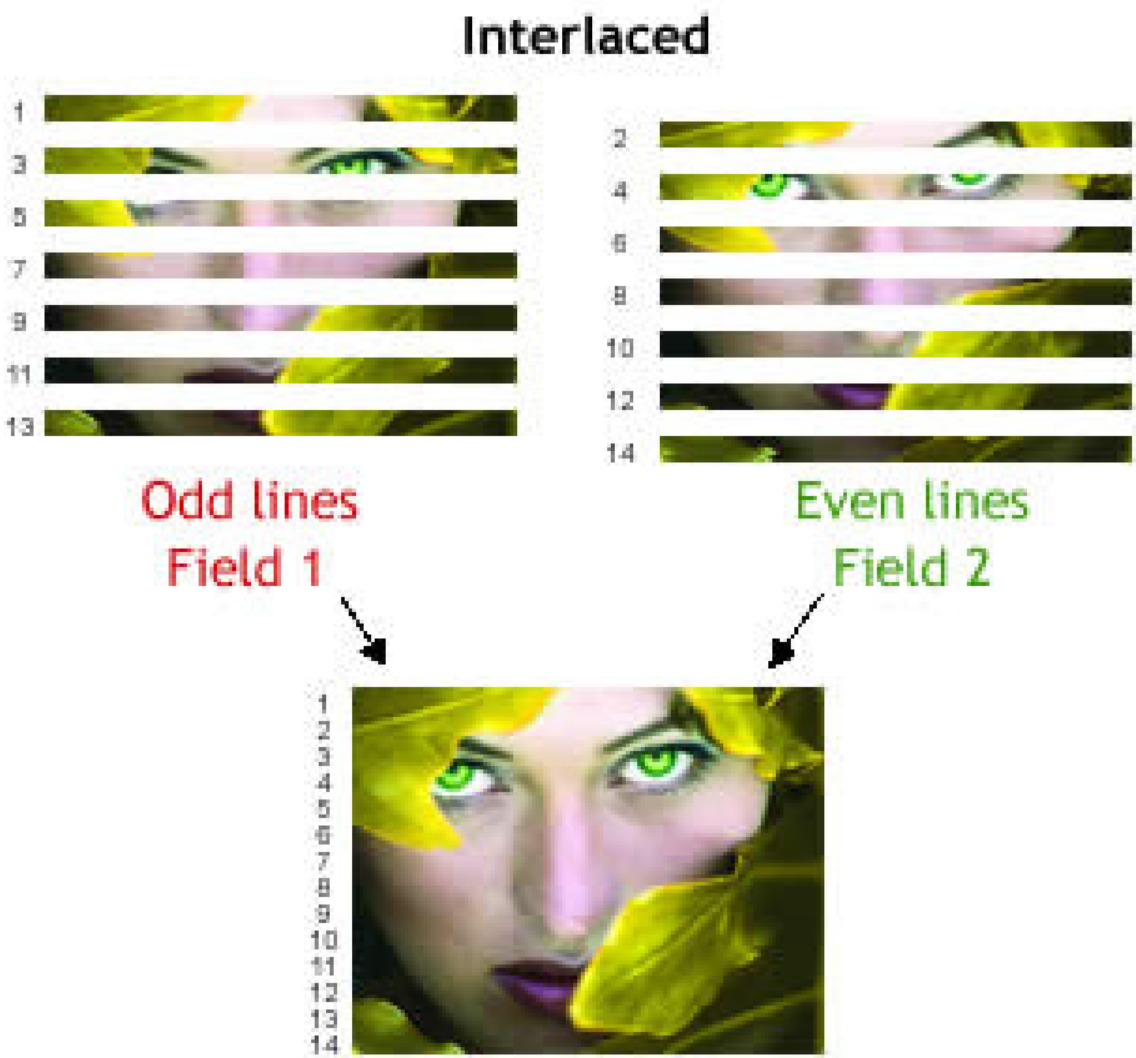
25 images/s ⇒ 50 fields/s

Nº images/s does not change !

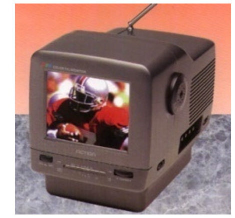
Nº lines /image does not change !

Bandwidth does not change !

Frames and Fields …



Gamma Correction

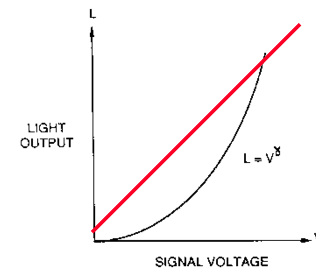


The gamma correction is introduced to compensate the fact that cameras and CRTs are non-linear devices.

- **Being Y_{orig} the luminance of the original scene, the camera produces a luminance signal Y_c**

$$Y_c = K_1 \, Y_{orig}^{\gamma 1} \qquad (\gamma_1 \sim 0.3 - 1)$$

- **At the receiving CRT, the luminance as a similar variation**



$$Y_{trc} = K_2 \, Y_c^{\gamma 2} \; (\gamma_2 \sim 2 - 3)$$

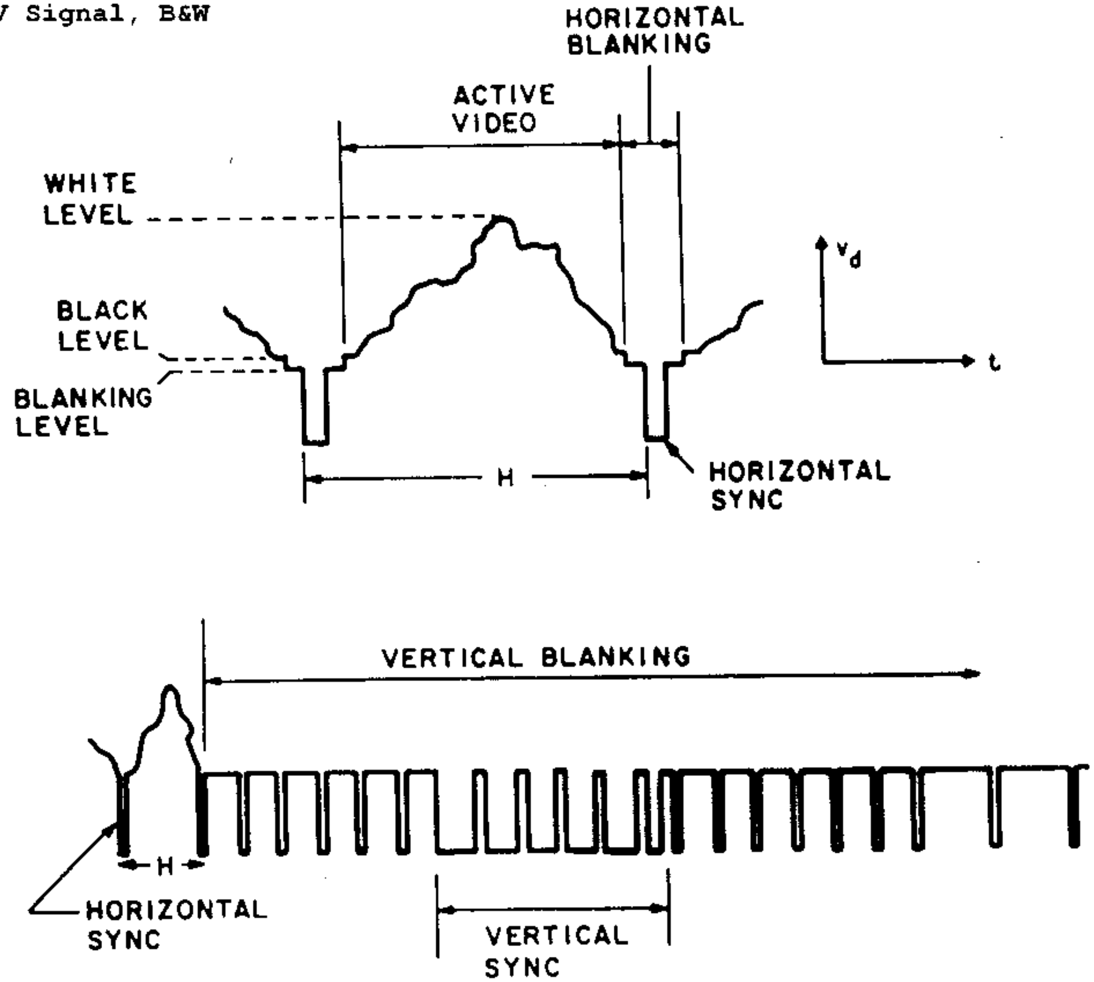
this means the original and the reproduced luminances relate as

$$Y_{trc} = K_2 \, K_1^{\gamma 2} \, Y_{orig}^{\gamma 1 \gamma 2}$$

- **To obtain a total gama ($\gamma_1 \gamma_2$) between 1 and 1.3, a non-linear device is introduced at the camera output which makes the gama correction with $\gamma_1 \gamma_2 \gamma_{cor} \sim 1.3$.**

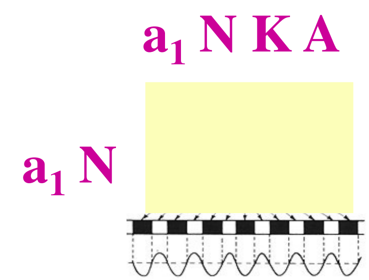
Composite Video Signal in Time …

TV Signal, B&W



Due to equipment limitations, there was a need to take a certain amount of time between the end of a line and the starting of the next line as well as the end of a field and the starting of the next field – called horizontal and vertical retraces – which may be useful, e.g. for teletext …

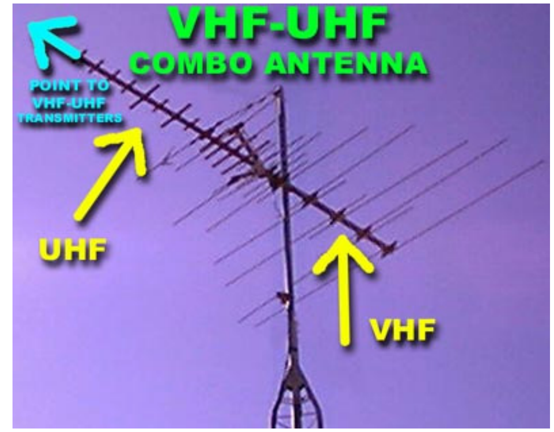
Video Signal Bandwidth …



Assuming that similar vertical and horizontal image elements densities are desired $a_1 \sim 0.92$ and $a_2 \sim 0.8$) :

- ✶ Number of vertical scan image elements: $N_v = a_1 N$
- ✶ Number of vertical resolvable image elements: $N_r = a_1 N K$
- ✶ Nº of horizontal image elements (for same density): $N_h = a_1 N K A$
- ✶ Number of image elements in the image: $N_v N_h = a_1^2 N^2 K A$
- ✶ Frequency of image elements (line): $f_{ele} = a_1 N K A / (a_2 / N F)$
- ✶ Frequency of image elements (image): $f_{ele} = a_1^2 N^2 K A / (a_1 a_2 / F)$
- ✶ Maximum frequency present in the video signal: $f_{max} = a_1 N^2 F K A / 2 a_2$
- ✶ Video bandwidth: $LB \sim f_{max} = a_1 N^2 FKA / 2 a_2$

Terrestrial TV: VHF and UHF Bands



VHF

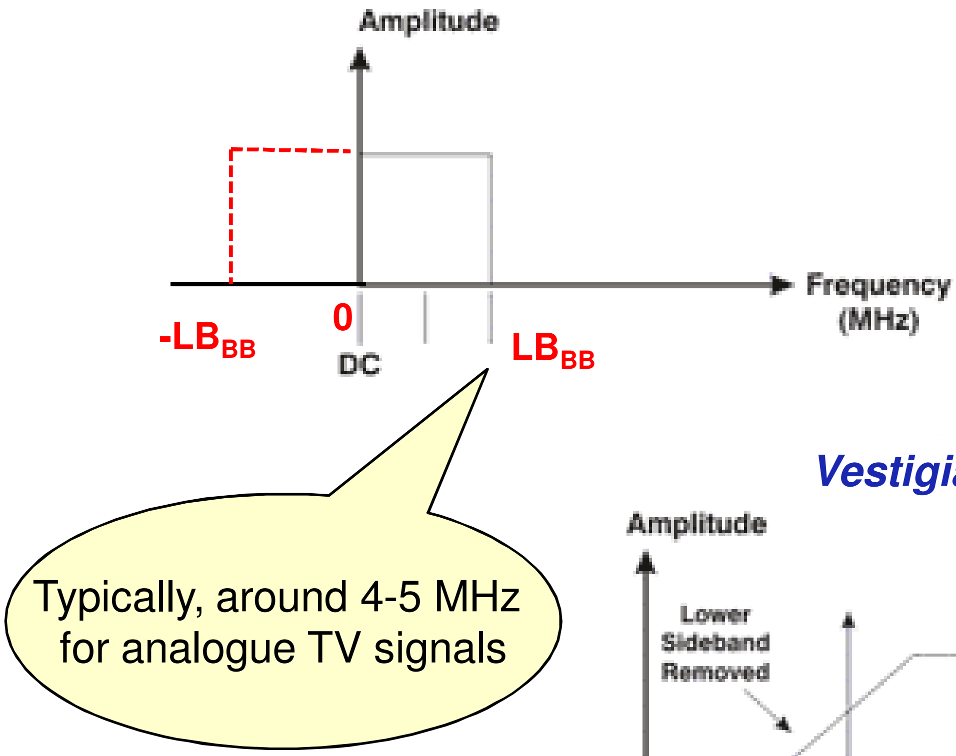
- VHF is the acronym for ***Very High Frequency***.
- It refers to the radio frequencies from 30 MHz to 300 MHz. This bandwidth range is commonly used for radio and TV transmissions.

UHF

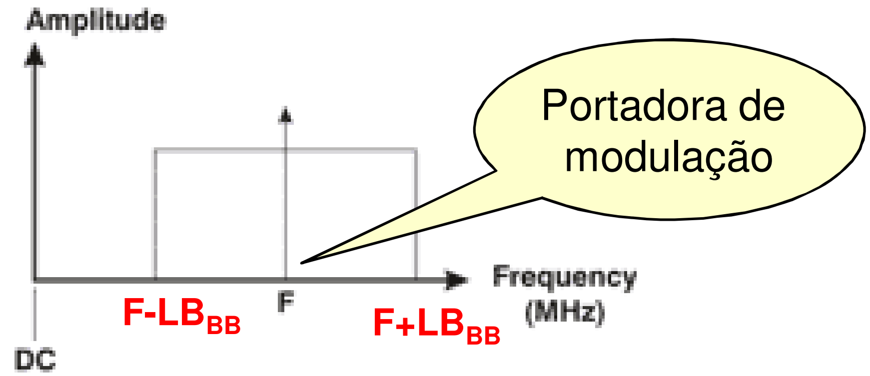
- UHF is the acronym for ***Ultra High Frequency***.
- It refers to the radio frequencies from 300 MHz to 3 GHz. This bandwidth range is commonly used for radio and TV transmissions.
- Electromagentic waves in this band have higher atmosferic attenuation and lower ionosphere reflection than VHF waves.

Amplitude Modulation…

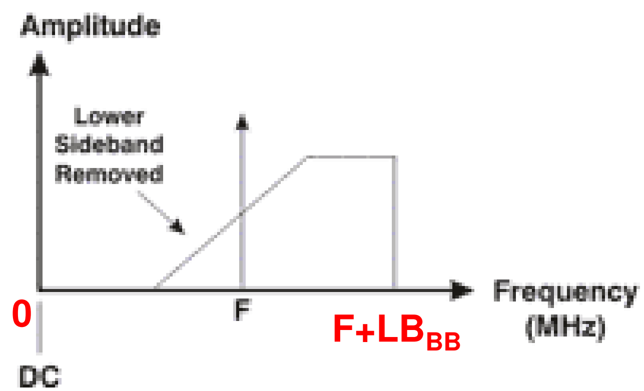
Baseband



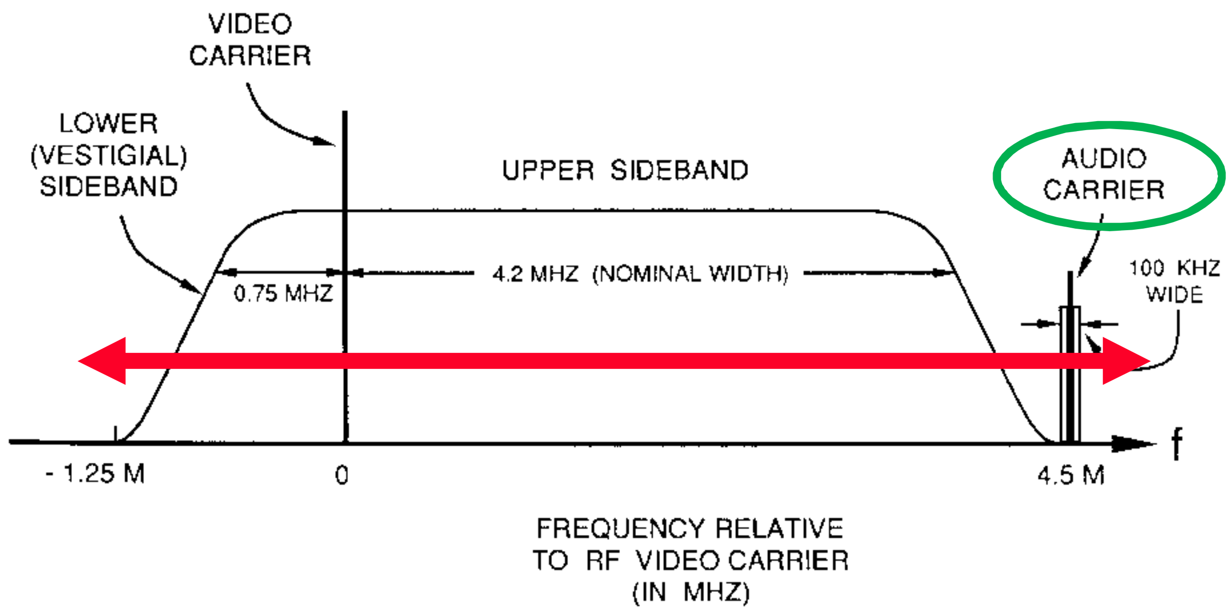
***Double Side Band* (DSB)**



***Vestigial Side Band* (VSB) = DSB+filter**

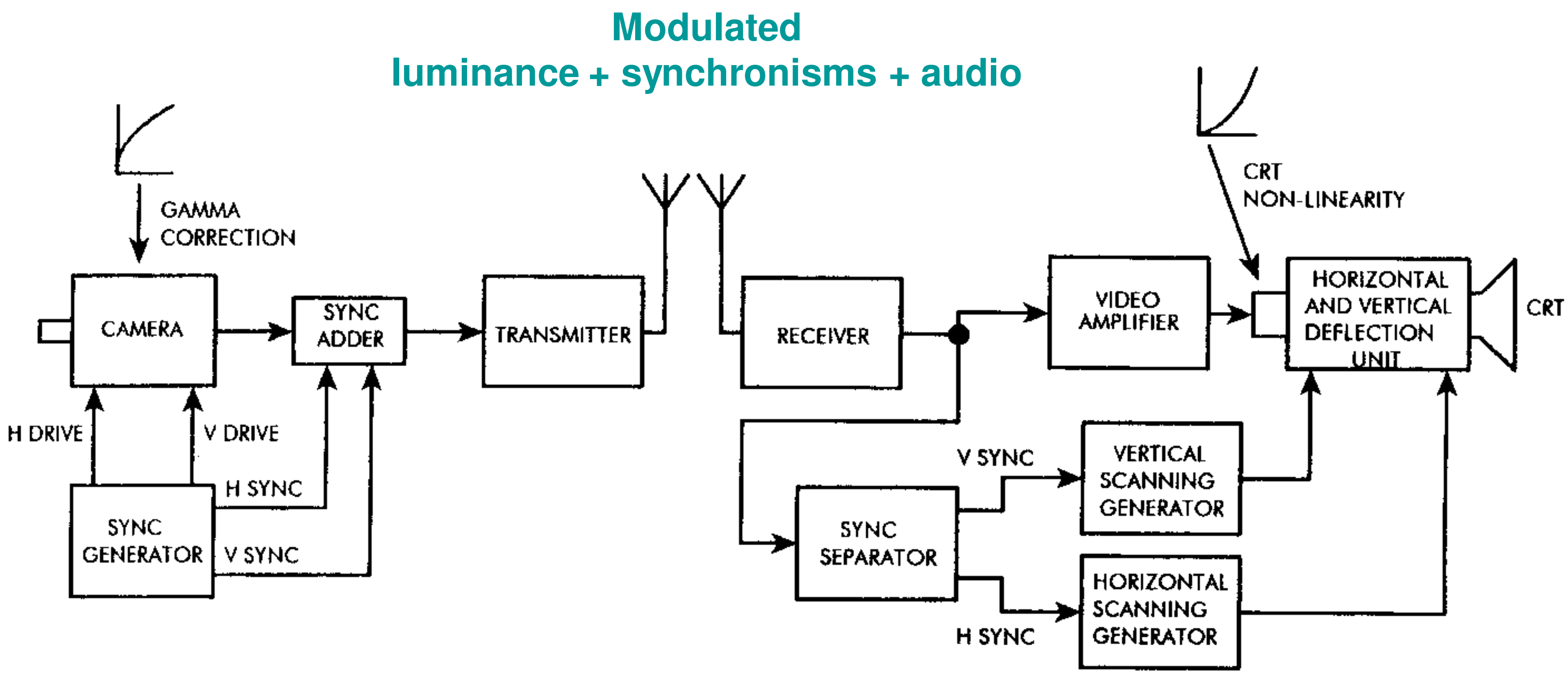


TV Signal in Modulated Frequency …



- The modulation selected for the luminance is *Vestigial Side Band* (VSB) since it is spectrally rather efficient (lower bandwidth) and allows to use relatively simple demodulating systems.
- The VBS signal is obtained at the sender from the Double Side Band (DSB) signal using adequate vestigial filtering.
- The audio signal is treated separately and modulated in a different carrier, using amplitude or frequency modulation (typically FM).

Monochrome TV System



COLOUR

TELEVISION

About TV Compatibilities

Colour TV is another natural development in the emulation of human capabilities by Telecommunications.

Colour TV takes benefit of technological developments and must guarantee compatibility without using more bandwidth than black and white TV.

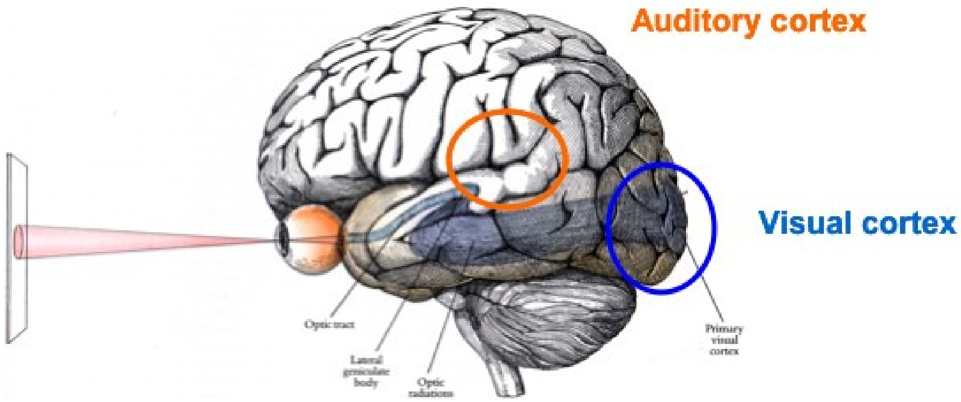
- **BACKWARD COMPATIBILITY (directa) – <u>A colour TV emission must be able to be received by a black and white TV receiver (of course, in black and white).</u>**
- **FORWARD COMPATIBILITY (inversa) – A colour TV receiver must be able to receive (in black and white) a black and white emission.**

Human Visual System: Rods and Cones

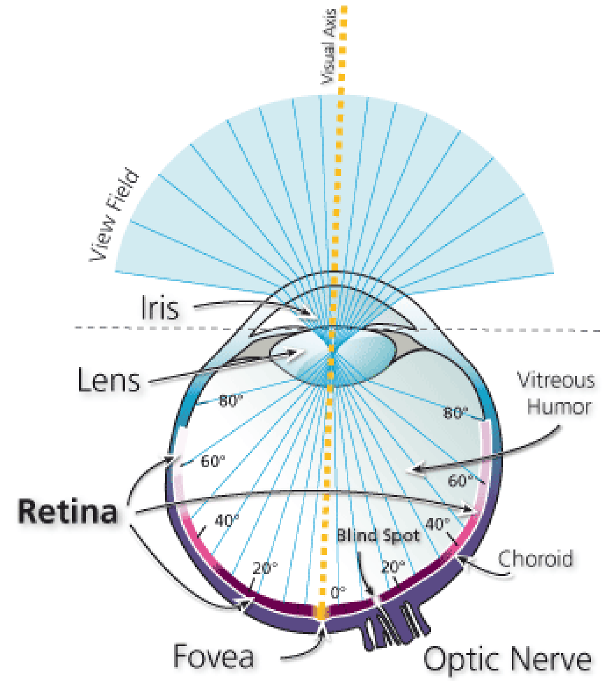
- Rod cells, or rods (bastonetes), are photoreceptor cells in the retina of the eye that can function in less intense light than can the other type of photoreceptor, the cone cells. Named for their cylindrical shape, rods are concentrated at the outer edges of the retina and are used in peripheral vision. There are about 90 million rod cells in the human retina. More sensitive than cone cells (100 times more), rod cells are sensitive to luminance and are almost entirely responsible for night vision.

- Cone cells, or cones, are photoreceptor cells in the retina of the eye that function best in relatively bright light. The cone cells gradually become sparser towards the periphery of the retina (there are about 4-6 million in the human eye). Cones are less sensitive to light than the rod cells in the retina (which support vision at low light levels), but allow the perception of color. They are also able to perceive finer detail and more rapid changes in images, because their response times to stimuli are faster than those of rods.

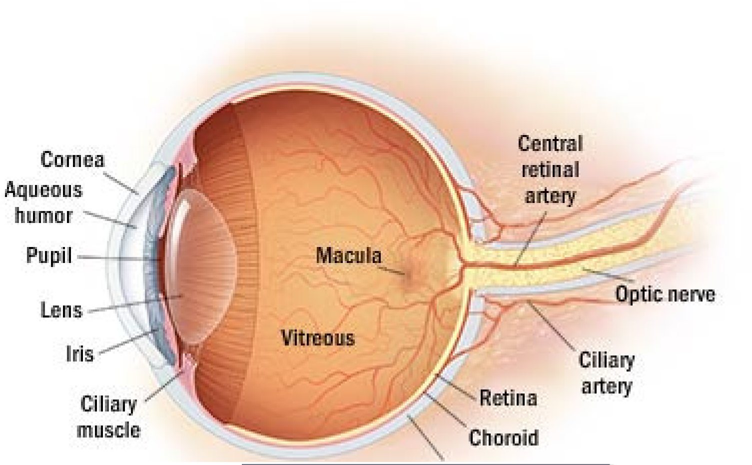
- Because humans usually have three kinds of cones with different response curves and, thus, respond to variation in color in different ways, they have trichromatic vision.



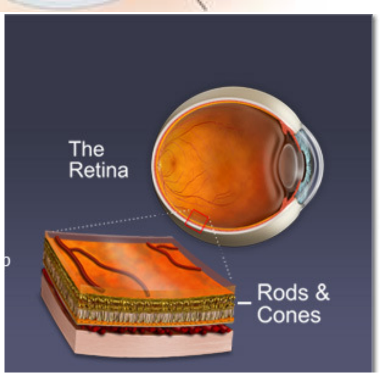
Auditory cortex
Visual cortex
Optic tract
Lateral geniculate body
Optic radiations
Primary visual cortex



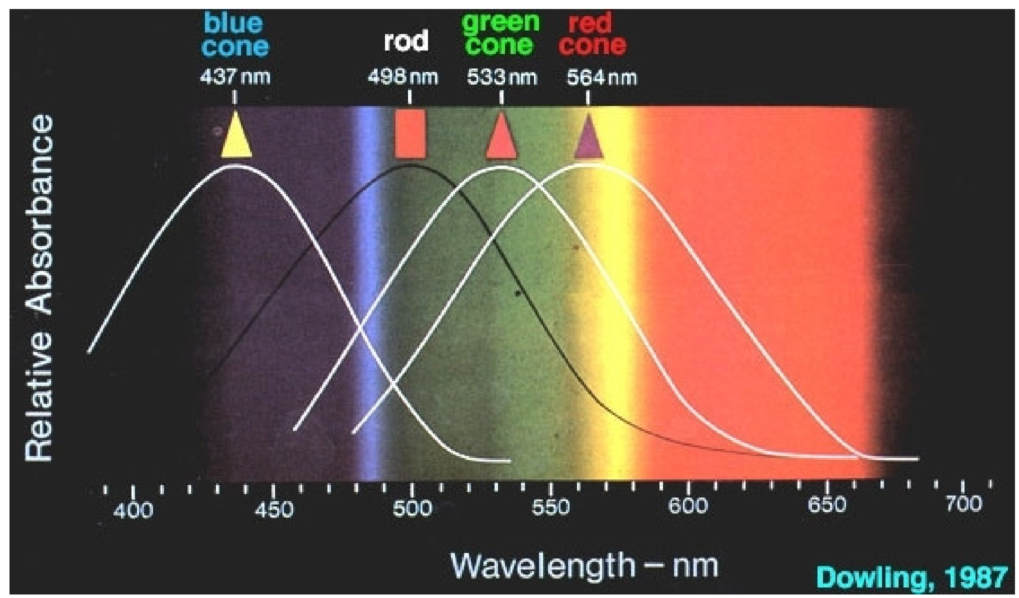
Visual Axis
View Field
Iris
Lens
Vitreous Humor
Retina
Choroid
Blind Spot
80°
60°
40°
20°
0°
Fovea
Optic Nerve



Cornea
Aqueous humor
Pupil
Lens
Iris
Ciliary muscle
Macula
Vitreous
Central retinal artery
Optic nerve
Ciliary artery
Retina
Choroid



The Retina
Rods & Cones



blue cone
437 nm
rod
498 nm
green cone
533 nm
red cone
564 nm
Relative Absorbance
400
450
500
550
600
650
700
Wavelength – nm
Dowling, 1987

A Bit of Colorimetry …

- In additive colour systems, the sum of all colours gives white and the subtraction of all colours gives black.

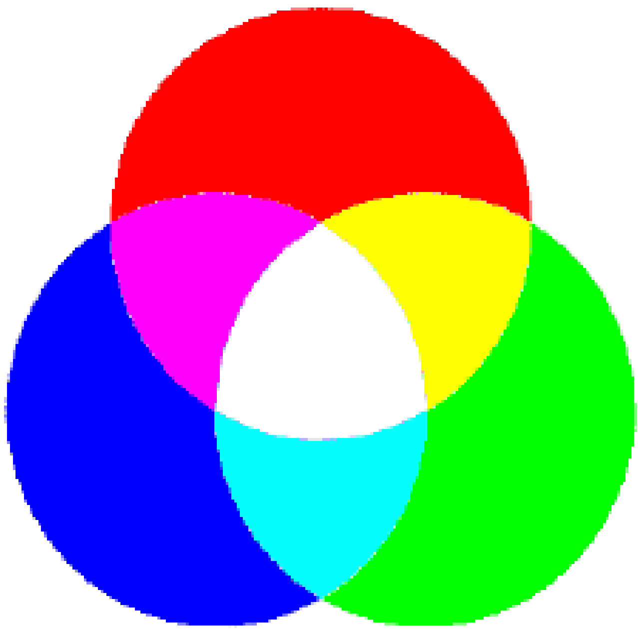
- Colorimetry studies show that it is possible to reproduce a high number of colours through the addition of only 3 primary colours, carefully chosen.

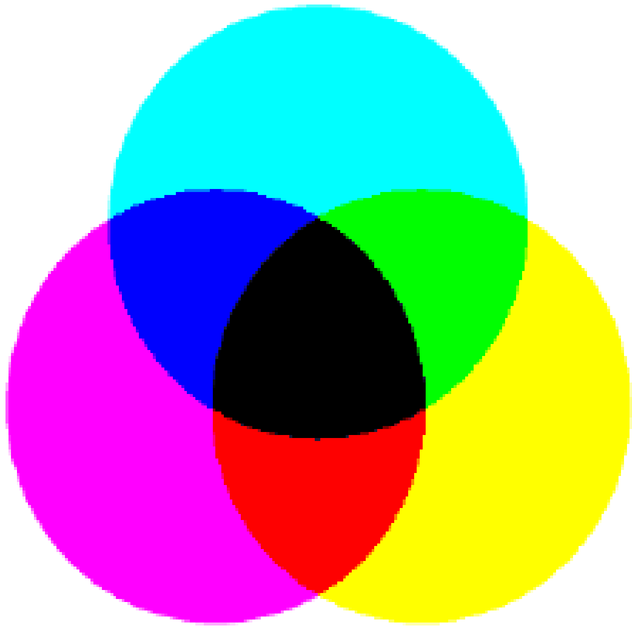
- The <u>primary colours</u> used in television to generate all the other colours are
  - Vermelho (RED)
  - Verde (Green)
  - Azul (Blue)

- Luminance, Y, may be obtained from the primary colours as

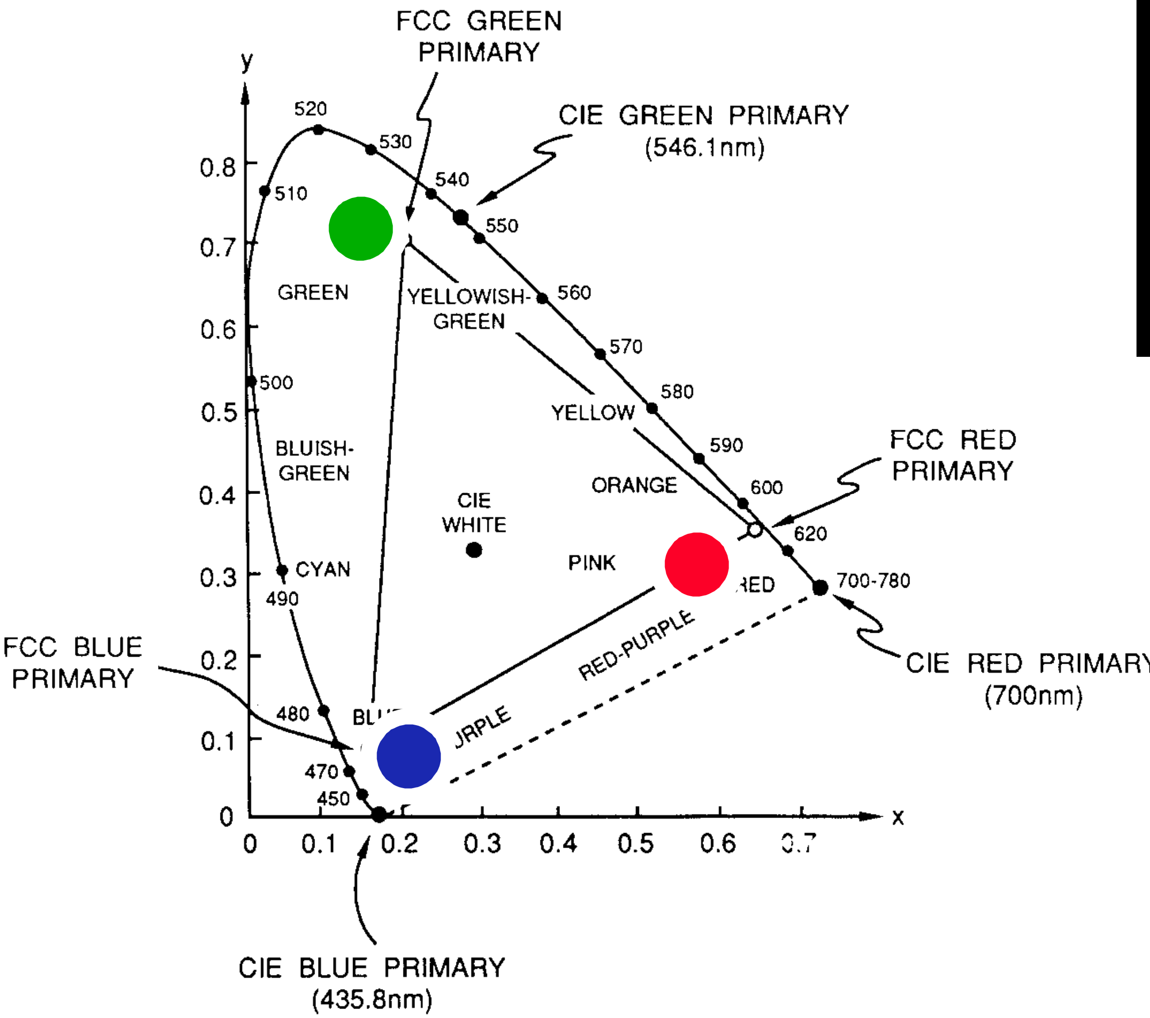
$$Y = 0.3\ R + 0.59\ G + 0.11\ B$$

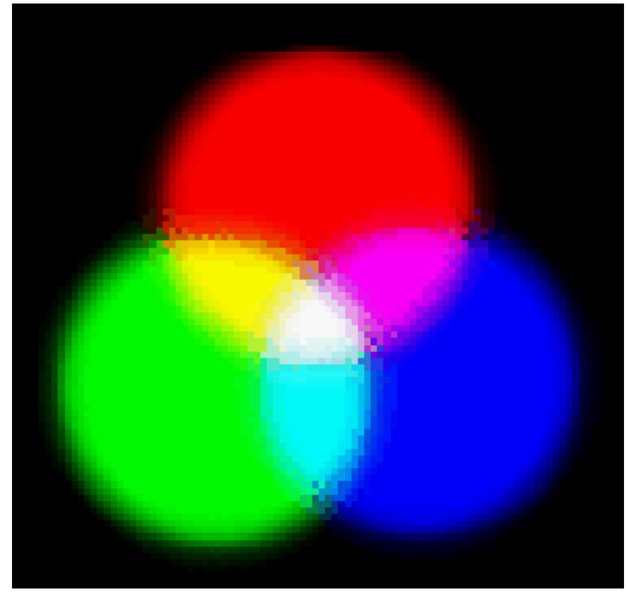
Additive and Subtractive Color Synthesis

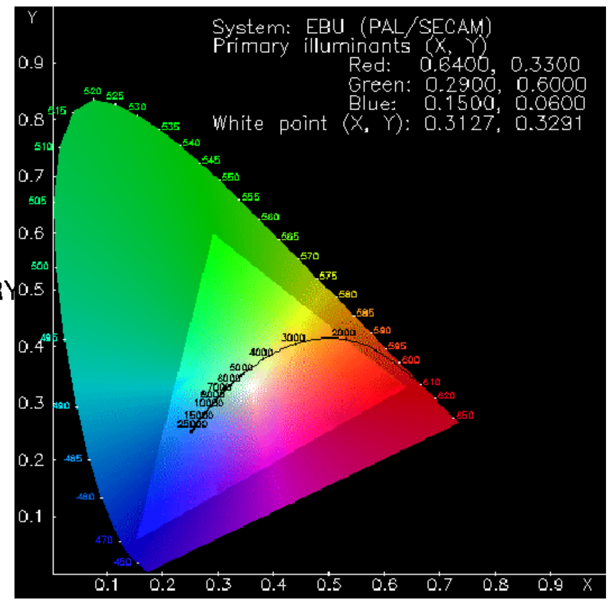


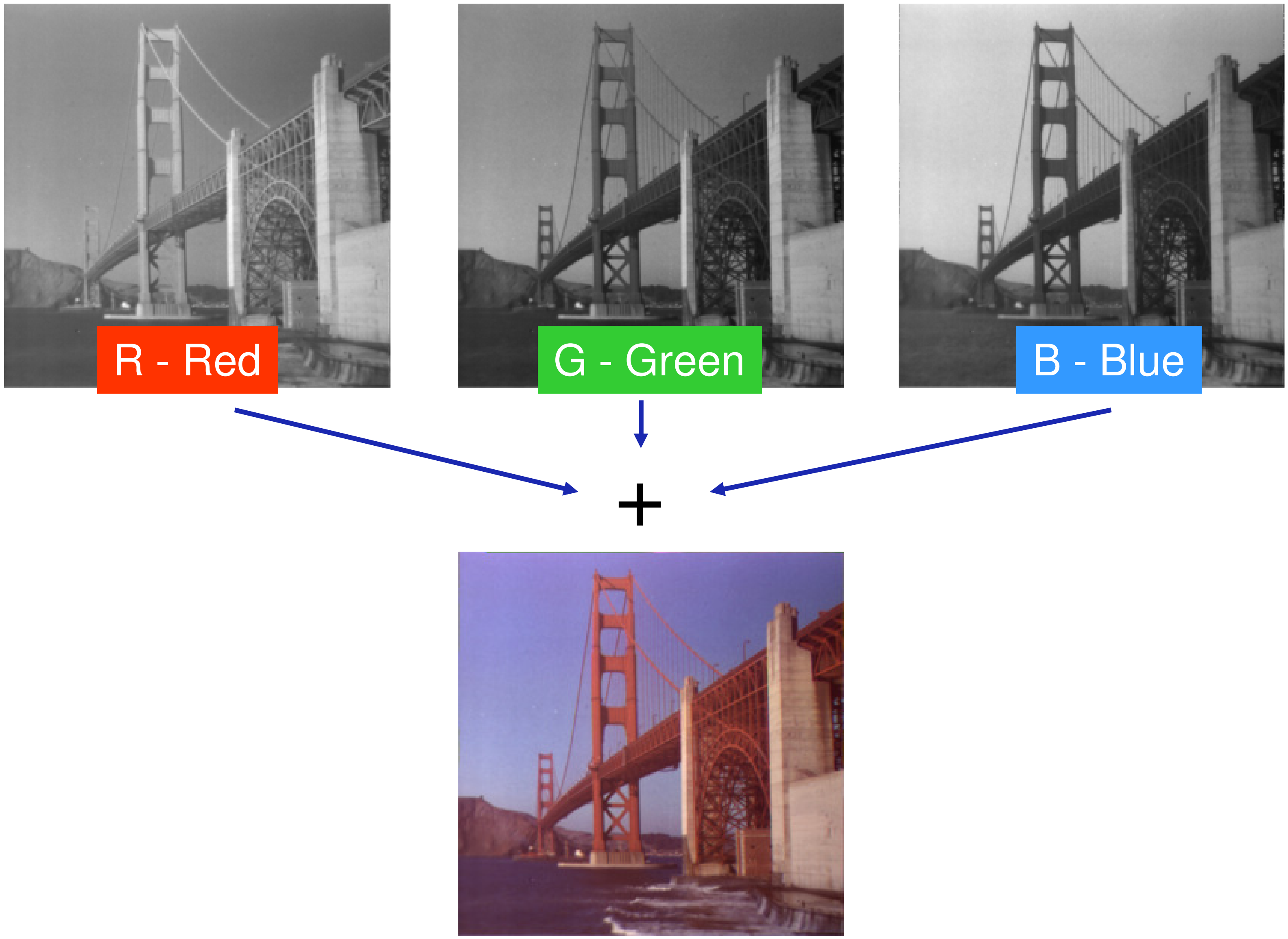


Chromaticity Diagram …





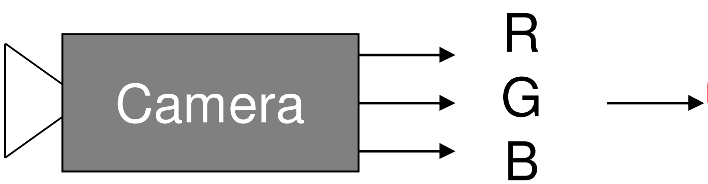



R - Red
G - Green
B - Blue
+

Colour TV: Selecting the Signals …

- **BACKWARD COMPATIBILITY (Y signal):**
  - RGB signals are not selected for colour TV transmission because they cannot guarantee backward compatibility and would ask, at least, in principle, three times the bandwidth of the luminance signal.
  - Backward compatibility mandates the transmission of the luminance signal, Y, which may be obtained from the primary colours as $Y = 0.3R + 0.59G + 0.11B$.
- **ADDING COLOUR (2 signals more):**
  - Colour transmission requires the selection of 2 other signals which together with Y allow to easily recover the RGB signals in colour receivers.
  - These signals must use the smallest possible bandwidth by exploiting the lower human sensibility to colour information.
- **FORWARD COMPATIBILITY (2 chrominance signals, R-Y and B-Y):**
  - The R-Y, B-Y and G-Y CHROMINANCE SIGNALS allow to recover the R,G,B signals in a simple way, provide forward compatibility and need less bandwidth (than R,G,B); R-Y and B-Y are selected because they provide higher SNR.

Luminance and 2 Chrominances ...



$Y = 0.30R + 0.59G + 0.11B$ ~ 5 MHz

$B - Y = U$ ~ 1 MHz

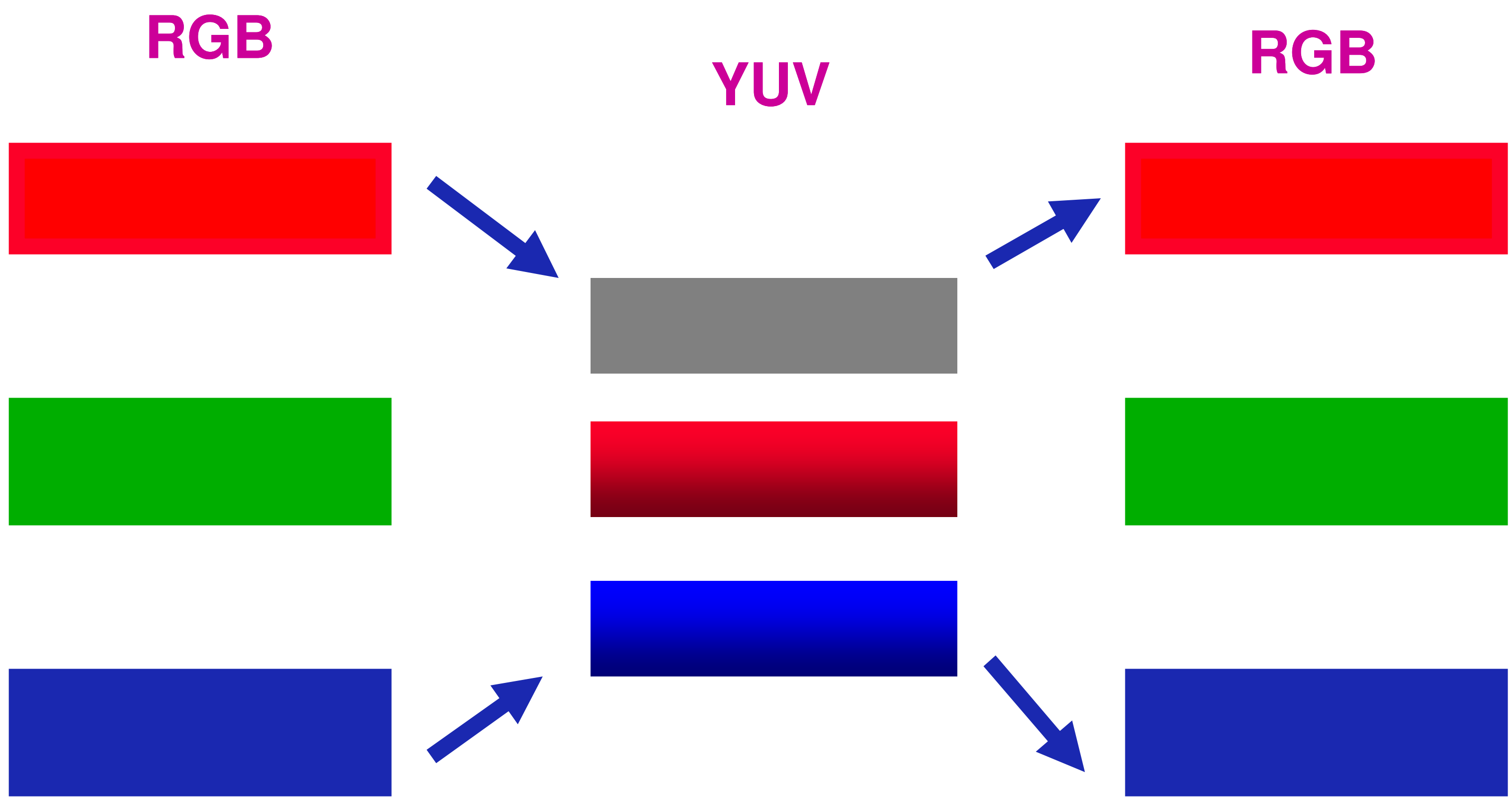
$R - Y = V$ ~ 1 MHz

Y - Luminance

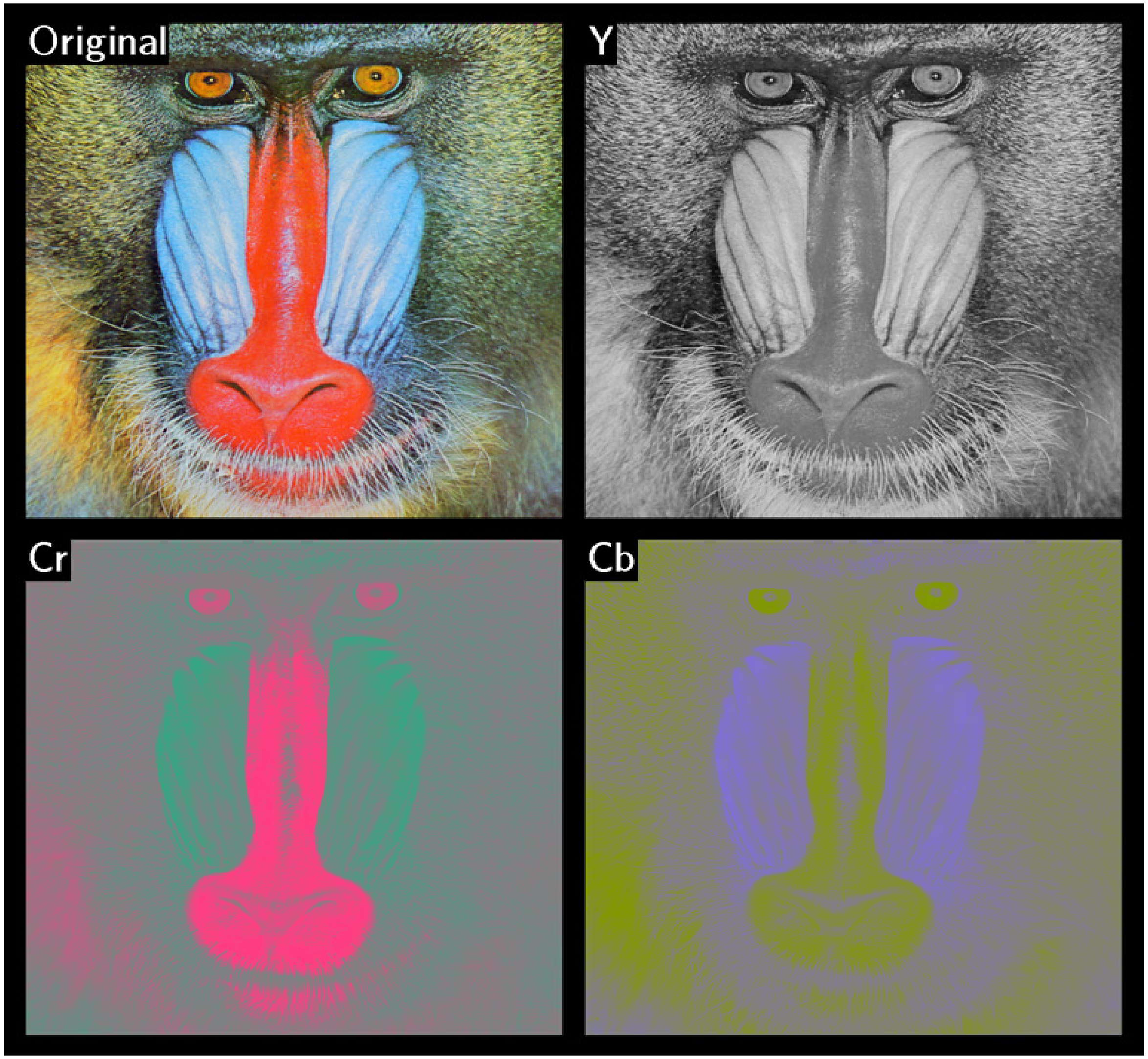
B - Y = U

R - Y = V

Acquisition, Transmission and Synthesis Signals ...



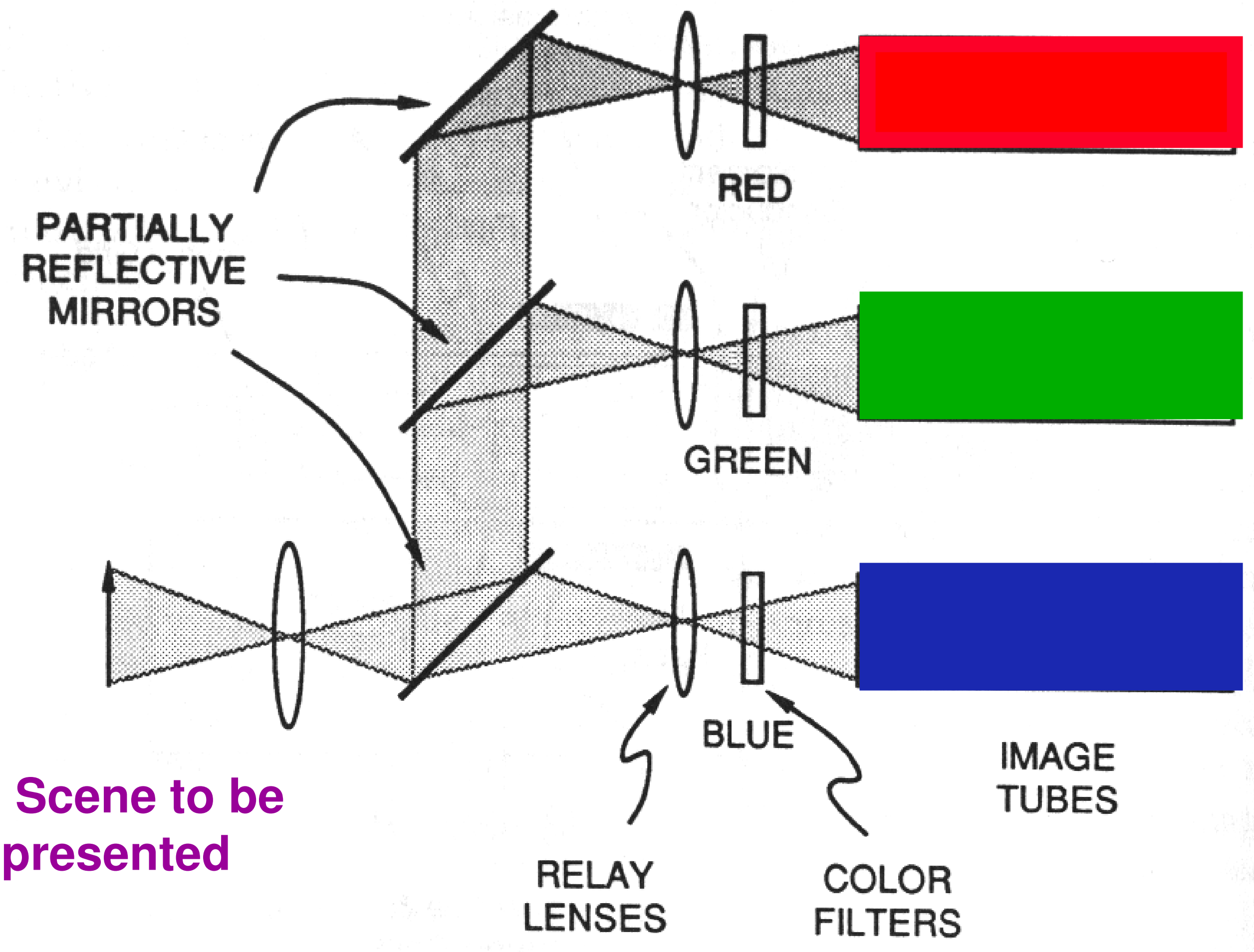

Original
Red
Green
Blue


Original
Y
Cr
Cb

INSTITUTO SUPERIOR TÉCNICO

Image Analysis

The image is analyzed using 3 image tubes, each one preceded by a filter with a spectral behavior adapted to the spectrum of the corresponding phosphors in the CRT.

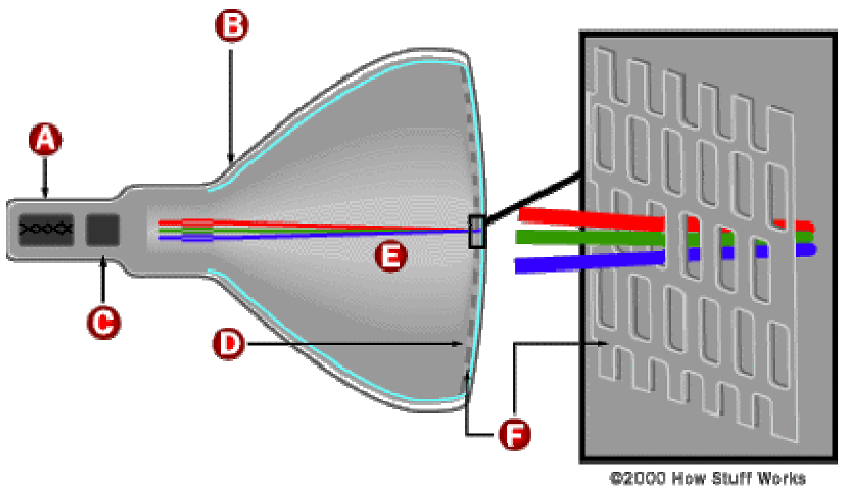


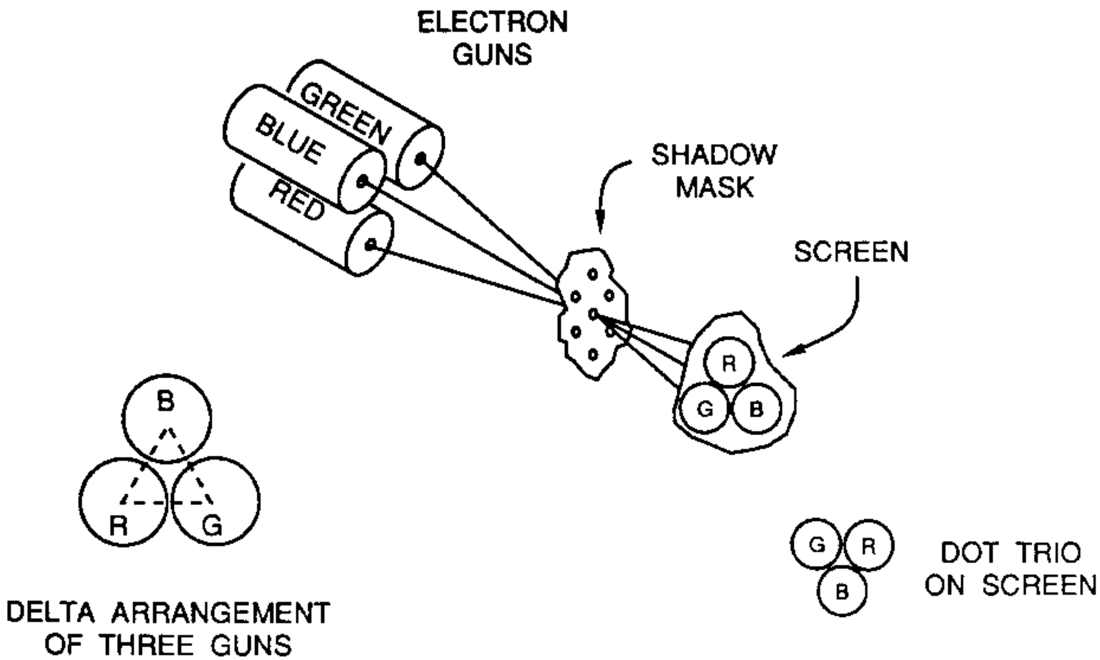
Real Scene to be represented

Cathodic Ray Tubes (CRT): the First Displays

- The cathode ray tube (CRT) is a vacuum tube containing an electron gun (a source of electrons) and a fluorescent screen, with internal or external means to accelerate and deflect the electron beam, used to create images in the form of light emitted from the fluorescent screen.
- In colour CRTs, there are three electron guns, and three fluorescent materials in the screen, one for each primary colour (R,G,B).
- The CRT uses an evacuated glass envelope which is large, deep, heavy, and relatively fragile.

Image Synthesis





Gamma Correction …

YUV $\Rightarrow$ RGB at reception !

- To compensate the luminance conversion non-linearities at the camera and display, gamma correction is needed in the luminance signal like in black and white TV; this means

$$Y^{1/\gamma} = (0.3\,R + 0.59\,G + 0.11\,B)^{1/\gamma}$$

should be transmitted with $1/\gamma$ being the transmitted gamma.

- As each of the primary colour tubes has a characteristic similar to the one for the monochrome CRTs, it is essential to make also the gamma correction for each primary component; this means the colour receiver must be able to obtain

$$R^{1/\gamma}, B^{1/\gamma} \text{ e } G^{1/\gamma}$$

- To avoid the resolution of non-linear equations at the colour receivers, an approximation of the luminance signal is transmitted

$$Y' = 0.3\,R^{1/\gamma} + 0.59\,B^{1/\gamma} + 0.11\,G^{1/\gamma}$$

which prevents to reach perfect backward compatibility since $Y^{1/\gamma} \neq Y'$.

Gamma Correction … in Detail …

Should send

1. $Y^{1/\gamma} = (0.3\,R + 0.59\,G + 0.11\,B)^{1/\gamma}$
2. $R^{1/\gamma} - Y^{1/\gamma}$
3. $B^{1/\gamma} - Y^{1/\gamma}$

Difficult equation system to be solved by colour TVs!

But sends

1. $Y' = 0.3\,R^{1/\gamma} + 0.59\,G^{1/\gamma} + 0.11\,B^{1/\gamma}$
2. $R^{1/\gamma} - Y'$
3. $B^{1/\gamma} - Y'$

Linear (easier) equation system to be solved by colour TVs!

Because it is easier to recover the $R^{1/\gamma}$, $B^{1/\gamma}$ and $G^{1/\gamma}$ signals at the colour receivers.

Bandwidth: How do you Fit Big in Small ?

CONDITION 1

- The total available bandwidth for a colour TV channel is the same as for a monochrome TV channel (8 MHz in Europe and 6 MHz in US).

CONDITION 2

- Instead of transmitting only the luminance signal, it is now necessary to transmit (in the same bandwidth) the luminance signal and two chrominance signals.

Chrominance Transmission: Quadrature Modulation

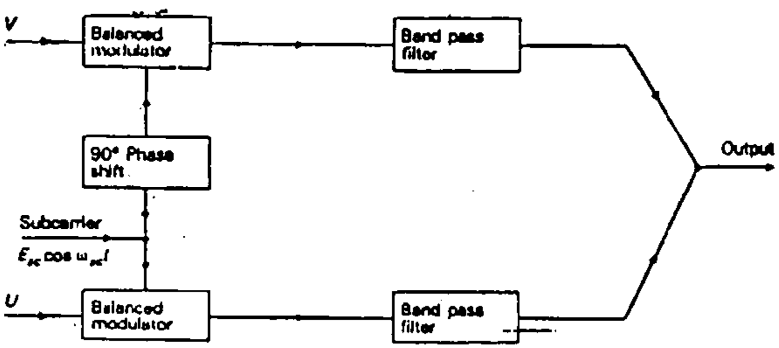
- The 2 chrominance signals modulate 2 carriers with the same frequency but with a phase difference of 90º.

- To limit saturation, the following signals are used
  - V' = 0.877 (R'-Y')
  - U' = 0.493 (B'-Y') (both gamma corrected)

  which have lower amplitude and are filtered to have a bandwidth much inferior to the luminance bandwidth.

- The chrominance modulated signal comes

  $U' \cos \omega_c t + V' \text{ sen } \omega_c t$



Chrominance Transmission: Quadrature Demodulation

- To recover the 2 chrominances, the modulated signal is multiplied by

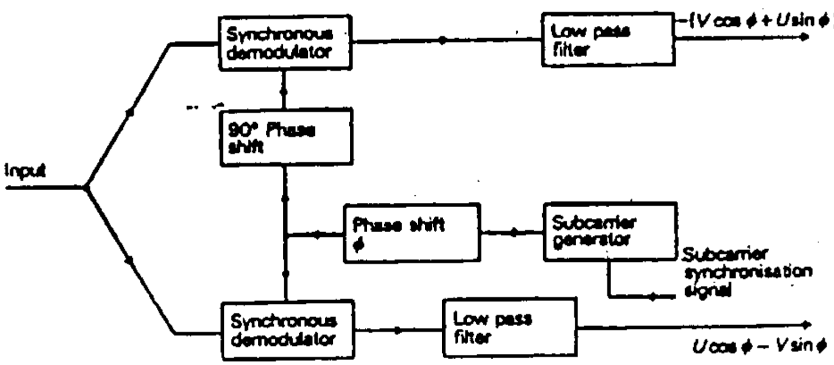
$$\cos \omega_c t \quad e \quad \text{sen}\, \omega_c t$$

and the result is adequately filtered.

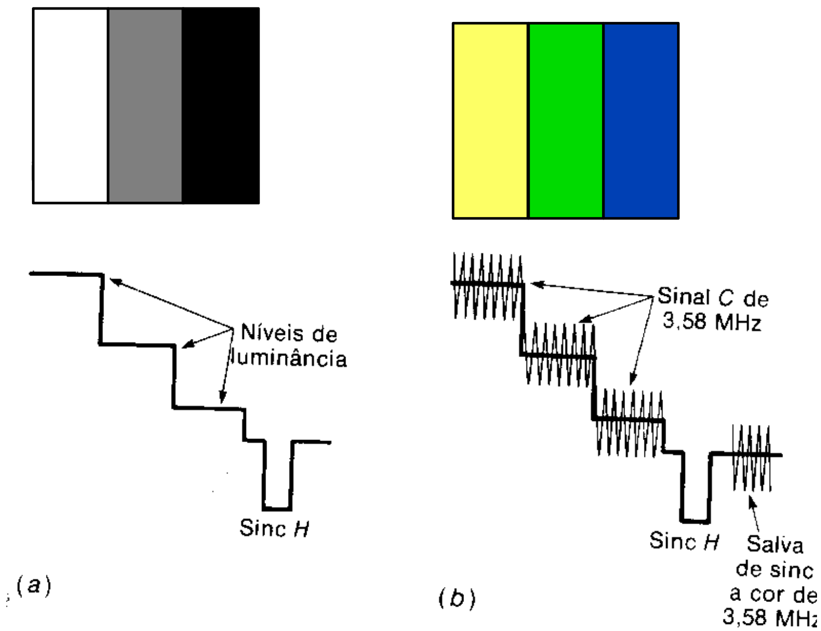
- With quadrature amplitude modulation, a phase error in the demodulation carrier leads to undesirable mixtures of the 2 modulating signals

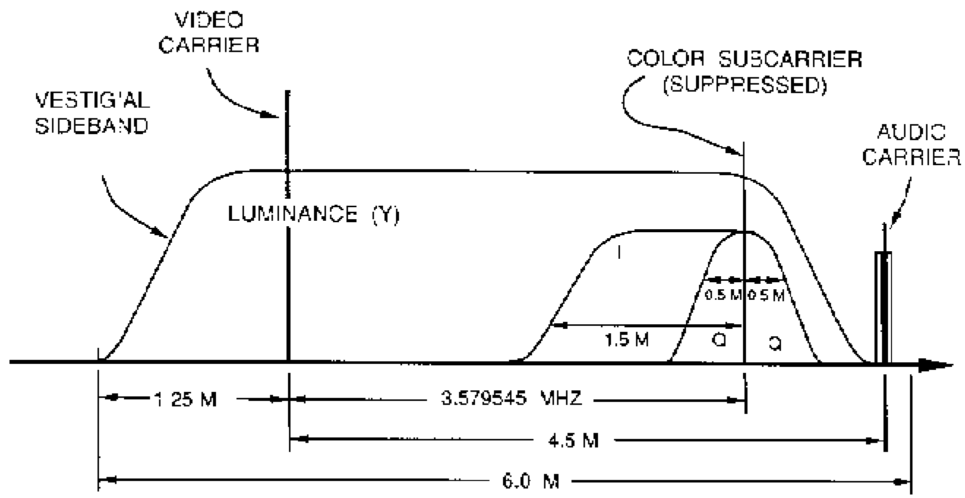
instead of U', it comes U' cos ϕ - V' sen ϕ

instead of V', it comes -V' cos ϕ - U' sen ϕ



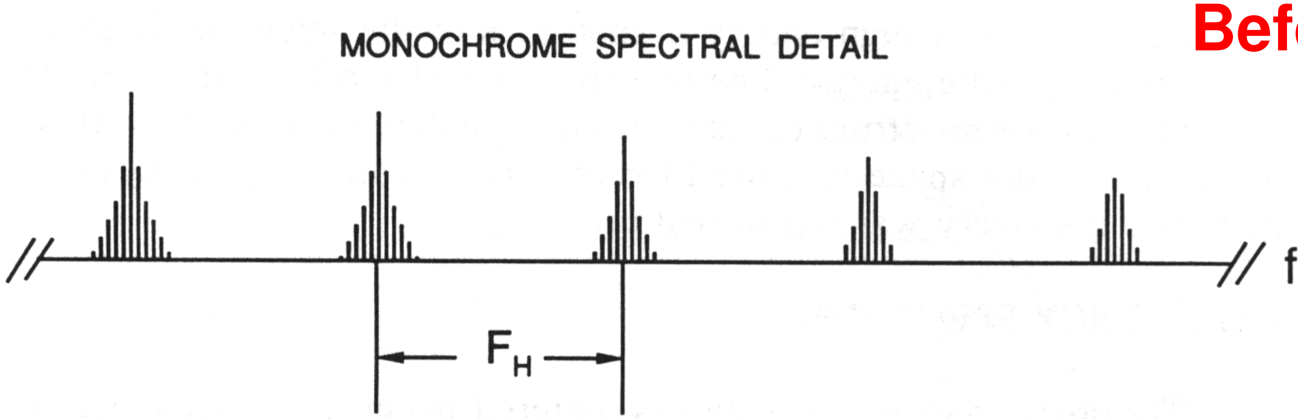
Colour TV Signals: in Time and in Frequency …



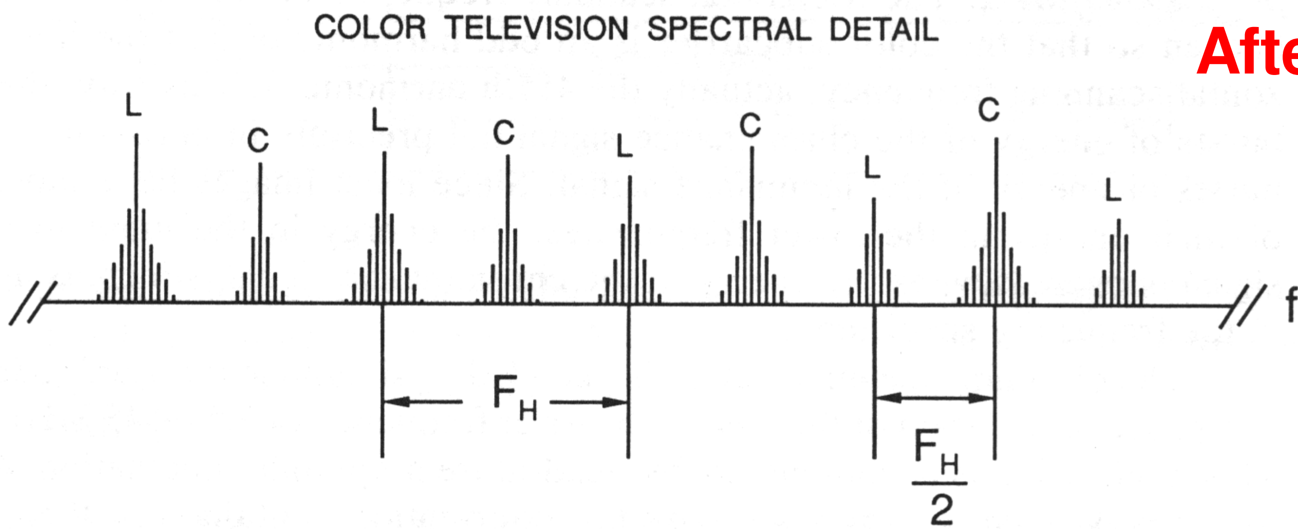


Mixing but not Too Much ...

Before



After



Vector Diagram

The quadrature modulated signal comes

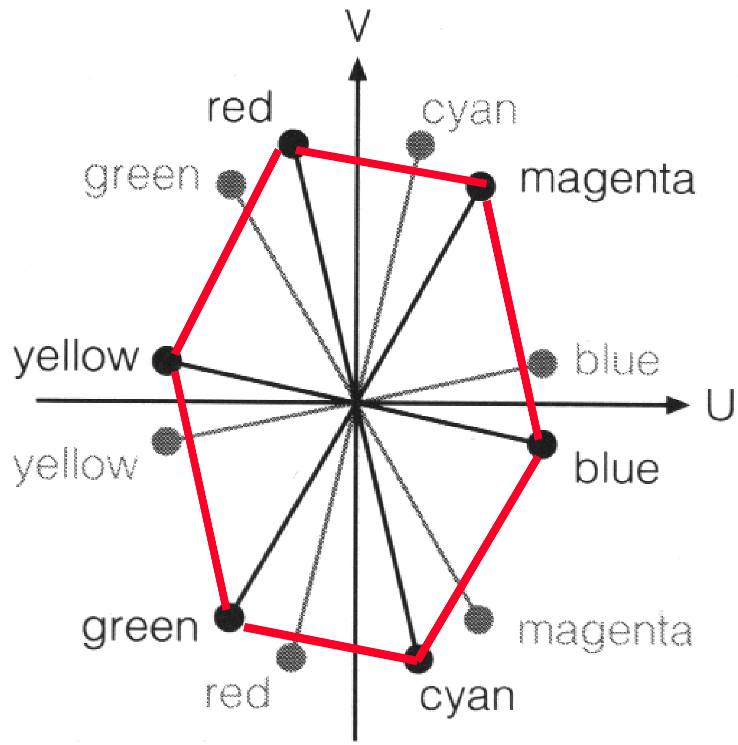
$U' \cos \omega_c t + V' \text{sen } \omega_c t =$

$A \cos (2 \pi f\omega_c t + \phi)$

where A and ϕ are the amplitude and phase of the colour carrier

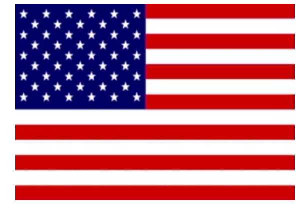
$A = (U'^2 + V'^2)^{1/2}$

$\phi = \text{arctg} (V' / U')$



NTSC SYSTEM

The NTSC System (*National Television Standards Committee*)



- For the NTSC system, the signals transmitted are

$$I' = -\,0{,}27\,(B'-Y') + 0.74\,(R'-Y') = \cos 33^{o}\,V' - \text{sen}\,33^{o}\,U'$$

$$Q' = 0.41\,(B'-Y') + 0.48\,(R'-Y') = \cos 33^{o}\,U' + \text{sen}\,33^{o}\,V'$$

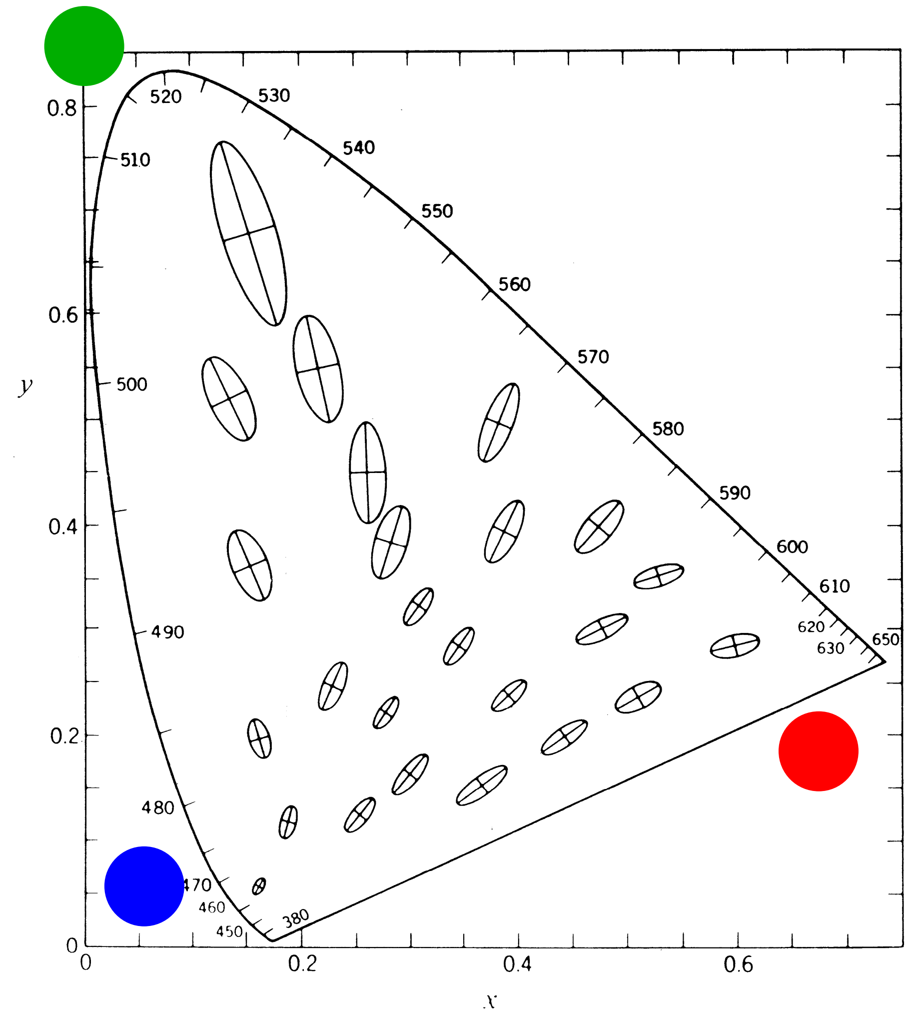
obtained by linear transformation of the U' and V' signals.

- The NTSC system takes benefit from the fact that the human sensibility to colour variations depends on the direction the colour is varying in a chromaticity diagram.
- If the chrominance signals express colour variations along directions to which humans are differently sensitive, it is acceptable that the bandwidth for these signals is also different.

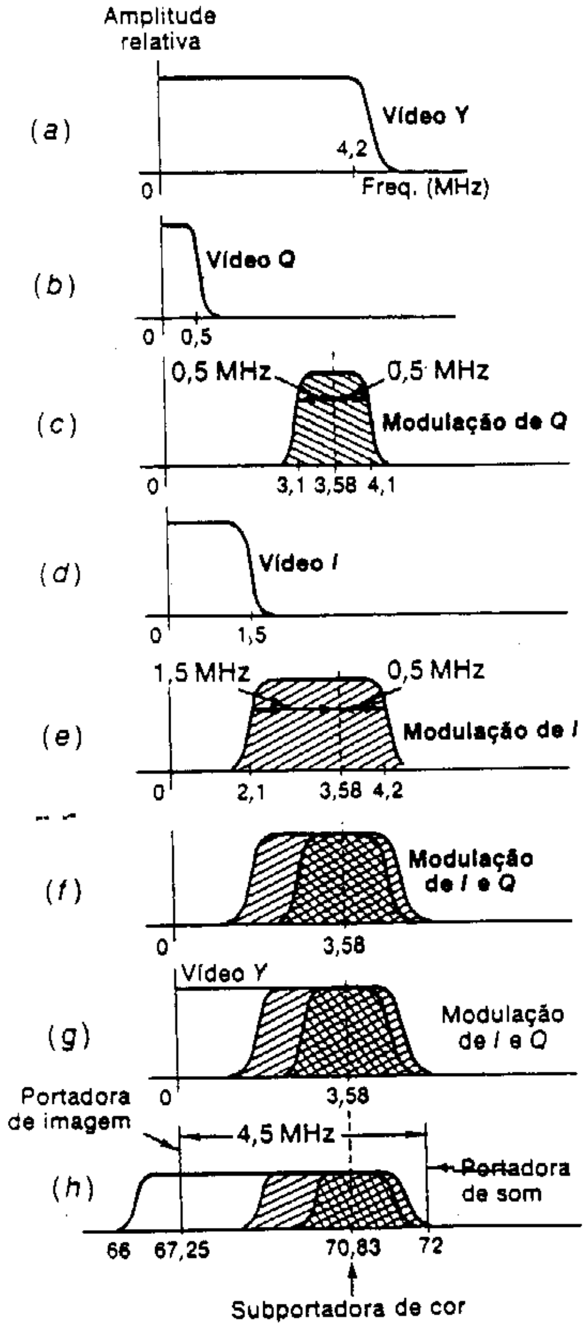
Colour Variation Sensibility: MacAdam Ellipses

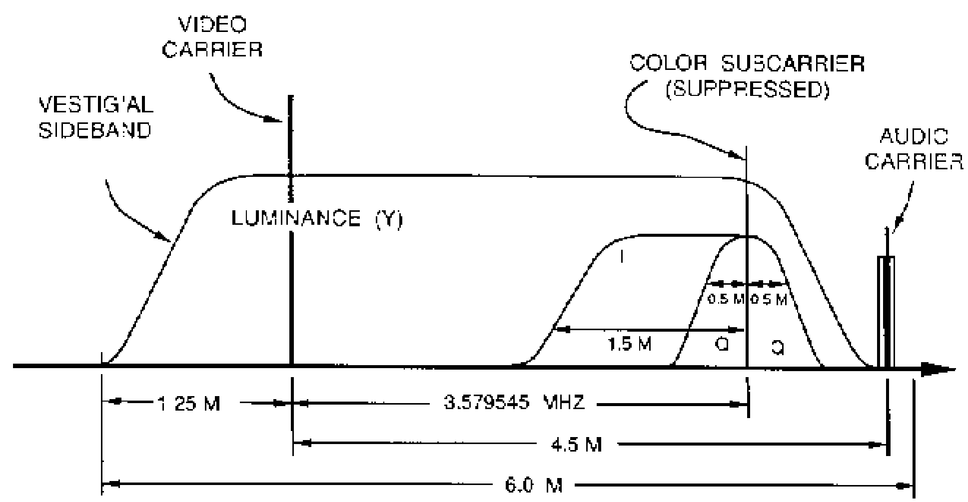
MacAdam ellipses refer to the region on a chromaticity diagram which contains all colors which are indistinguishable, to the average human eye, from the color at the center of the ellipse. Therefore, the contour of the ellipse represents the just noticeable differences of chromaticity.

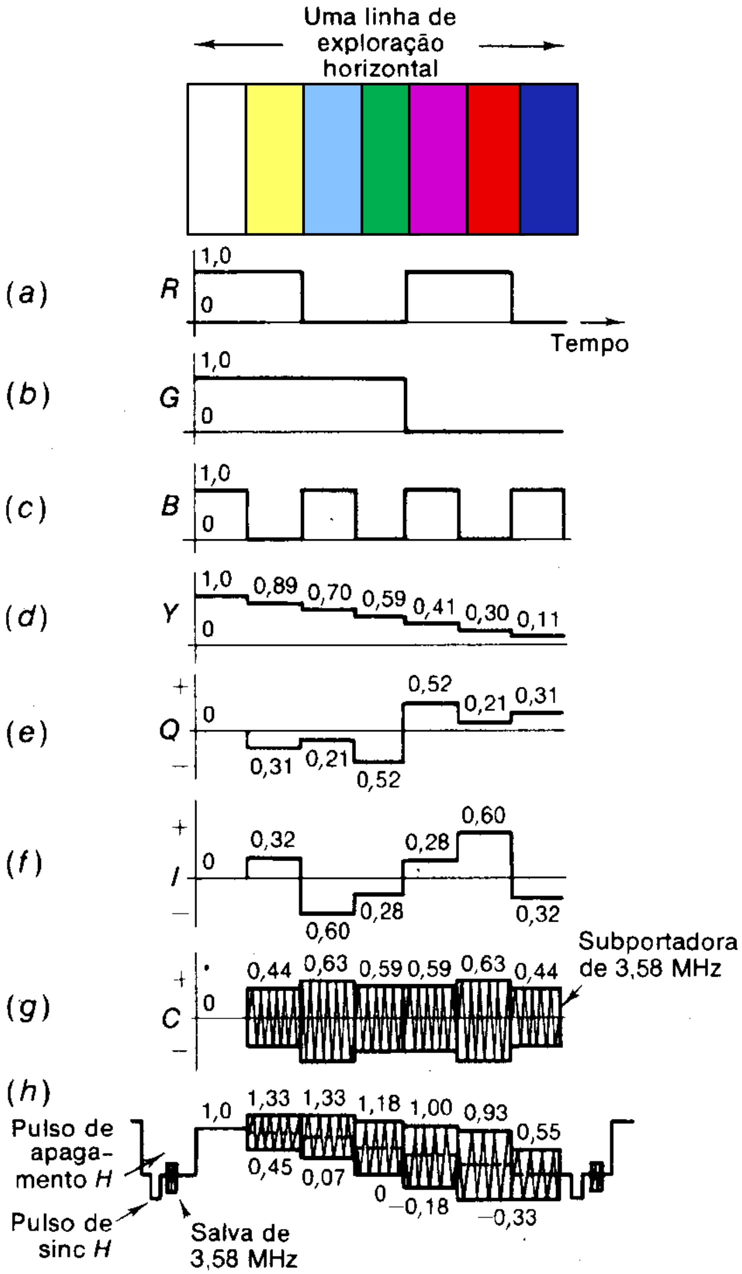
The human visual system is not equally sensitive to colour variations along all directions.



NTSC Signal in Frequency







NTSC Composite Signal in Time

$$c(t) = I' \cos(360^o f_c t + 33^o) + Q' \text{ sen } (360^o f_c t + 33^o)$$

$$c(t) = A_{NTSC} \cos(2 \pi f_c t + \phi)$$

with

$$A_{NTSC} = (I'^2 + Q'^2)^{1/2}$$

$$\phi_{NTSC} = 123^o - \text{arctg } (Q'/I')$$

(in relation to U)

Separation of NTSC Chrominances

- To recover the quadrature modulating chrominance signals, the modulated signal is multiplied by

$$\cos \omega_c t \quad \text{and} \quad \text{sen}\ \omega_c t$$

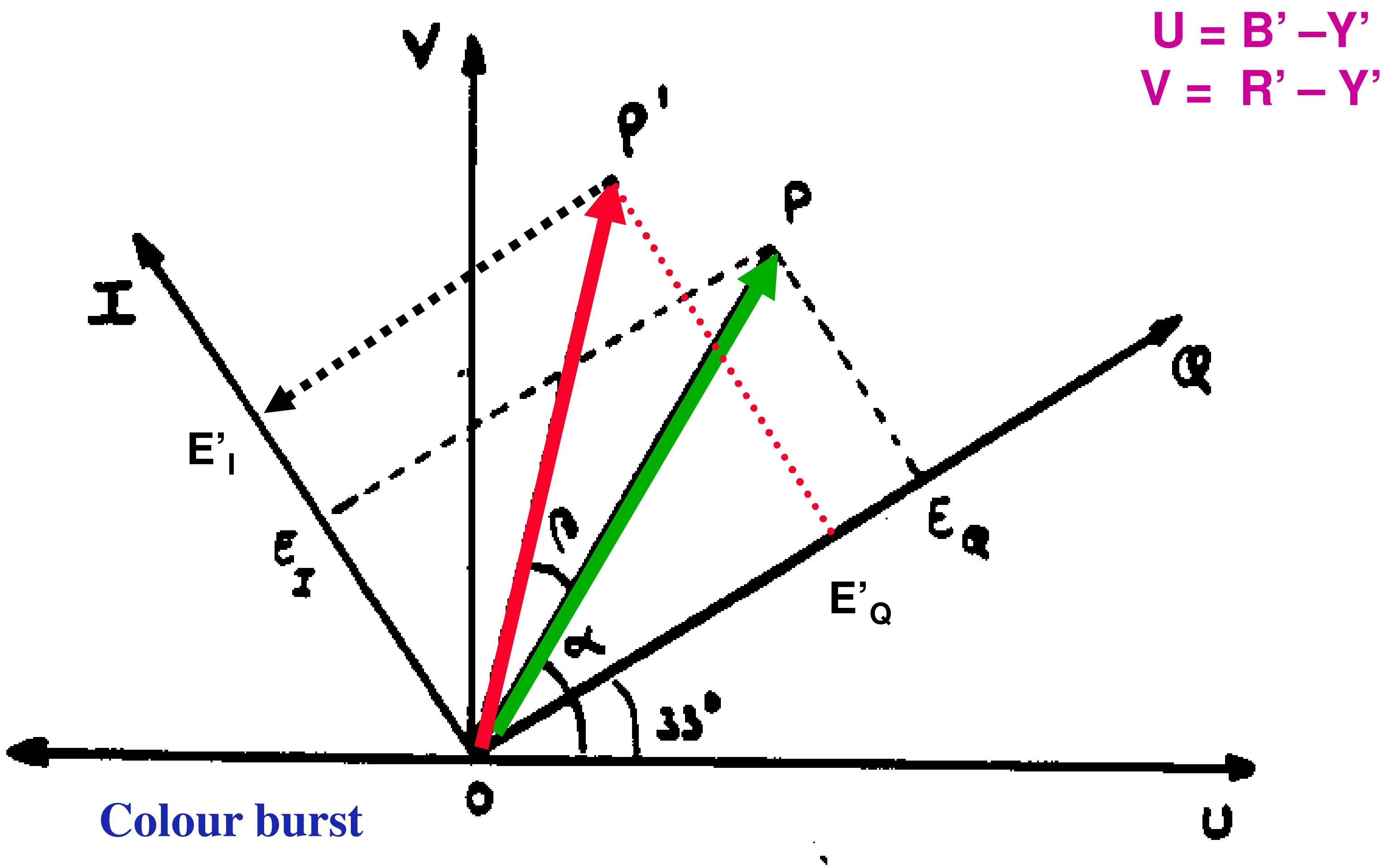
and the result is adequately filtered.

- The perfect quadrature demodulation is only possible if the modulated signal does not suffer any interference and the equipment is perfectly tuned. This is, in practise, impossible !

- Since
  - there are small frequency or phase shifts in the demodulating carrier
  - transmission channels introduce differential amplitude or phase gains

it is not possible to perfectly recover the quadrature modulated signals (U and V) which means there are <u>colour mixtures</u> and, thus, colour errors.

NTSC Mixtures or *Never Twice the Same Colour*



PAL SYSTEM

The PAL System (Phase Alternate Line)

- The chrominance signals selected are
  - $U' = 0.493\ (B'-Y')$
  - $V' = 0.877\ (R'-Y')$

  in order to limit the saturation at the emitter.

- The chrominances are sent in quadrature, modulating a colour subcarrier with the U' and V' signals; the signal of V' is alternated (+ and -) for every image line.

N lines: $c_N(t) = U' \text{ sen } (2 \pi f_c t) + V' \cos (2 \pi f_c t) = A_{PAL} \cos (2 \pi f_c t + \phi_{PAL})$

P lines: $c_P(t) = U' \text{ sen } (2 \pi f_c t) - V' \cos (2 \pi f_c t) = A_{PAL} \cos (2 \pi f_c t - \phi_{PAL})$

with

$A_{PAL} = (U'^2 + V'^2)^{1/2}$ and $\phi_{PAL} = \text{arctg } (V' / U')$ (em relação a V)

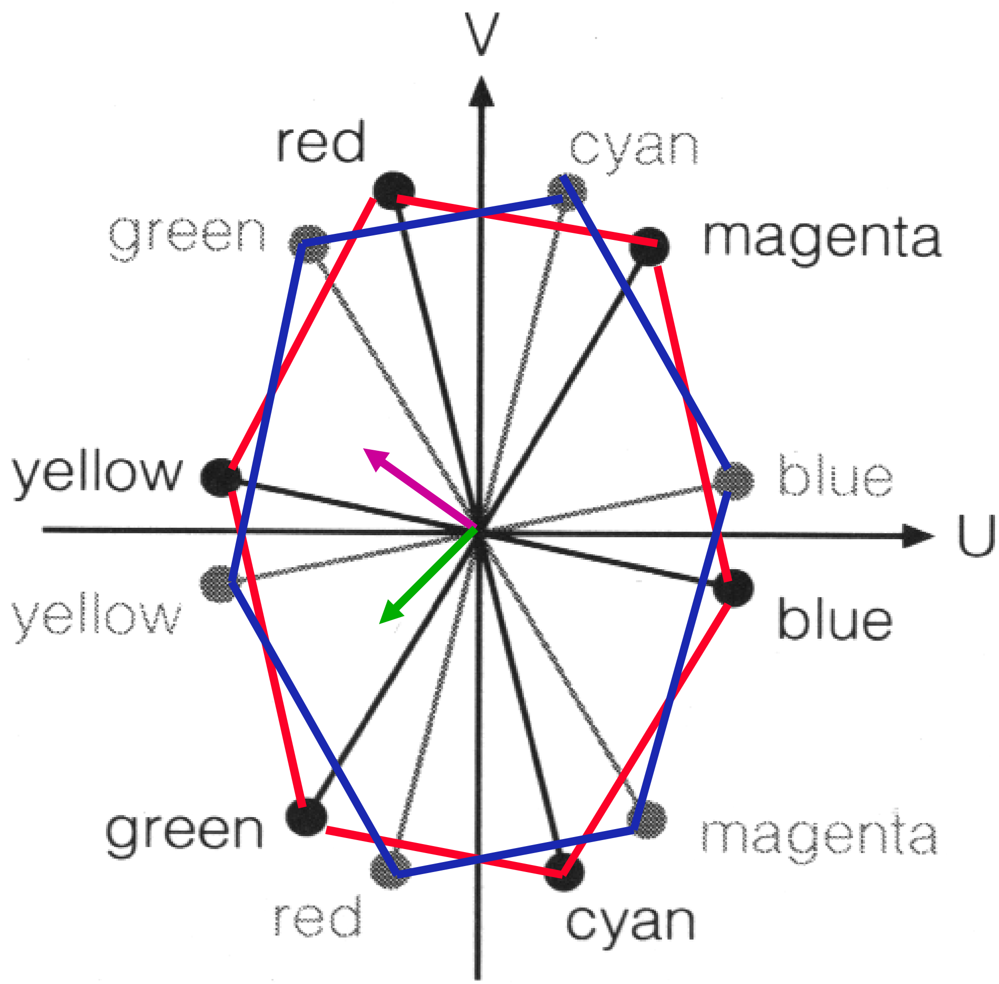
PAL Vector Diagram

N Lines

P Lines

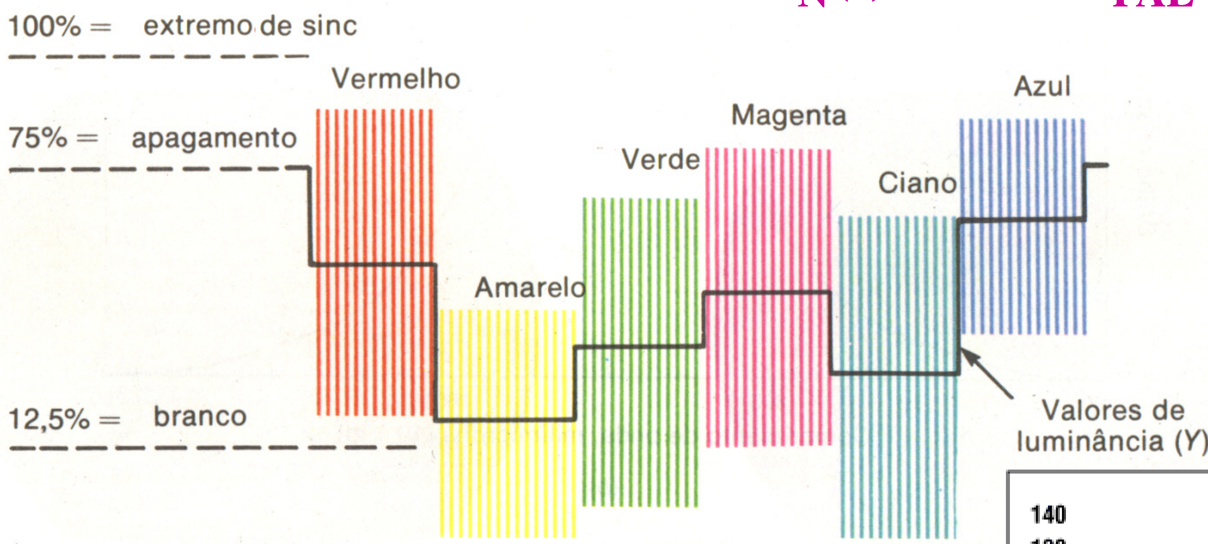
N Burst

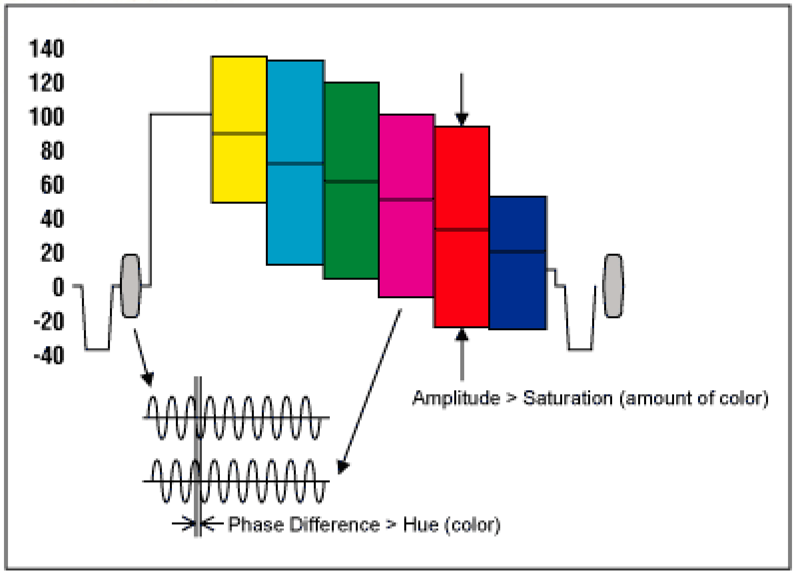
P Burst



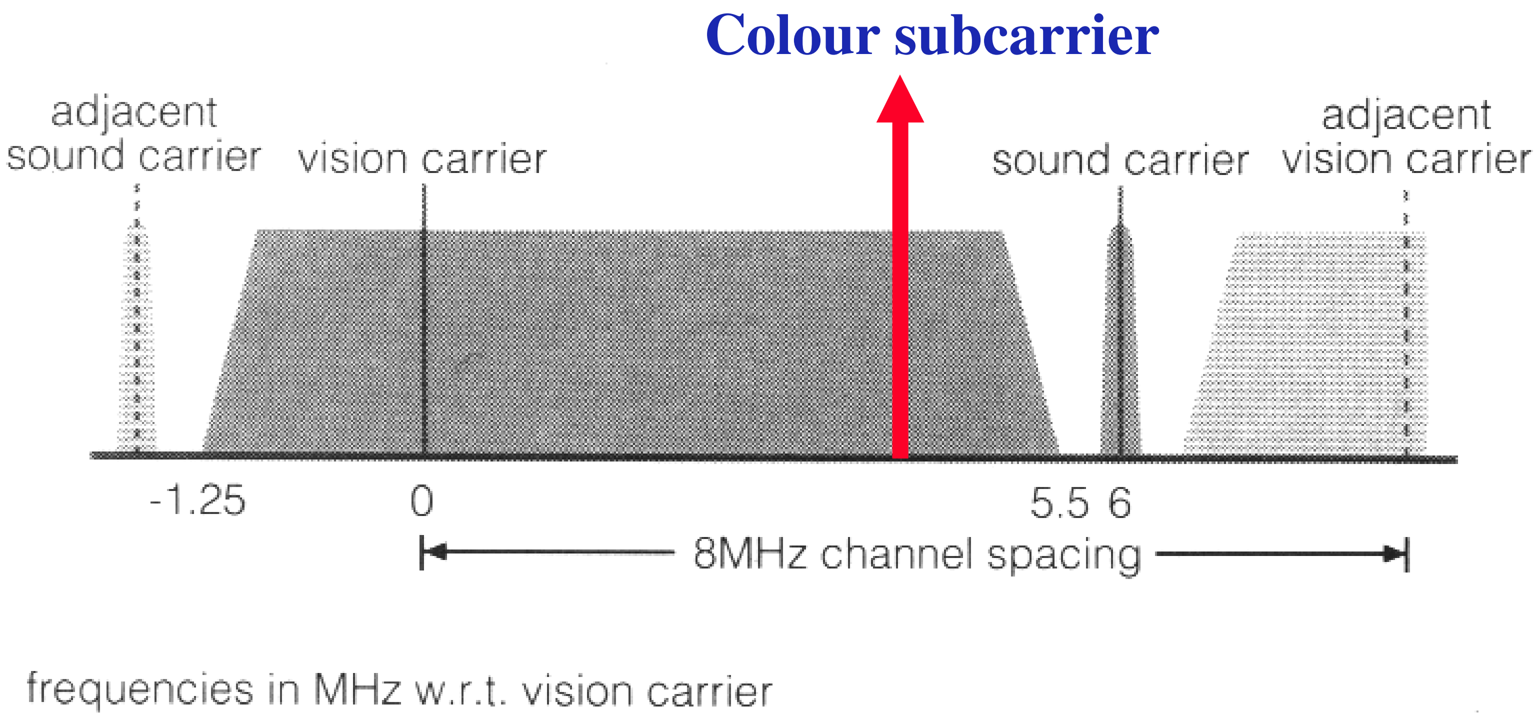
PAL Video Signal in Time

$$c_N(t) = Y + A_{PAL} \cos(2\pi f_c t + \phi_{PAL})$$





PAL Signal in Frequency



PAL Demodulation

- Assuming that the chrominance information is more or less the same for 2 consecutive lines, if the receiver stores the modulated chrominance signal for each line, than it is possible for the next line to recover the modulated U' and V' signals by adding and subtracting the received and stored chrominance signals (using a delay line).

- If the stored line is N:

$$U' \text{ sen } (2 \pi f_c t) = (c_N (t) + c_P (t)) / 2$$

$$V' \cos (2 \pi f_c t) = (c_N (t) - c_P (t)) / 2$$

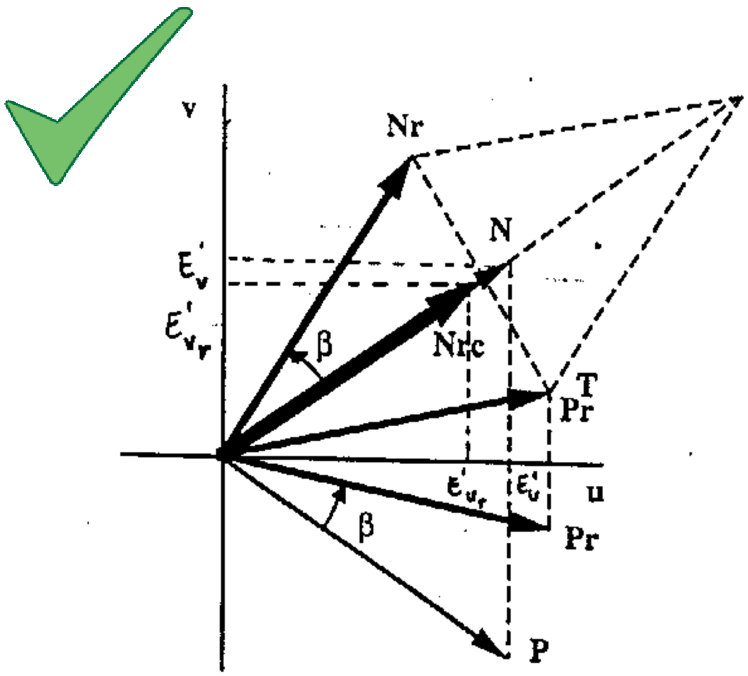
- If the stored line is P:

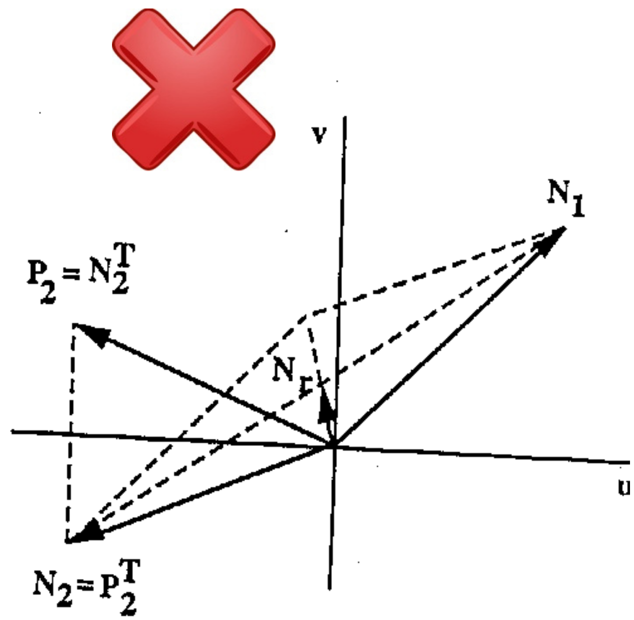
$$U' \text{ sen } (2 \pi f_c t) = (c_N (t) + c_P (t)) / 2$$

$$V' \cos (2 \pi f_c t) = (c_N (t) - c_P (t)) / 2 = - (c_P (t) - c_N (t)) / 2$$

Trading Colour Mixtures with Saturation Errors

By using N and P lines, the PAL system is able to transform colour mixture artefacts into colour saturation artefacts to which the human visual system is less sensitive.

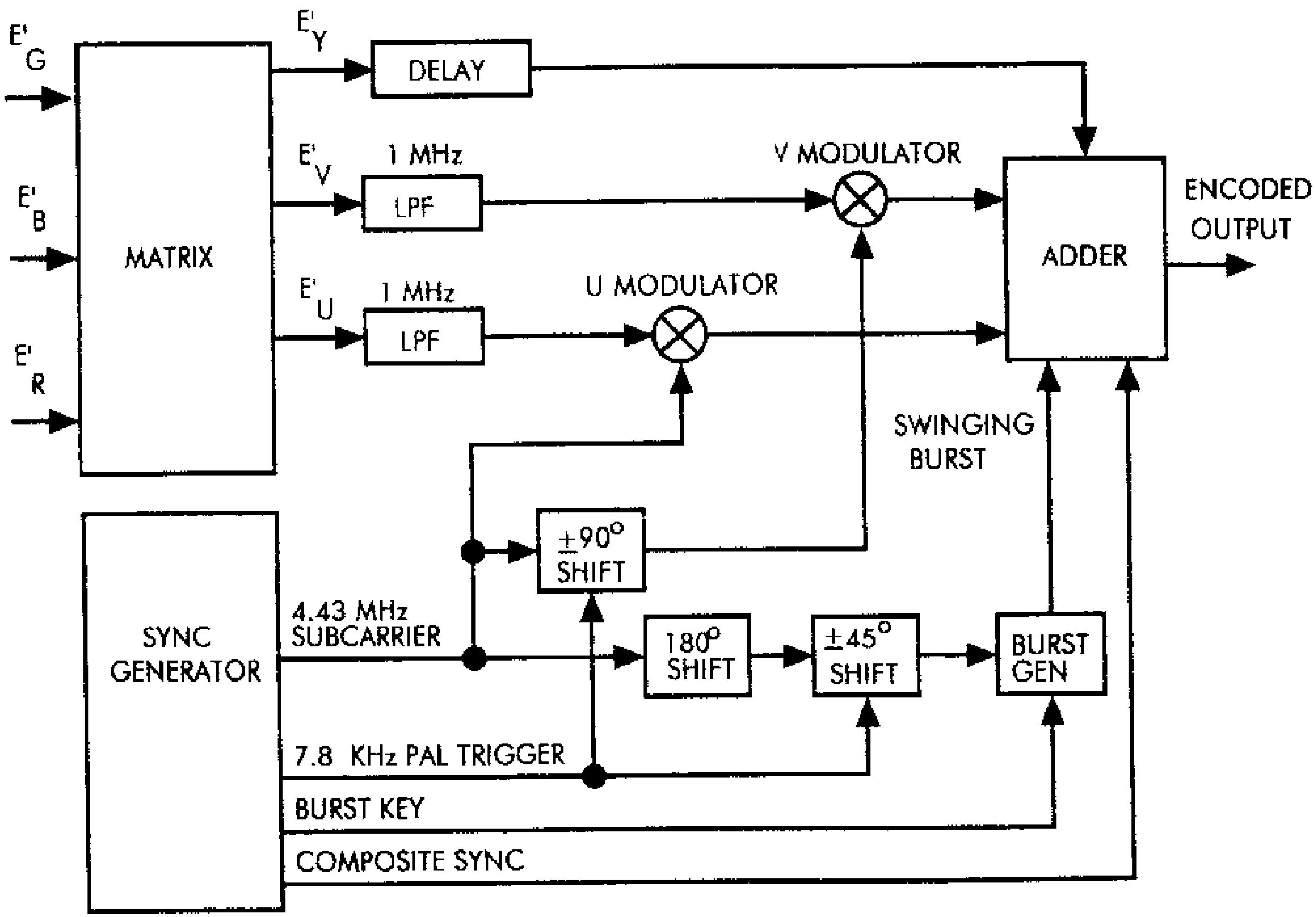




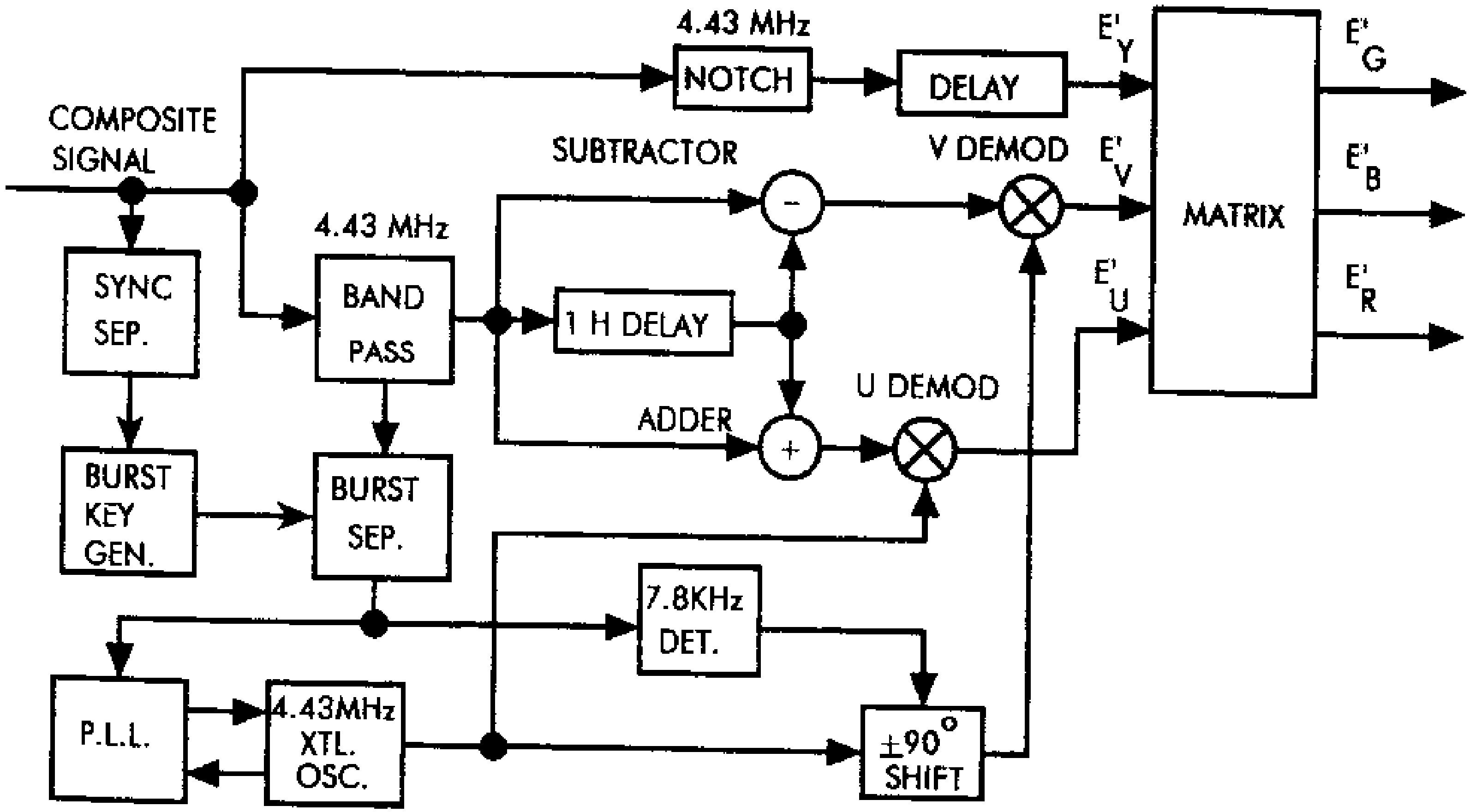
$$U'_r = U' \cos \beta$$

$$V'_r = V' \cos \beta$$

PAL Modulator

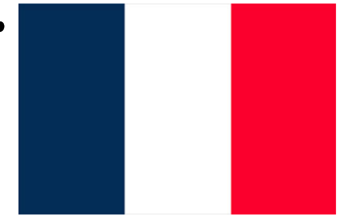


PAL Demodulator



SECAM SYSTEM

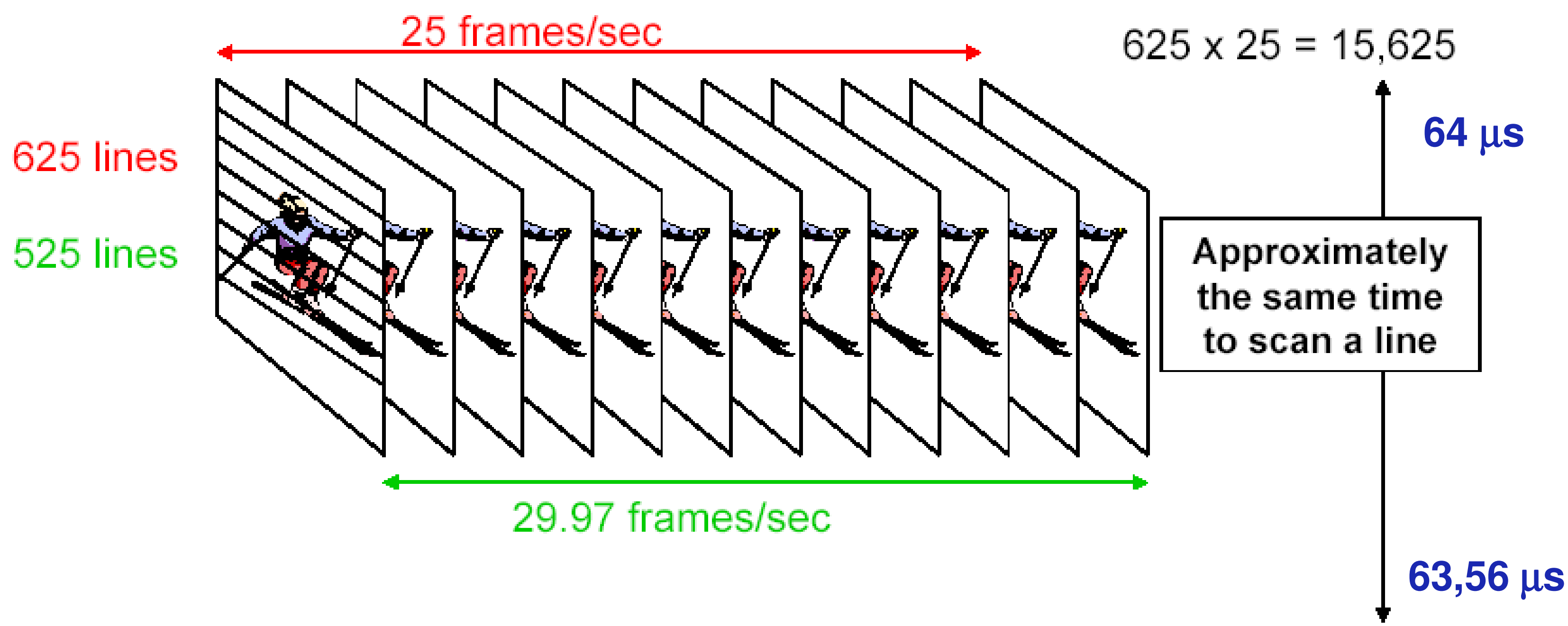
The SECAM System (*Sequentiel Couleur Memoire*)



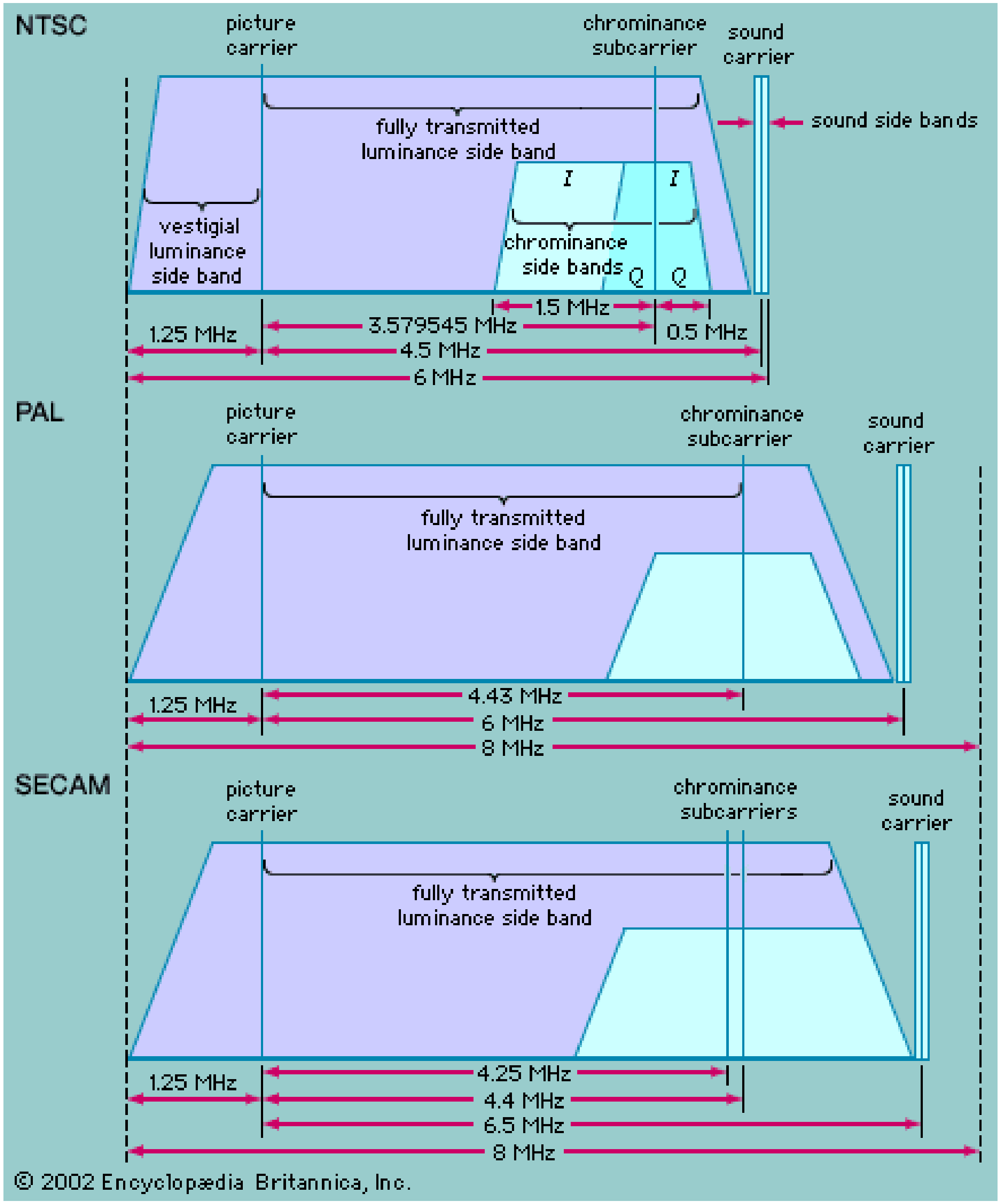
- The SECAM chrominance signals are
  - DR' = - 1.9 (R'-Y')
  - DB' = 1.5 (B'-Y')
- The two chrominance signals are frequency modulated and alternately transmitted, line by line (reducing the colour spatial resolution).
- There are no colour mixtures with SECAM since the two chrominance signals never coexist in time.
- Although the SECAM vertical resolution for the chrominances is about half of the PAL/NTSC resolution, there is no evident reduction of the subjective quality.
- As PAL (but not NTSC), also SECAM needs a delay line.

Different but so Similar after all ...

- 625/50 television (PAL, SECAM)

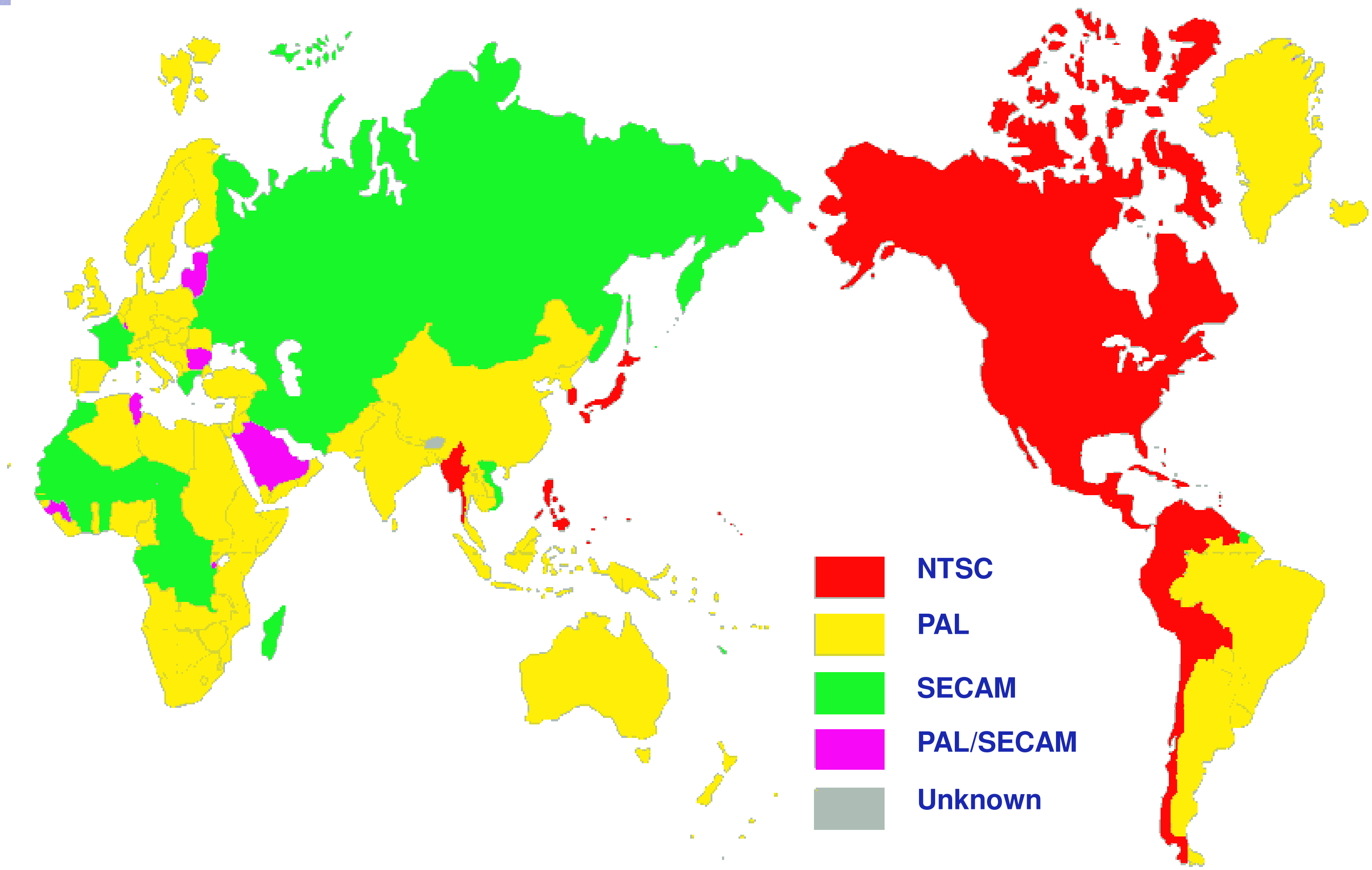


- 525/60 television (NTSC)



NTSC, PAL and SECAM Spectrum Allocations for TV Channels

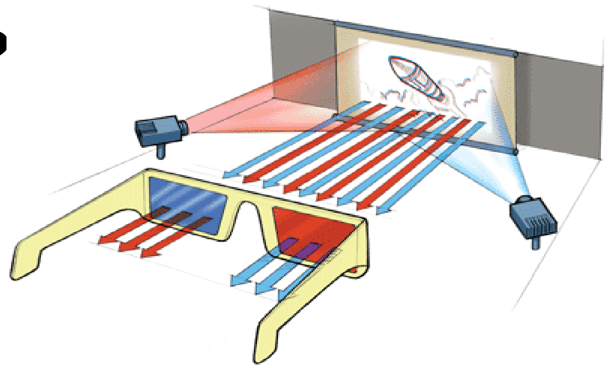
The World of Analogue TV

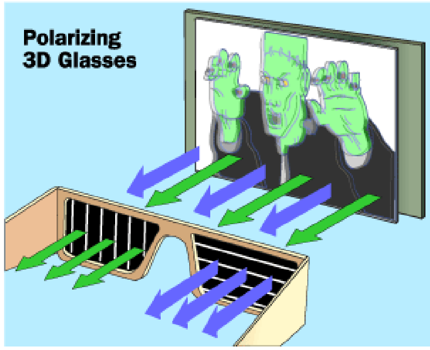


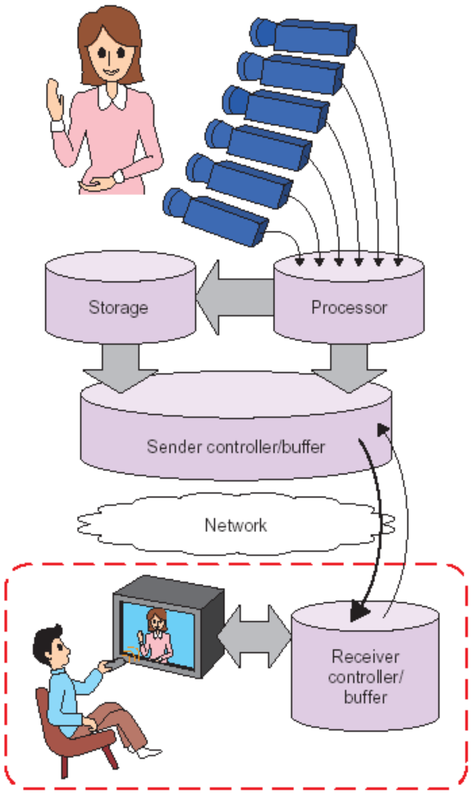
Television: Where is it Going ?

- ✶ Analogue Monochrome TV
- ✶ Analogue Colour TV
- ✶ Digital TV
- ✶ High Definition TV
- ✶ Interactive TV
- ✶ Stereoscopic TV
- ✶ Multiview TV
- ✶ Free viewpoint TV
- ✶ ...

in which transmission systems ?







DISPLAY REVOLUTION

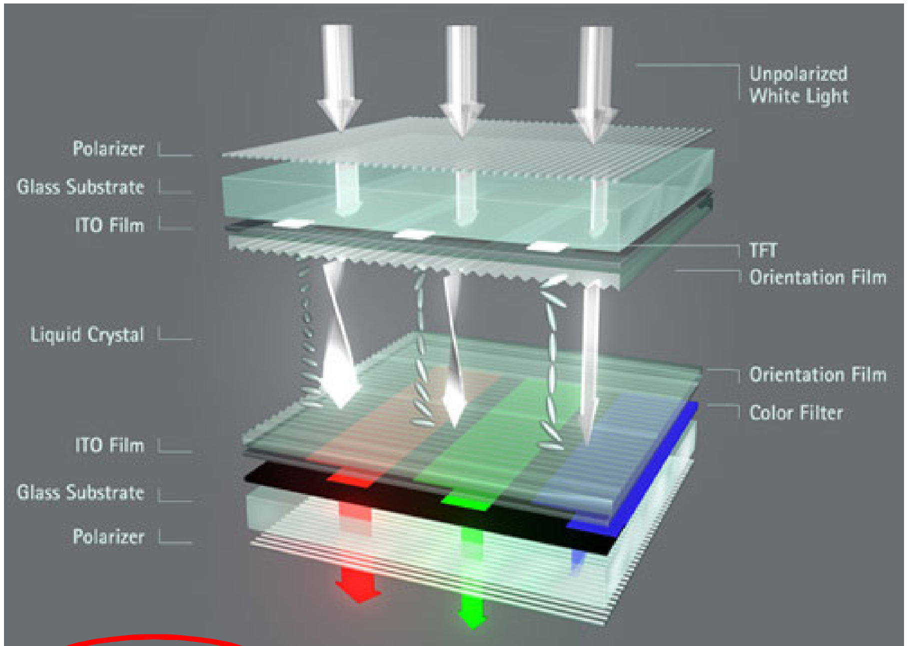
CRT Weaknesses

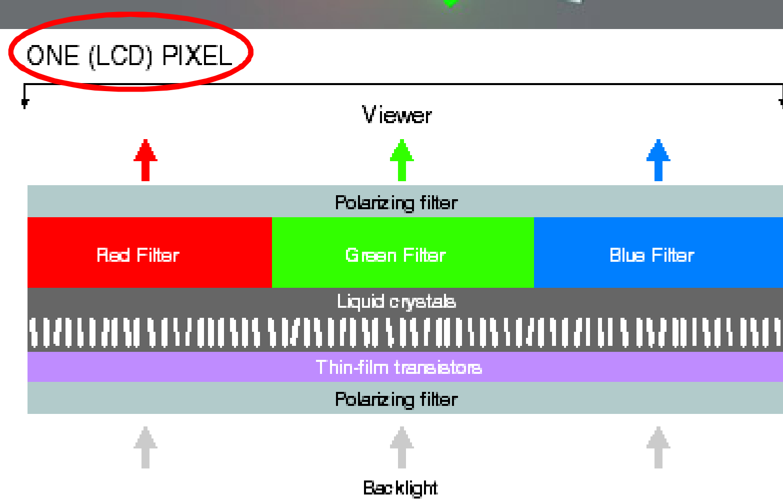
- Big
- Heavy
- Fragile
- High power consumption
- Limited contrast (about 50:1)
- Limited maximum brighness (50-100 cd/m^2)
- Colour variations due to poor 3 gun convergence
- …

INSTITUTO SUPERIOR TÉCNICO

The New Displays: LCDs and Plasmas

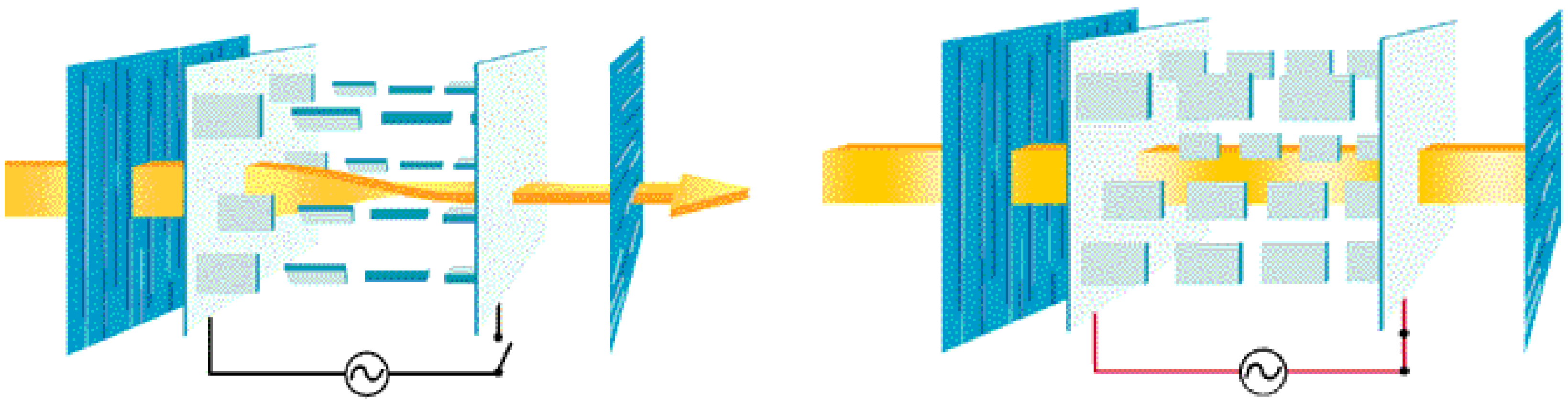
LCD Image Synthesis





- ✶ The screen uses liquid crystal to control the passage of light.
- ✶ The display points – pixels - are controlled by a matrix of transistors. To generate an image, two components are needed – light and colour.
- ✶ Any colour can be created from three basic colours. For each such part of each pixel (a colour dot), there is a transistor controlling the associated liquid crystal.
- ✶ The front glass is fitted with a colour filter, while the back glass has transistors fabricated on it.
- ✶ A light source, called the backlight unit, is located at the back of the panel.
- ✶ When voltage is applied to a transistor, the liquid crystal is bent, allowing light to pass through to form a pixel.
- ✶ The colour filter of the front glass gives the pixel its own colour. The combination of these pixels in different colours forms the image on the panel.

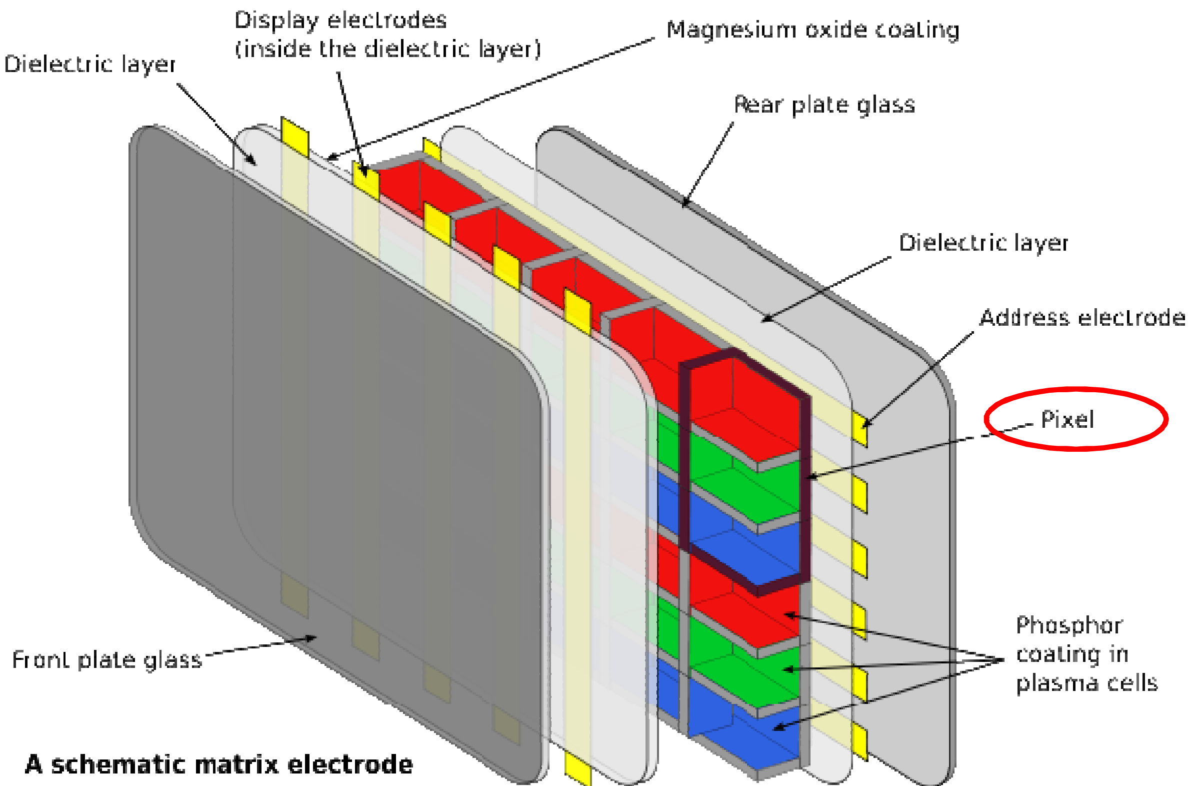
LCD Working Principle



With no voltage applied to the colour dot unit, the passing light rays are rotated so that they may pass unhindered through the second (output) polarised filter. Consequently, the full background light passes through the colour dot and the visual effect is white light.

If full control voltage is applied to the colour dot, the light rays pass through the liquid crystal unaffected and are consequently blocked by the second polarised filter. The resulting visual effect is black light.

Plasma Image Synthesis



A schematic matrix electrode configuration in an AC PDP

- The basic idea of a plasma display is to illuminate tiny colored fluorescent lights to form an image.
- Each pixel is made up of three fluorescent lights: a red, a green and a blue light. Like CRTs, the plasma display varies the intensities of the different lights to produce a full range of colors.
- Many tiny cells between just two panels of glass hold a mixture of noble gases.
- The gas in the cells is electrically turned into a plasma which emits ultraviolet light which then excites phosphors to emit visible light.

LCDs Pros and Cons

- LCD television occupies less space.
- LCD are easier to keep since they are lighter and can be placed anywhere.
- LCDs are designed to hang even in ceiling like a picture or painting.
- LCD technology televisions are far less fragile.
- LCDs are much better at an angle.
- LCDs create much less heat and consume less power (even more with the LED LCDs)
- As they consume low power and produce low heat, they reduce the usage of ventilation fans.
- LCD technology does not suffer by light output degrades due to phosphor wear.
- LCDs have become the reference for personal computing.

- LCD technology has not grown in the screen size like plasma.
- The manufacturing cost of LCD is somewhat high.
- LCD technology has very high response delay; this delay may cause fast motion to blur.
- LCD televisions are not available in larger sizes.
- The viewing angle of LCD technologies can be a big problem.
- LCD televisions are facing the problem of producing inappropriate colour of black while some light passes. So the best black on most LCD screens is a dark gray.

These pros and cons change every day !

Plasma Displays Pros and Cons

- Slim profile
- Can be wall mounted
- Lighter and less bulky than rear-projection televisions
- Achieves better and more accurate color reproduction than LCDs (68 billion/236 versus 16.7 million/224)
- Produces deep, true blacks allowing for superior contrast ratios (up to 1:2,000,000)
- Far wider viewing angles than those of LCD (up to 178°); images do not suffer from degradation at high angles unlike LCDs
- Virtually nonexistent motion blur, thanks in large part to very high refresh rates and a faster response time, contributes to the superior performance of plasma displays when displaying video containing significant amounts of rapid motion.

- Older models are susceptible to screen burn-in and image retention
- Phosphors in older models lose luminosity over time, resulting in gradual decline of absolute image brightness
- Generally do not come in smaller sizes than 32 inches
- Susceptible to reflection glare in bright rooms
- Heavier than LCD due to the requirement of a glass screen to hold the gases
- Use more electricity, on average, than an LCD TV
- Do not work as well at high altitudes due to pressure differential between the gases inside the screen and the air pressure at altitude; it may cause a buzzing noise.

These pros and cons change every day !

LCD versus Plasmas

	LCD TV	PLASMA TV
Picture Quality Considerations		
CONTRAST/BLACK LEVEL		✓
BRIGHTNESS	✓	
COLOR ACCURACY		✓
VIEWING ANGLE		✓
Functional Consideration		
COMPUTER USE	✓	
FAST MOVING VIDEO		✓
SCREEN GLARE	✓	
LONGEVITY	✓	✓
SCREEN BURN IN	✓	
Other Considerations		
PRODUCTION SIZE AND COST		✓
POWER CONSUMPTION	✓	
PRICE AND VALUE		✓
Totals:	6	7

- These relative advantages/weaknesses change with time !
- There is no definitive conclusion on which type of display is better !
- This conclusion may strongly depend on the consumption conditions and contents, e.g. big/small room, sports/cinema, …
- But power consumption seems to be becoming more and more a killing factor for the plasmas.

http://www.plasmatvbuyingguide.com

TERRESTRIAL TV

IN PORTUGAL

7 March 1957 (Thursday), 21:30: Starting of Monochrome TV Regular Transmissions

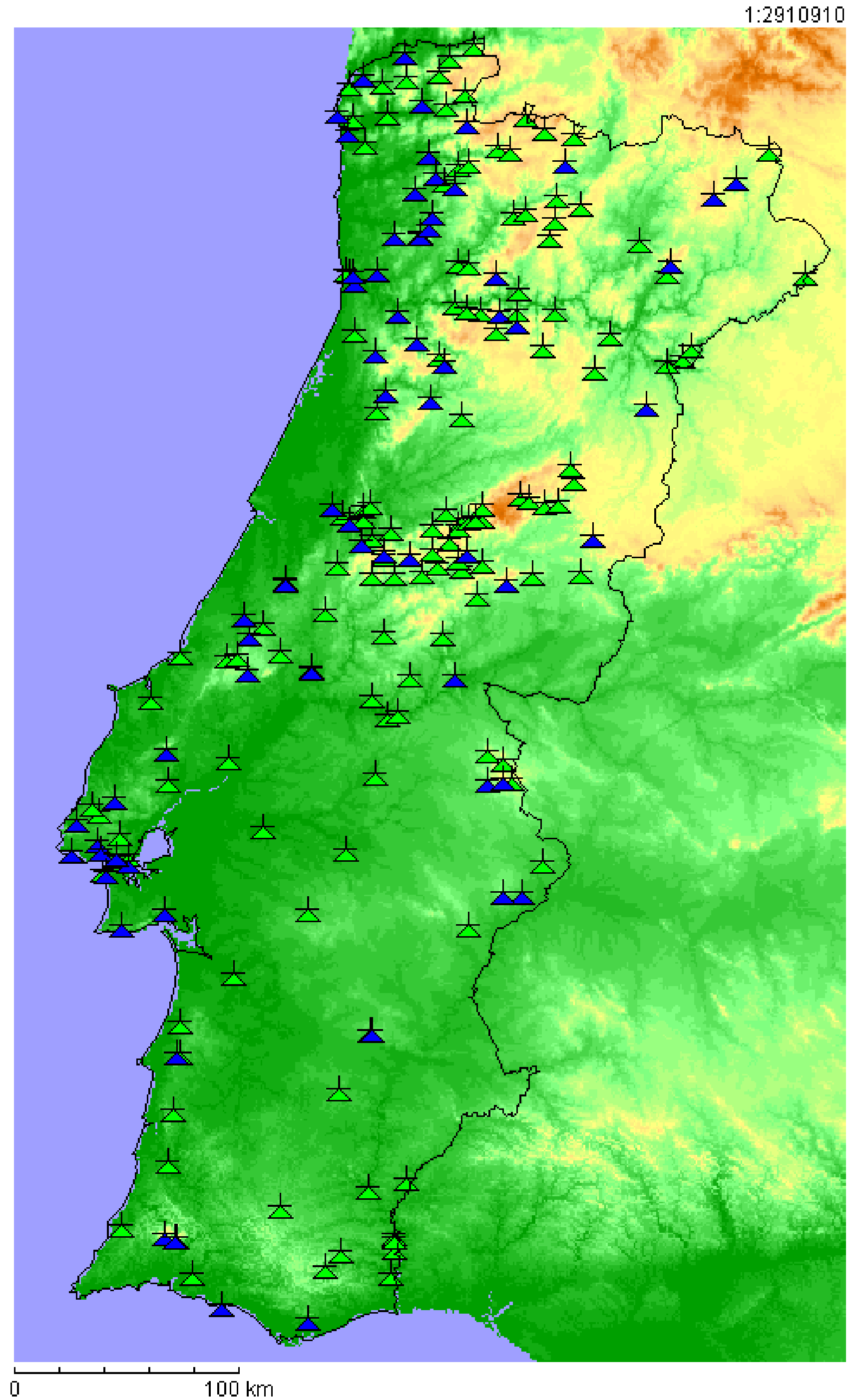
1957, 17 a 23 de Fevereiro - "Reportagens da Rainha", realizadas durante a visita a Portugal de Isabel II de Inglaterra, prenunciam o arranque das emissões regulares.

1957, 7 de Março - 21:30 - Início das emissões regulares, a partir dos Estúdios do Lumiar, em Lisboa, difundidas por um pequeno emissor provisoriamente instalado em Monsanto.

Current Situation: Transmission Networks

Until 2008, there were two terrestrial broadcasting networks in Portugal:

- ✶ PT Comunicações (green in the map) network which has the network that was initially from RTP and TDP
- ✶ RETI, Rede Teledifusora Independente, (blue in the map) network which developed from the radio network from Rádio Renascença (bought by PT in 2008)



Business Models

Public Broadcasters (RTP) – Public & private sponsorship + Publicity

- *"A concessão geral do serviço público de televisão é atribuída à Rádio e Televisão de Portugal, SGPS, S. A., pelo prazo de 16 anos, nos termos de contrato de concessão a celebrar entre o Estado e essa sociedade."*
- *"O Estado assegura o financiamento do serviço público de televisão, nos termos estabelecidos na lei e nos contratos de concessão."*
- *"Os operadores que actuem ao abrigo de concessão do serviço público de televisão devem assegurar uma programação de qualidade, equilibrada e diversificada, que contribua para a formação cultural e cívica dos telespectadores, promovendo o pluralismo político, religioso, social e cultural, e o acesso de todos os telespectadores à informação, à cultura, à educação e ao entretenimento de qualidade."* *Lei da Televisão, 2003*

Private Broadcasters (SIC and TVI) – Private sponsorship + Publicity

- Sociedade Independente de Comunicação (SIC) has been the first private television network in Portugal, starting the 6th October 1992; it uses the PT broadcasting network.
- Televisão Independente (TVI) was the second private network in Portugal, starting the 20th February 1993; it used his own broadcasting network until 2008.

Curiosity: Time for Ads (*Lei da Televisão, 2003*)

- *Nos serviços de programas televisivos de cobertura nacional e acesso não condicionado, o tempo reservado às mensagens publicitárias não pode exceder 15% do período diário de emissão, salvo quando inclua outras formas de publicidade ou mensagens de televenda, caso em que esse limite pode elevar-se a 20%.*
- *Nos serviços de programas televisivos de cobertura nacional e acesso condicionado, a difusão de publicidade ou de mensagens de televenda não deve exceder 10% do período diário de emissão.*
- *Nos serviços de programas televisivos temáticos de televenda ou de autopromoção, o tempo destinado à publicidade não deve exceder 10% do período diário de emissão.*
- *O tempo de emissão destinado às mensagens publicitárias e de televenda, em cada período compreendido entre duas unidades de hora, não pode exceder 10% ou 20%, consoante se trate ou não de serviços de programas televisivos de acesso condicionado.*
- *Excluem-se dos limites fixados no presente artigo as mensagens difundidas pelos operadores de televisão relacionadas com os seus próprios programas e produtos directamente deles derivados, os patrocínios, os blocos de televenda a que se refere o artigo seguinte, bem como as que digam respeito a serviços públicos ou fins de interesse público e apelos de teor humanitário, transmitidas gratuitamente.*

Digital Terrestrial TV in Portugal

- **2002: First tentative to deploy digital terrestrial TV in Portugal failed ….**
- **2007: Models for and launching of digital terrestrial TV continued to be discussed …**
- ***17 Feb 2009 (delayed to 12 June 2009) – US analogue switch off***
- **April 2009 – Digital terrestrial TV starts in Portugal with PT-Comunicações (service is free but not the boxes …)**
- **26 April 2012: Deployment of digital terrestrial TV should be finished; for security, 12 more months of simulcasting …**

Bibliography

- **Television Technology: Fundamentals and Future Prospects**, Michael Noll, Artech House, 1988

- **Broadcast Television Fundamentals,** Michael Tancock, Pentech Press, 1991