University of Canberra
Advanced Communications Topics

Elements of Digital Television

Lecture 1
Television Fundamentals, Analog TV and Formats

by: Neil Pickford

1

Overview of Topics

1 - Fundamentals of Television Systems
2 - Digital Video Sampling & Standards
3 - Digital Audio/Video Stream Compression
4 - Digital Modulation Systems for DTV
5 - Transmission System Error Protection
6 - Digital System Parameters, Planning and SI and DTV Convergence

12 Hours total
6 x 2 Hour Lectures 11B24 Wed 17:30-19:30
1 Hour Multipart Question on Examination
Plus Assignment work as required

2

About the Lecturer

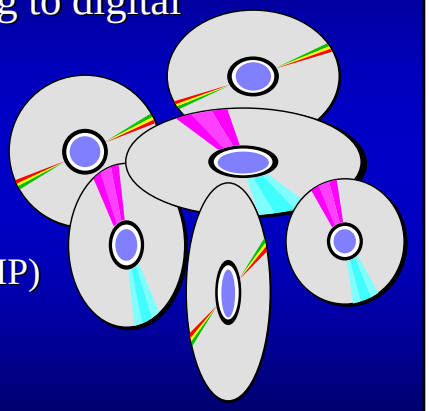
- Graduated B.Eng with distinction from Swinburne Institute of Technology (Victoria) in 1985
- 16 Years Experience working in New Technology Communications Research at the Communications Lab
- Now Employed in Digital Media Projects Area at Parliament House
- Contact: neilp@goldweb.com.au

COMMUNICATIONS LAB

3

Digital Media

- First media systems were Analog
- Most media are converting to digital
  - Computer storage
  - Music (LP-CD)
  - Telecommunications
  - Multimedia
  - Internet Networking (TCPIP)
  - Radio (DAB)
  - Television (DTTB)



4

What is Television

- Images - Black and White Shades of Grey
- Colour - Hue & Saturation
- Sound - Audio Information
- Data - Teletext & Other Data
- Synchronisation - Specifies the Timing
- Transport System - Gets the Above to your TV

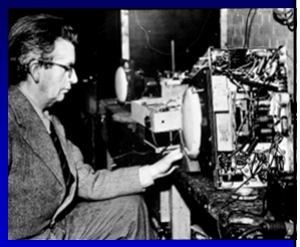
5

History - Ferdinand Braun - CRT

- 1890 Ferdinand Braun developed the Cathode Ray Tube.
- 1897 developed the Cathode Ray Oscillograph, the precursor to the radar screen and the television tube
- 1907 First use of cathode ray tube to produce the rudiments of television images.
- He shared the Nobel Prize for physics in 1909 with Guglielmo Marconi for his contributions to the development of wireless telegraphy.

6

John Logie Baird - Basic TV

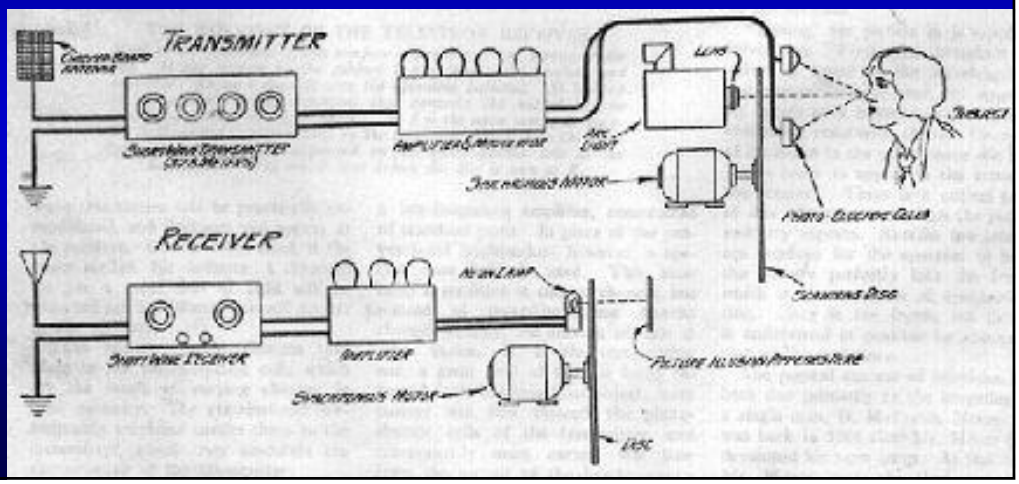


- Oct 1923 John Logie Baird was the first person anywhere in the world to demonstrate true television in the form of recognisable images, instantaneous movement and correct gradations in light and shade. Scanning was done mechanically with a Nipkow disc. The first 30 line picture transmitted was a Maltese cross.
- 1927 he also demonstrated video recording
- 1928 transatlantic television
- 1937 the broadcast of high definition colour pictures
- 1941 stereoscopic television in colour
- 1944 the multi-gun colour television tube, the forerunner of the type used in most homes today.

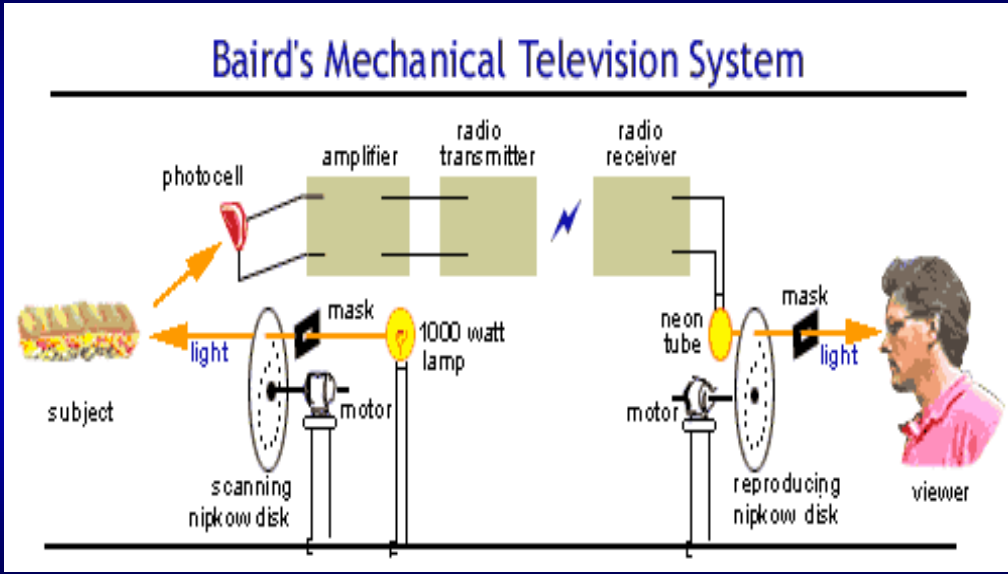
7

Early Mechanical Approach to TV

Mechanical Nipkow discs were used to scan the image and reconstitute the image at the receiver. PE cells were used to capture the image. The problem was synchronising the disks.



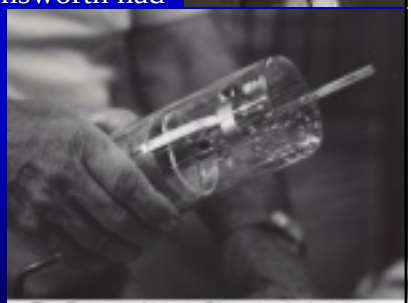
30 Line Mechanical TV



9

Electronic Television - Farnsworth

- In 1922 at Age 14 Philo Farnsworth had the idea of how to make Electronic Television possible.
- Sept. 7, 1927, Farnsworth painted a square of glass black and scratched a straight line on the centre. The slide was dropped between the Image Dissector (the camera tube that Farnsworth had invented earlier that year) and a hot, bright, carbon arc lamp. On the receiver they saw the straight-line image and then, as the slide was turned 90 degrees, they saw it move. This was the first all-electronic television picture ever transmitted.

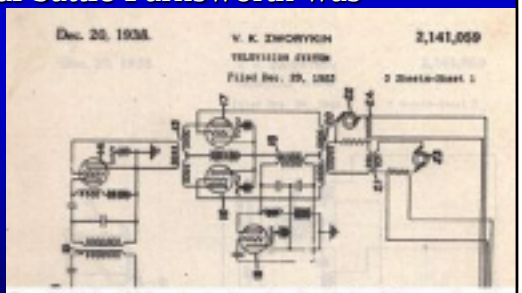


The Recreated Image Dissector, in the same hands that built the original 50 years earlier

10

Vladimir Zworykin - Iconoscope

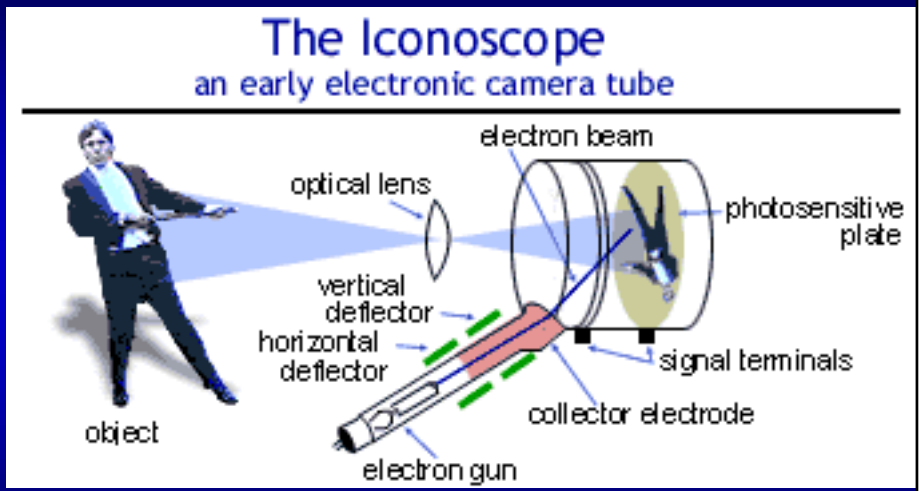
- In 1923 Vladimir Zworykin of RCA made a patent application for a camera device, and by 1933 had developed a camera tube he called an Iconoscope. Although Zworykin submitted his patent application first after many years of legal battle Farnsworth was acknowledged as the inventor of electronic television.
- By the end of 1923 he had also produced a picture display tube, the "Kinescope"



Zworykin's 1938 patent - bearing the date of the application that was ruled "inoperative" by the patent office in 1934

11

Significant Television Inventions



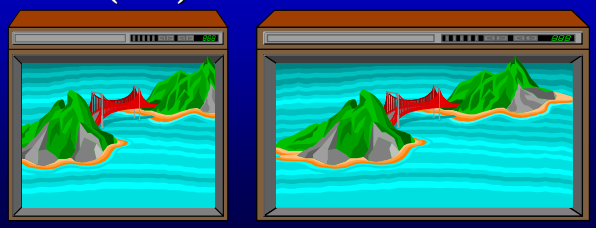
- These inventions were the underlying basis of the development of Television as we know it today

12

Aspect ratio

- First TV displays were Round
- Rectangular Rasters easier to Generate
- Television Developed using a 4:3 Aspect Ratio
- Cinematic formats are much wider
- World now moving to 16:9 Aspect Ratio

4:3 (12:9) **16:9**



13

Film

- Has been the highest Resolution storage format.
- Various frame sizes used. 16mm, 35mm & 70mm
- Difficult to produce, store, handle and display.
- Easily degraded due to contamination and scratches.
- Generally recorded at 24 fps.
- Generally projected at 72 fps (each frame 3x) to reduce flicker

14

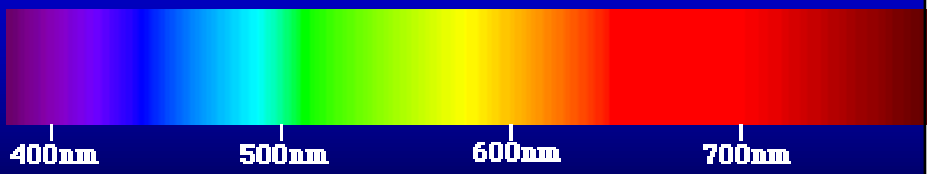
Telecine Chain

- Use a Telecine to convert Film media to television formats
- Two main types:
  - Flying Spot Scanner
  - CCD Line Sensor
- Film generally 24 Fps
  - Run at 25 Fps for 25 Hz video standards
  - Use 3:2 Pulldown for 30 Hz video standard

15

Colour

- Visible light has a Power Spectral Distribution that is interpreted by the eye and the brain.
- Sir Isaac Newton once said:
  "Indeed rays, properly expressed, are not coloured"
- Colour is the perceptual result of light in the visible region of the EM spectrum. (400-700 nm)

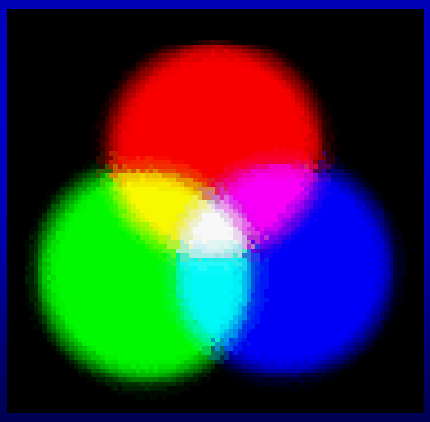


- The concept of colour is a construct of the brain

16

Primary Colours

- Two sets of colour Primaries:
- Subtractive
- Additive

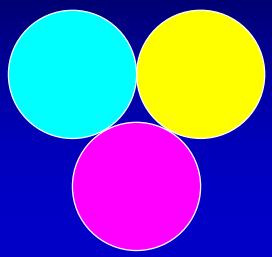


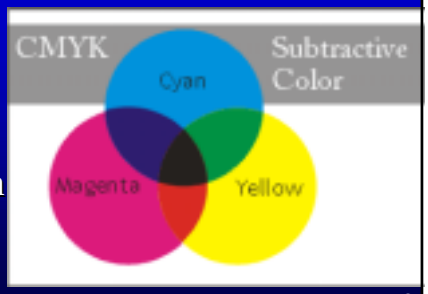
17

Subtractive Primary Colours

- Cyan, Magenta, Yellow
  - Subtractive Mixing - Absorbs power from selected regions of the spectrum
  - Applies to Reflected and Filtered Light Sources
  - Dyes, Paint and Printing use CMYK

Cyan - Filters Red
Magenta - Filters Green
Yellow - Filters Blue

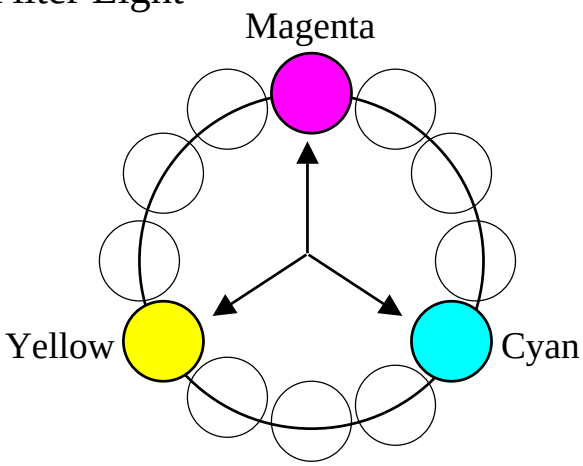




18

CMYK Primary Colours

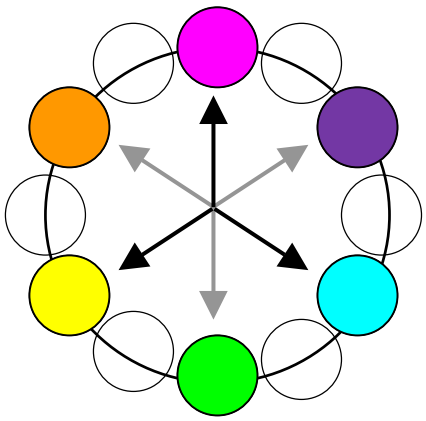
- CMY Filter Light



19

CMYK Secondary Colours

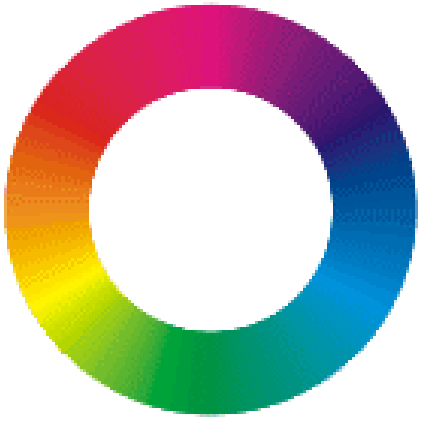
- Mixing Primaries Produces Secondary Colours



20

CMYK Tertiary Colours

- Tertiary colours result from further mixing



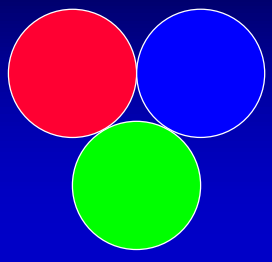
8 bit - 256 Colours

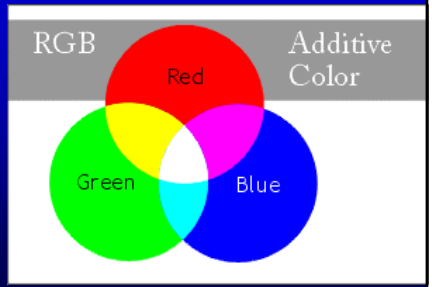
21

Additive Primary Colours

- Red, Green, Blue
  - Additive Mixing - Superposition of colours
  - Applies to Combined Light Sources
  - Television & Computer Displays use RGB

Green+Blue = Cyan
Red+Blue = Magenta
Red+Green = Yellow

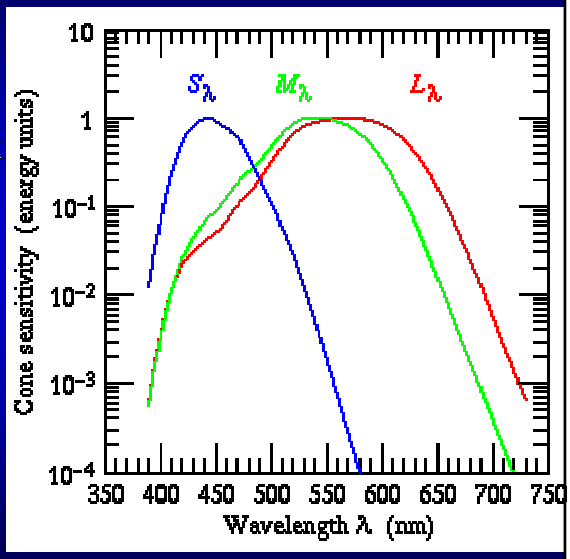




22

Human Colour Vision

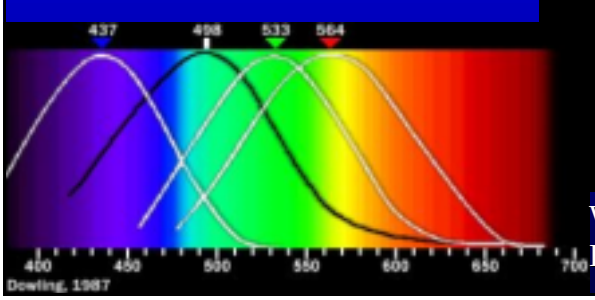
- Cones in Eye respond to colour
- Short, Medium & Long wavelength cone sensitivities
- Colours that are perceived from cone stimulation are coloured by processing in the brain

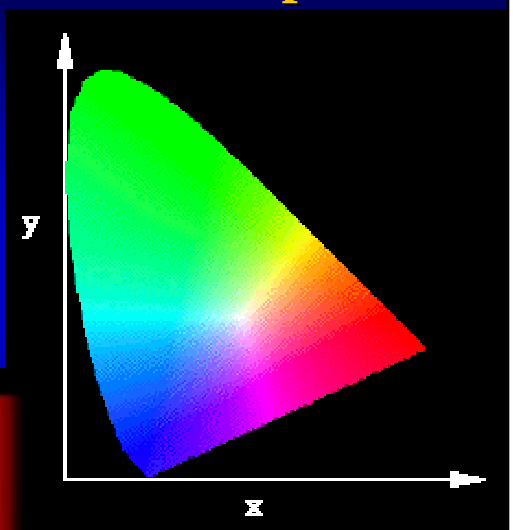


23

Human Eye - Colour Space

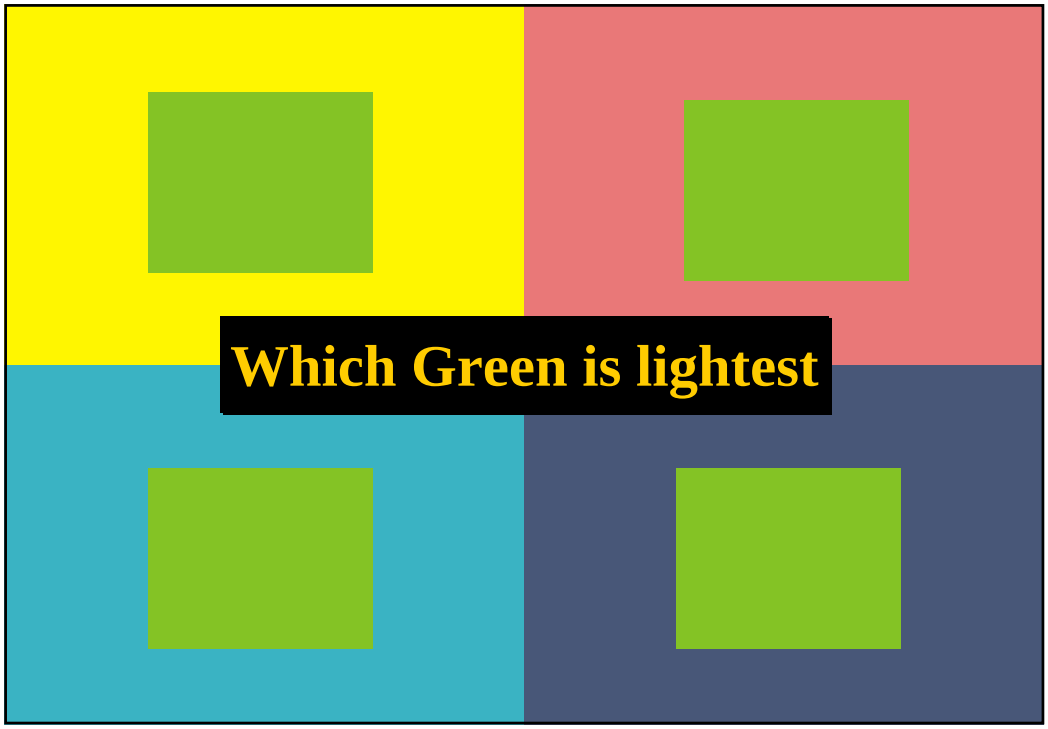
- Fin shaped diagram represents the colour space that can be discerned by the human visual system.





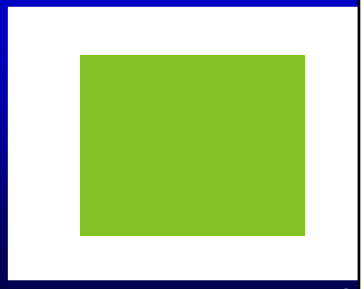
White lines are Cone sensitivity
Black line is Rod sensitivity

24



Colour Temperature

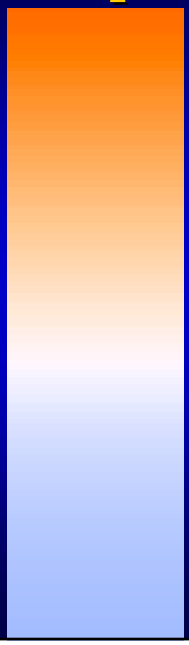
- In Human vision the brain looks for a white area to calibrate it's colour perception.
- Images without white can confuse the brain.
- Light sources have varying colour temperatures.
- TV cameras adjust the proportion of R G & B to obtain white for the colour temperature of the illuminating light source.
- This is called the white balance adjustment.



26

Light Sources - Colour Temp

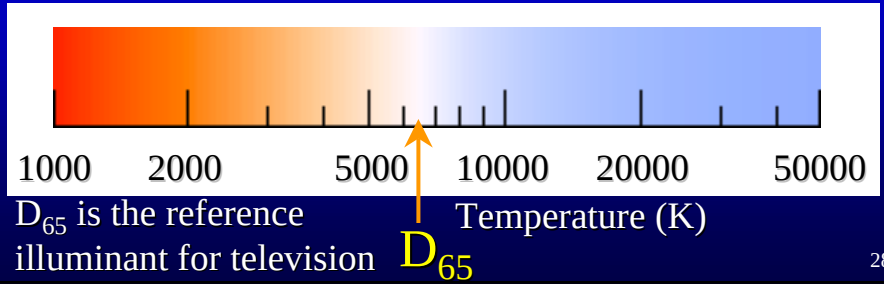
Candle	1500 K
Sunset	2000 K
Incandescent	3000 K
Tungstan	3200 K
Flourescent Cool	4200 K
Carbon Arc	5000 K
Flourescent White	5000 K
Clear Sky Day	5300 K
Average Sunlight	6000 K
Cloudy Day	6500 K
Television Phosphor	6500 K
Flourescent Daylight	6700 K
Electronic Flash	7000 K
Shade	8000 K
Computer Monitor	9300 K



27

Light Sources - Black Body

- Planck found the spectrum radiated from a hot object – a *black body radiator* – is a function of the temperature to which the object is heated.
- Many sources of illumination have, at their core, a heated object, so it is often useful to characterise an illuminant by specifying the temperature of a black body radiator that appears to have the same hue.

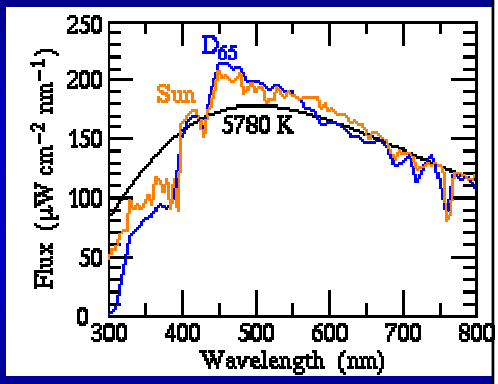


D_{65} is the reference illuminant for television

28

Light Sources - The Sun

- The effective surface temperature of the Sun is 5780 K
- The spectrum of the Sun (above atmosphere) is not a precise black body
- Television is based on the D_{65} Illuminant that has a spectral power distribution that is a close match to the Sun

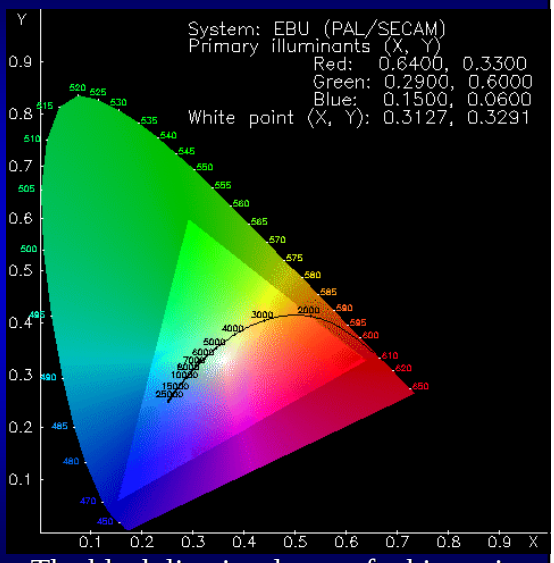


- The Earths atmosphere filters the sun's light and so the time of day (angle through the atmosphere) affects the colour temperature of daylight.

29

PAL - Colour Space

- Television can reproduce only some of the colours visible to Humans
- The highlighted triangle represents the range of colours that a TV display is able to reproduce

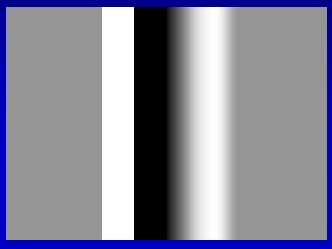


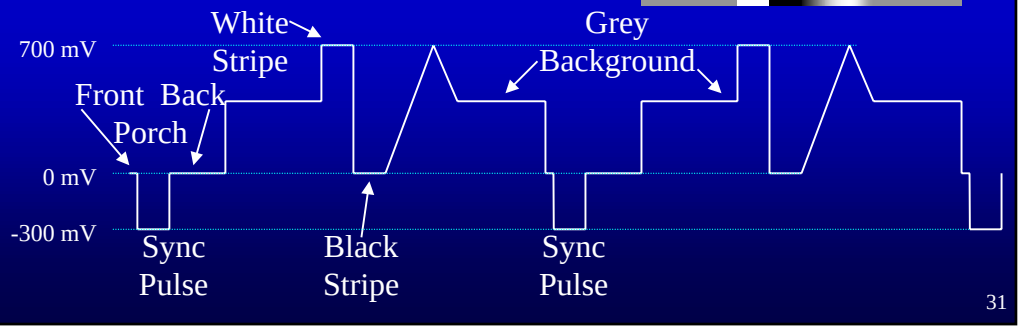
The black line is a locus of white points

30

The Video Signal

- First Television Pictures were Black & White Referred to as Luminance
- Video refers to the linear base-band signal that contains the image information

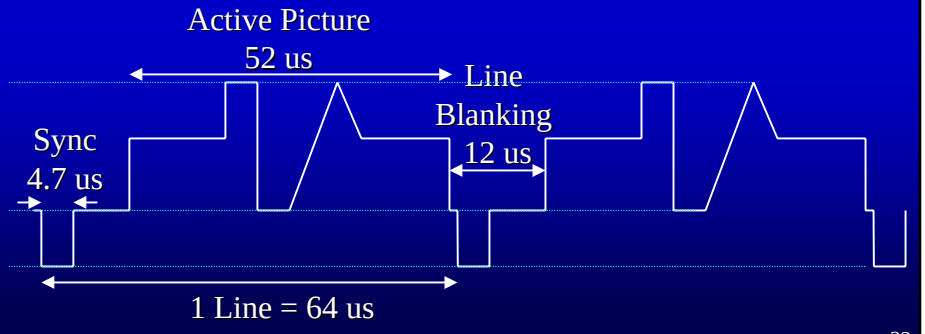




31

Video Timing

- SDTV
  - 64 us for each line (15.625 kHz)
  - 52 us Active Picture Area
  - 12 us Blanking and Synchronisation
- Two level sync pulse 300 mV below blanking



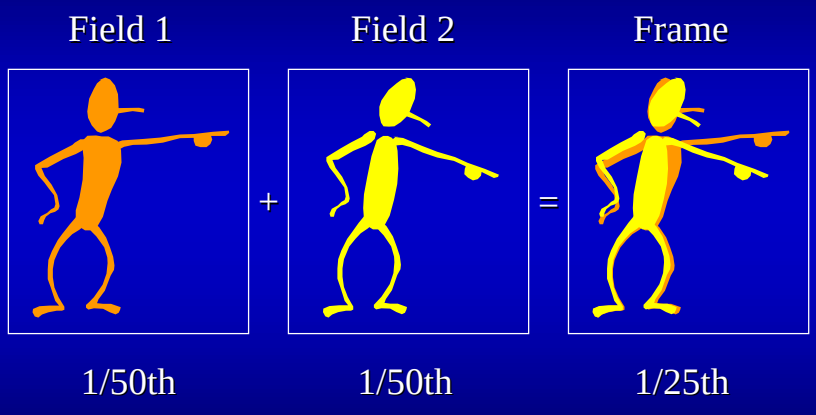
32

Frame Rate

- A Frame represents a complete TV picture
- Our analog TV Frame consists of 625 lines.
- A Frame is usually comprised of 2 Fields each containing 1/2 the picture information
- Our system has a Frame rate of 25 Hz
- The Field rate is 50 Hz
- Pictures displayed at 25 Hz exhibit obvious flicker
- Interleaving the Fields reduces flicker.

33

Fields and Frames



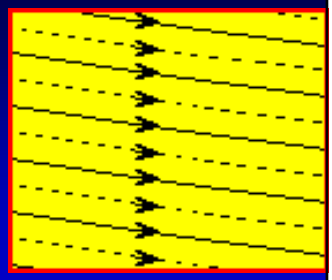
34

Flicker and Judder

- Flicker and Judder are terms used to describe visual interruptions between successive fields of a displayed image. It affects both Film & TV.
- If the update rate is too low, persistence of vision is unable to give illusion of continuous motion.
- Flicker is caused by:
  - Slow update of motion Information
  - Refresh rate of the Display device
  - Phosphor persistence Vs Motion Blur
- Judder usually results from Aliasing between Sampling rates, Display rates and Scene motion

35

Interlace



- To reduce the perceived screen flicker (25 Hz) on a television, a technique called 'interlacing' is employed.
- Interlacing divides each video frame into two fields; the first field consists of the odd scan lines of the image, and the second field of each frame consists even scan lines.
- Interlace was also used to decrease the requirement for video bandwidth.
  It is a form of Compression

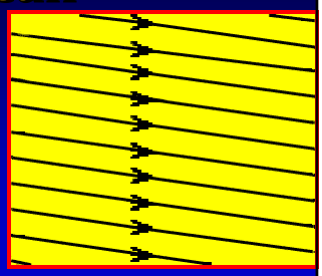
36

Interlaced Vs Progressive Scan

- Interlaced pictures. - 1/2 the lines presented each scan
  1,3,5,7,9,11,13.....623,625 field 1
  2,4,6,8,10,12,14.....622,624 field 2
- Because the fields are recorded at separate times this leads to picture twitter & judder
- Progressive pictures - all the lines sent in the one scan.
  1,2,3,4,5,6,7,8.....623,624,625 picture
- No twitter or judder.
- But twice the information rate.

37

Progressive Scan



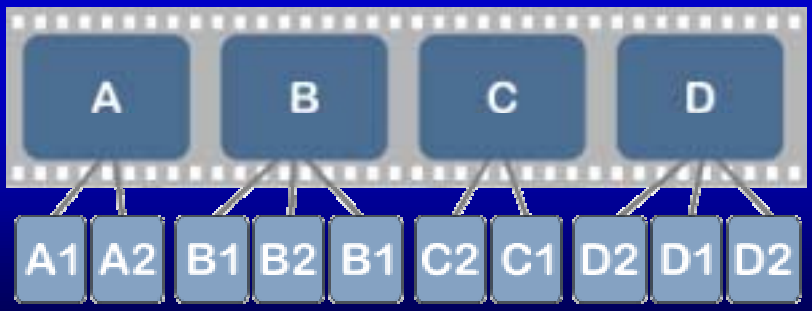
- Simplifies the interpolation and filtering of images
- Allows MPEG-2 compression to work more efficiently by processing complete pictures
- Direct processing of progressively-scanned sources
- 24 frame/second progressive film mode can be provided.
- Assists video conversions with different:
  - numbers of scan lines
  - numbers of samples per line
  - temporal sampling (i.e., picture rate)

Progressive Doubles Raw Data Requirement

38

3/2 Pulldown for Film to Video

- Used to convert 24 Fps film to 30 Fps in USA
  - Each film Frame is 1/24th Second
  - Each video field is 1/60th Second
- 5 Fields = 5/60th ≡ 2/24th = 1/12th = 2 Frames

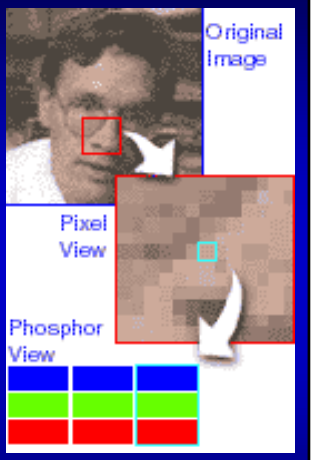


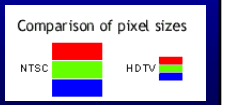
Extra Fields are B1 and D2

39

Resolution

- **The number of picture elements resolved on the display**
- **Resolution in TV is limited by:**
  - **Capture device**
  - **Sampling Rate**
  - **Transmission System / Bandwidth**
  - **Display Device**
    - **Dot Pitch, Phosphor**
    - **Focus & Convergence**
  - **Viewing distance / Display size**
  - **Human Eye**
- **Typical SDTV systems attempt to transfer 720 pixels per line**





40

Colour Equations for PAL

- For B&W only had to transmit Luminance (Y)
- A Colour Image has Red, Green & Blue Components which need to be transmitted.
- We already have the Y signal.
- To remain compatible with Monochrome sets use Y, U & V to represent the Full Colour Picture

$$Y = 0.299\ R + 0.587\ G + 0.114\ B$$

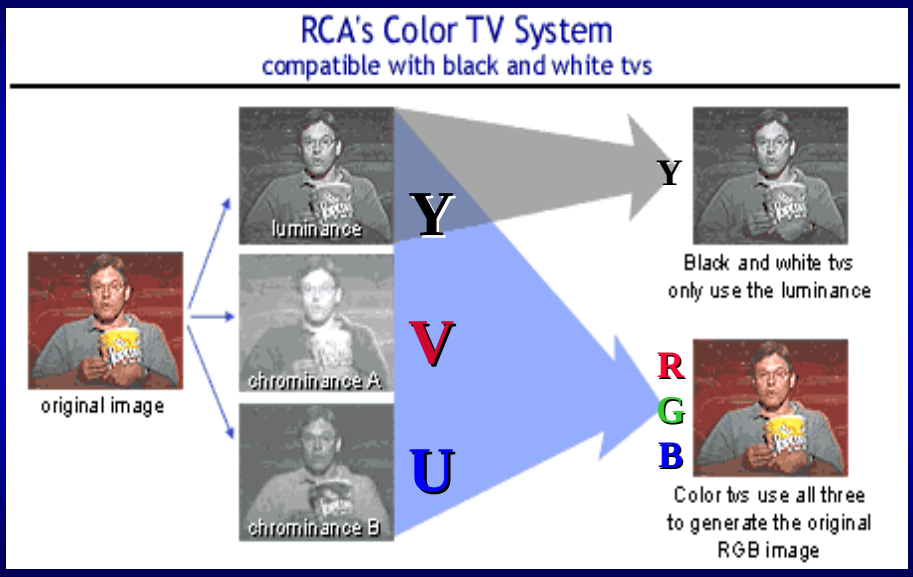
Colour Difference Signals

$$U = 0.564\ (B - Y)$$

$$V = 0.713\ (R - Y)$$

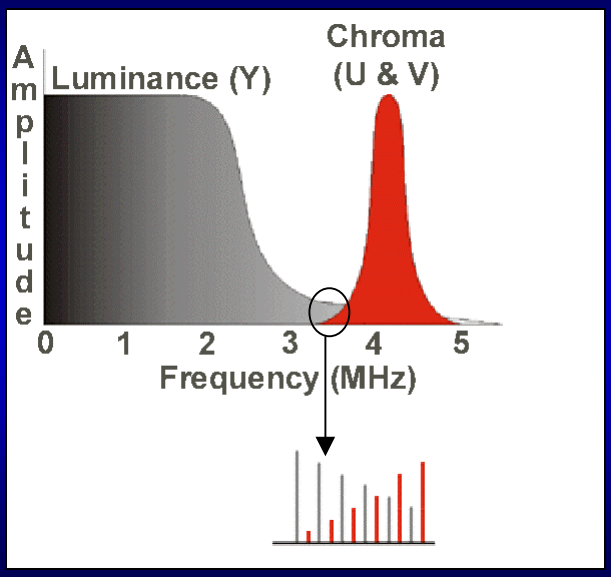
41

A Compatible Colour System



42

Colour Sub Carrier



- Colour Sub-Carrier is added at 4.43361875 MHz
- Frequency selected to interleave colour information spectra with Luma spectrum
- More efficient use of spectrum.

43

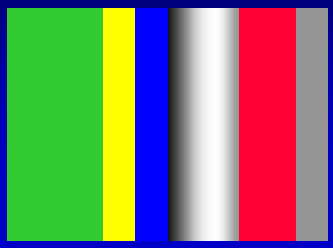
Adding Colour to B&W Video

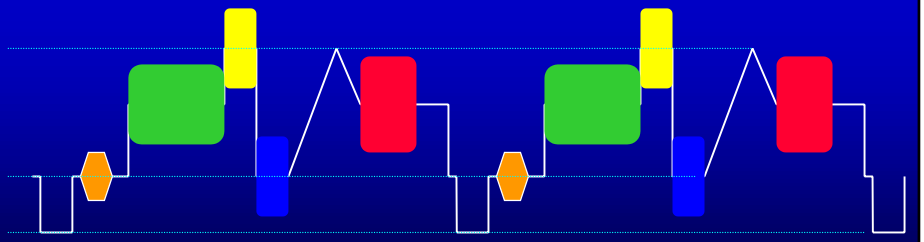
First TV signals were only Luminance

In 1975 we added PAL Colour System

A Colour Reference Burst on Back Porch

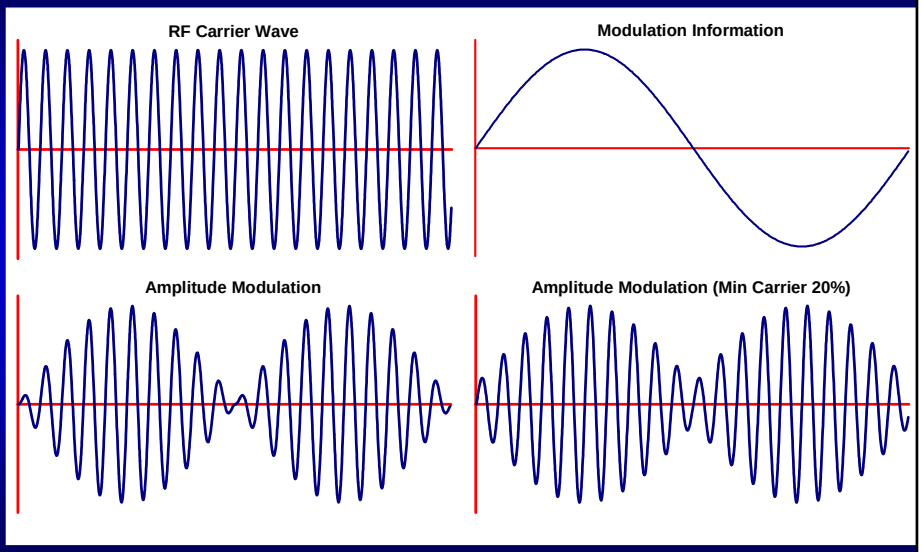
And IQ modulated Colour Information





44

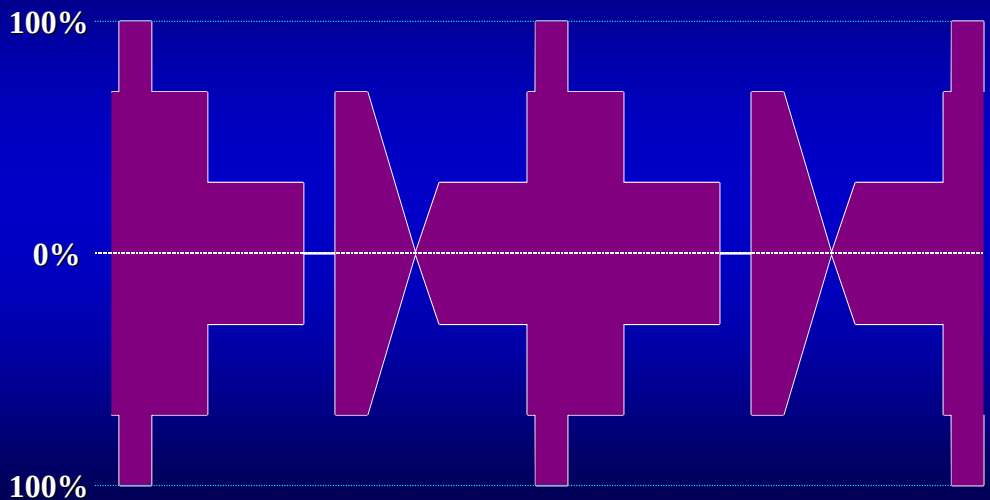
Amplitude Modulation - 1



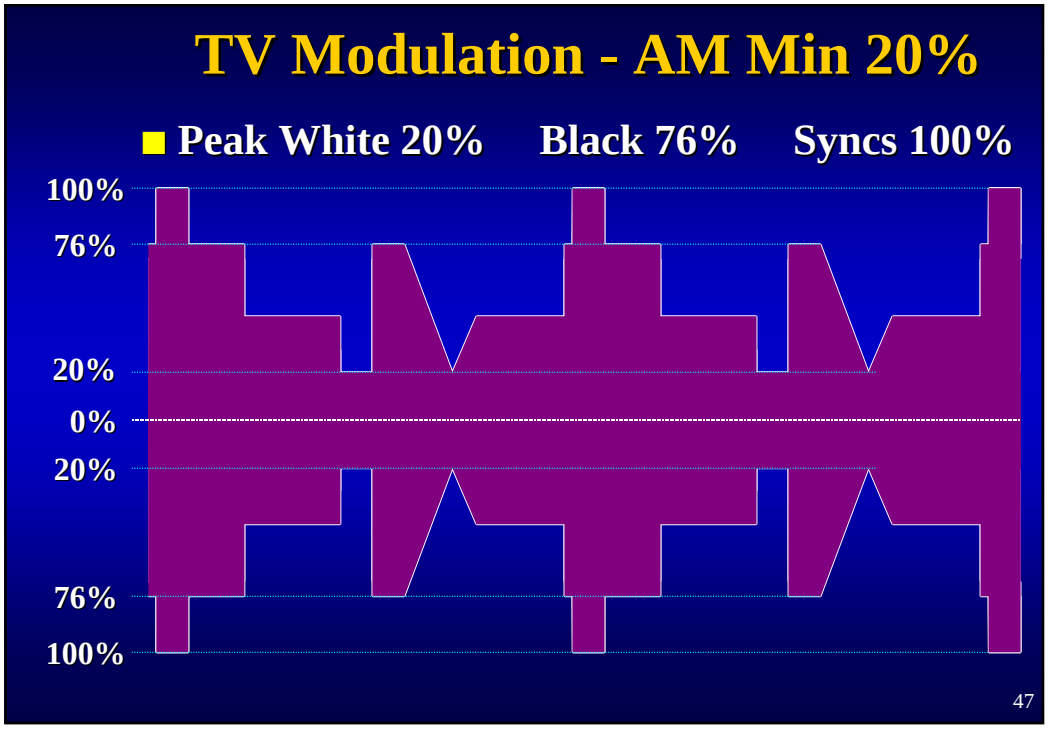
45

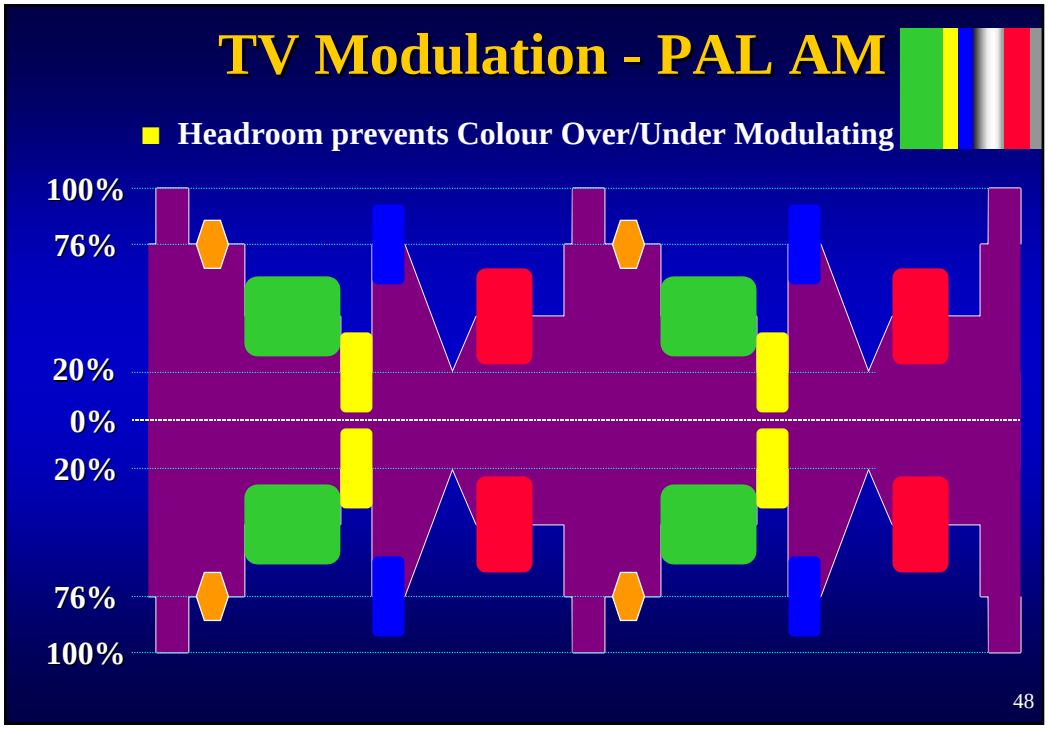
Television Modulation - AM

- TV uses Negative AM Modulation

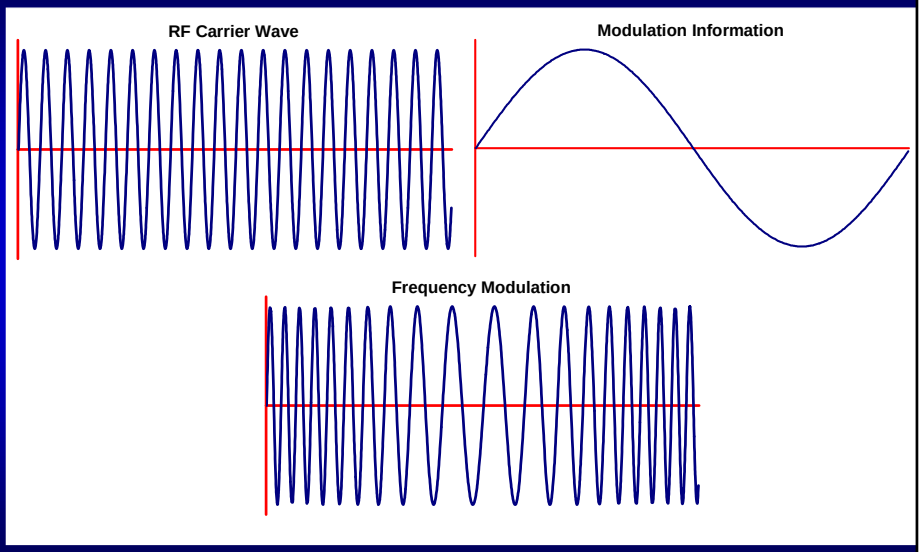


46


TV Modulation - AM Min 20%
Peak White 20%
Black 76%
Syncs 100%
100%
76%
20%
0%
20%
76%
100%
47


TV Modulation - PAL AM
Headroom prevents Colour Over/Under Modulating
100%
76%
20%
0%
20%
76%
100%
48

Frequency Modulation

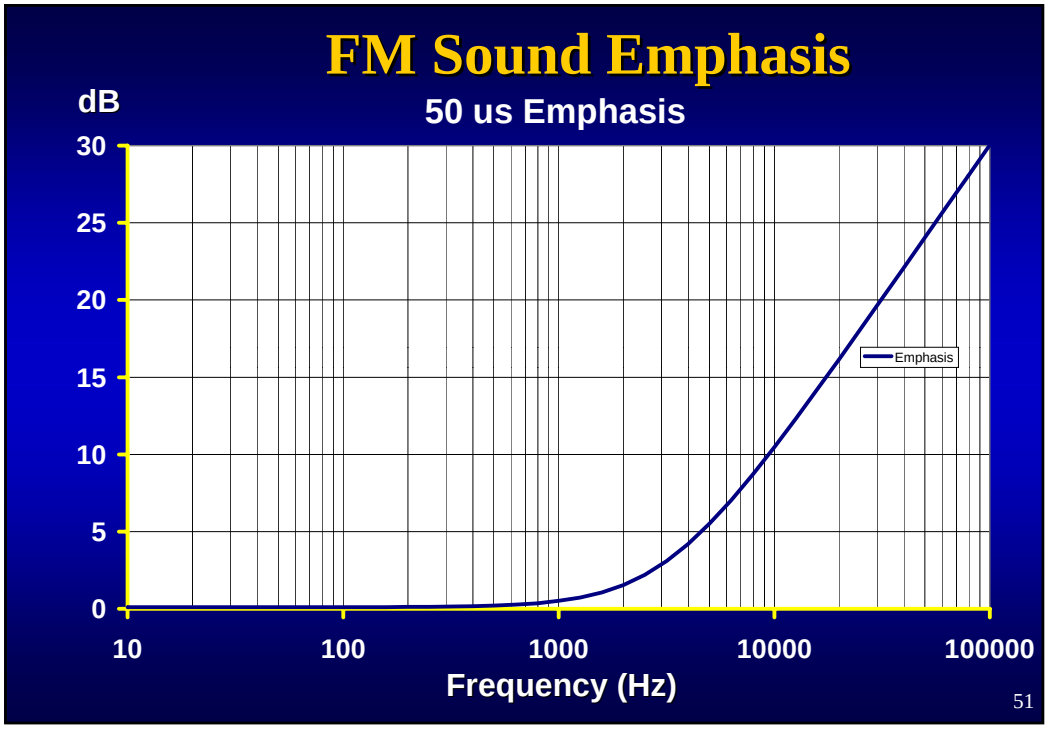


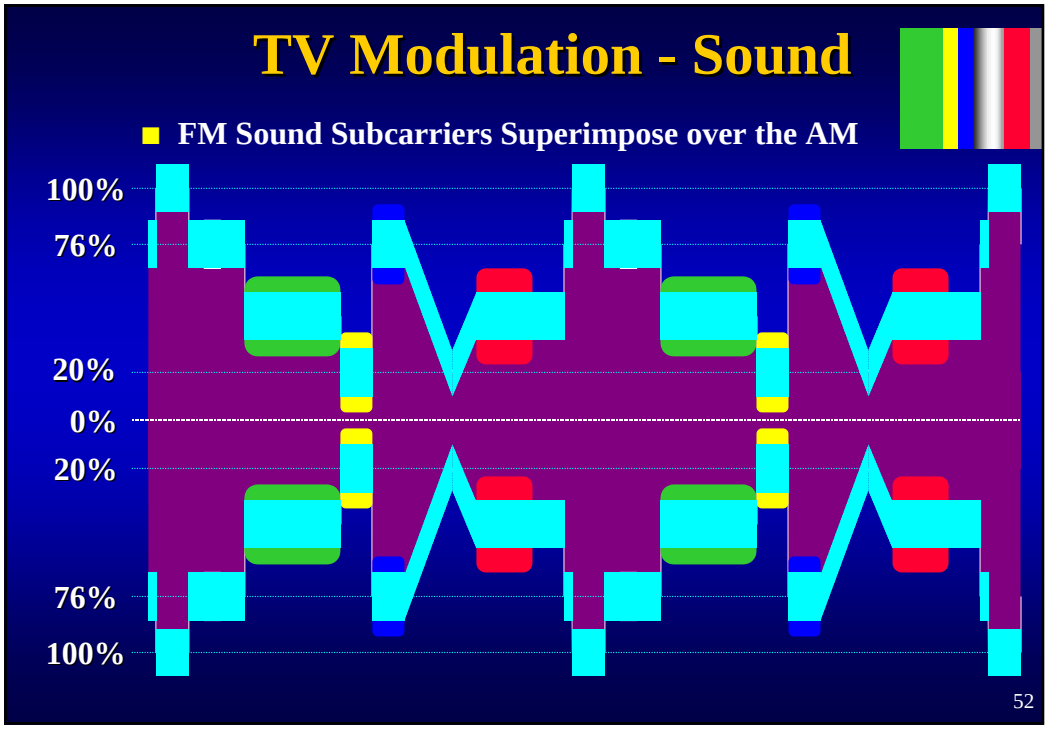
49

Intercarrier Sound

- A FM subcarrier is added to the AM picture to carry the Audio information
- FM Deviation 50 kHz used with 50 us Emphasis
- PAL-B uses 5.5 MHz Sound subcarrier (L+R)
  - -10 dB wrt Vision for mono single carrier mode
  - -13 dB wrt Vision for Stereo & Dual mode
- 2nd Sound subcarrier for Stereo (R)
  - 5.7421875 MHz (242.1875 kHz above main sound)
  - -20 dB wrt Vision carrier
  - 54.7 kHz Subcarrier Pilot tone added to indicate: Stereo (117.5 Hz) or Dual mode (274.1 Hz)

50


FM Sound Emphasis
50 us Emphasis
dB
30
25
20
15
10
5
0
10
100
1000
10000
100000
Frequency (Hz)
Emphasis
51


TV Modulation - Sound
FM Sound Subcarriers Superimpose over the AM
100%
76%
20%
0%
20%
76%
100%
52

University of Canberra
Advanced Communications Topics

Elements of Digital Television

Lecture 2
Television Fundamentals, Analog TV and Formats

by: Neil Pickford

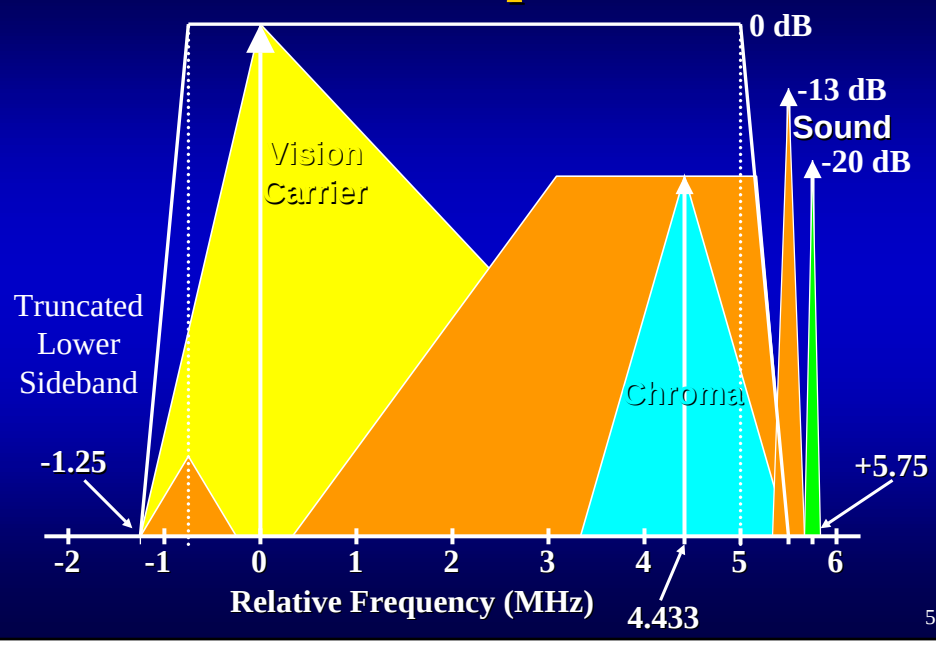
53

Vestigial Side Band - VSB

- AM Modulation gives a Double Side Band signal
  - Each sideband contains identical information
  - 5 MHz of information means required BW > 10 MHz
  - Only one sideband is required for demodulation
- To conserve spectrum Analog TV uses VSB
  - Only 1.25 MHz of the lower sideband is retained
  - VSB truncates the high frequency part of the lower sideband.
- To implement Analog TV in 1950s with no lower sideband would have been very expensive because of the filtering required.

54

PAL-B Spectrum



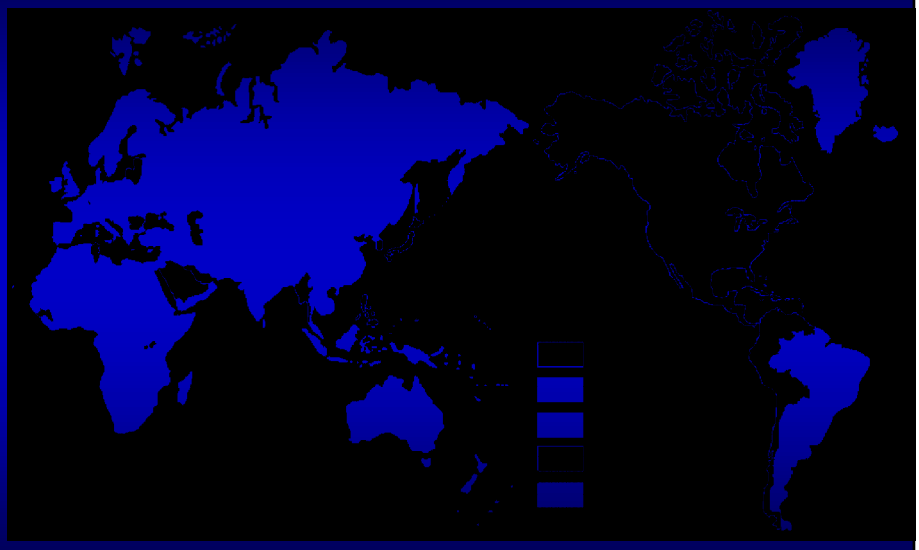
55

Frequencies Used

- Australia uses 7 MHz Channels
- VHF Band I Ch 0-2 45 - 70 MHz
- VHF Band III Ch 6-12 174 - 230 MHz
- UHF Band IV Ch 27-35 520 - 582 MHz
- UHF Band V Ch 36-69 582 - 820 MHz

56

World TV Standards



Australia is PAL

57

NTSC

- National Television Systems Committee (NTSC)
- First world wide Colour system Adopted (1966)
- Generally used in 60 Hz countries
- Predominantly 525 line TV systems
- AM modulation of Luma & Syncs (4.2 MHz)
- U & V Chroma AM Quadrature Modulated (IQ)
- Chroma Subcarrier 3.579545 MHz
- FM or Digital subcarrier modulation of Sound

58

SECAM

- Sequentiel Couleur Avec Memoire (SECAM)
- Developed by France before PAL
- 625 Line 50 Hz Colour system
- Uses AM modulation for Luminance & Sync
- Line sequentially sends U & V Chroma components on alternate lines
- Receiver requires a 1H chroma delay line
- Uses FM for Colour subcarrier 4.43361875 MHz
- Uses FM for sound subcarrier

59

PAL

- Phase Alternation Line-rate (PAL) Colour System
- Developed in Europe after NTSC & SECAM
- Generally associated with 50 Hz Countries
- Predominantly 625 Line system
- AM modulation of Luma & Syncs (5 MHz)
- U & V Chroma AM Quadrature Modulated with V (R-Y) component inverted on alternate lines
- Chroma Subcarrier 4.43361875 MHz
- FM or Digital subcarrier modulation of Sound

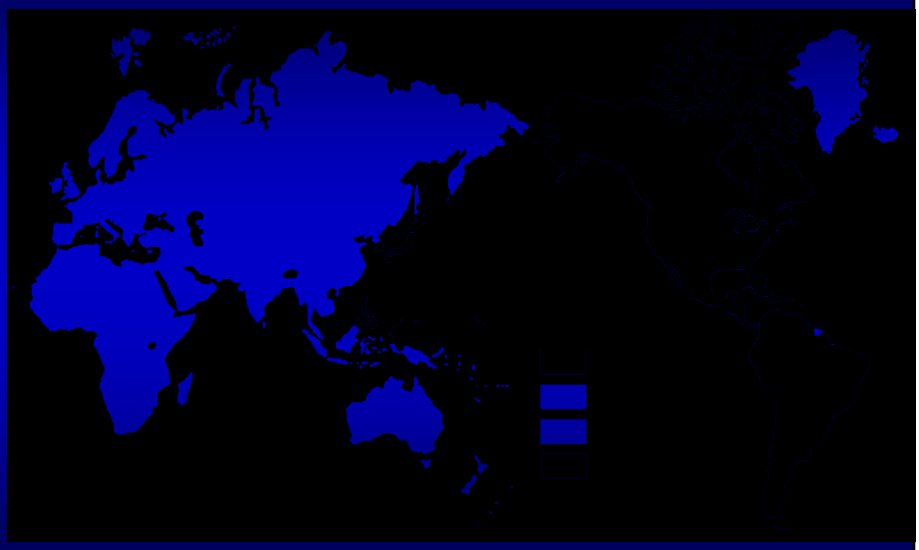
60

Transmission Bandwidth - VHF

Australia is one of a few countries with 7 MHz VHF TV

61

Transmission Bandwidth - UHF



Australia is Alone using 7 MHz on UHF

62

U & V Components

$$Y = 0.299\,R + 0.587\,G + 0.114\,B$$

$$B\text{-}Y = -0.299R - 0.587G + 0.886B$$

$$U' = B\text{-}Y$$

$$R\text{-}Y = 0.701R - 0.587G - 0.114B$$

$$V' = R\text{-}Y$$

63

Y, B-Y & R-Y Values

$$B\text{-}Y = -0.299R - 0.587G + 0.886B$$

Condition	R	G	B	Y	B-Y	R-Y
White	1	1	1	1	0	0
Black	0	0	0	0	0	0
Red	1	0	0	0.299	-0.299	0.701
Green	0	1	0	0.587	-0.587	-0.587
Blue	0	0	1	0.114	0.886	-0.114
Yellow	1	1	0	0.886	-0.886	0.114
Cyan	0	1	1	0.701	0.299	-0.701
Magenta	1	0	1	0.413	0.587	0.587

B-Y Range is too large

64

Y, B-Y & R-Y Values

R-Y = 0.701R - 0.587G - 0.114B

Condition	R	G	B	Y	B-Y	R-Y
White	1	1	1	1	0	0
Black	0	0	0	0	0	0
Red	1	0	0	0.299	-0.299	0.701
Green	0	1	0	0.587	-0.587	-0.587
Blue	0	0	1	0.114	0.886	-0.114
Yellow	1	1	0	0.886	-0.886	0.114
Cyan	0	1	1	0.701	0.299	-0.701
Magenta	1	0	1	0.413	0.587	0.587

R-Y Range is too large

65

Y, U & V Values

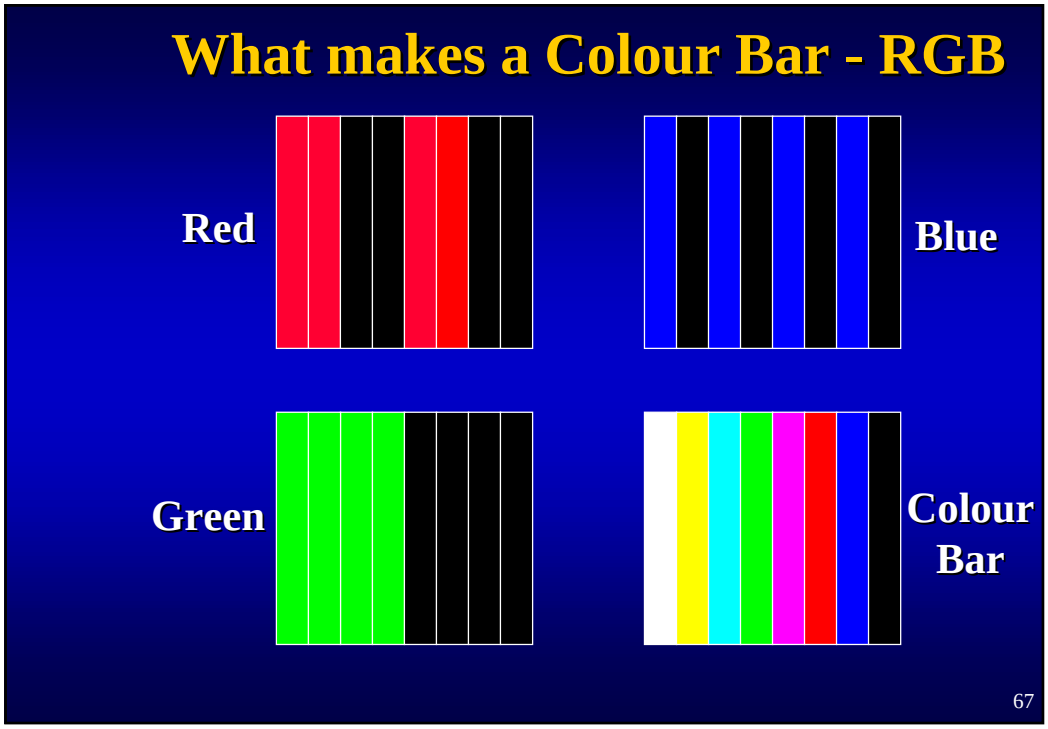
U = 0.564 (B-Y) V = 0.713 (R-Y)

Condition	R	G	B	Y	U	V
White	1	1	1	1	0	0
Black	0	0	0	0	0	0
Red	1	0	0	0.299	-0.169	0.500
Green	0	1	0	0.587	-0.331	-0.419
Blue	0	0	1	0.114	0.500	-0.081
Yellow	1	1	0	0.886	-0.500	0.081
Cyan	0	1	1	0.701	0.169	-0.500
Magenta	1	0	1	0.413	0.331	0.419

$C = 0.564\ U\ sin(w_c t) \pm 0.713\ V\ cos(w_c t)$

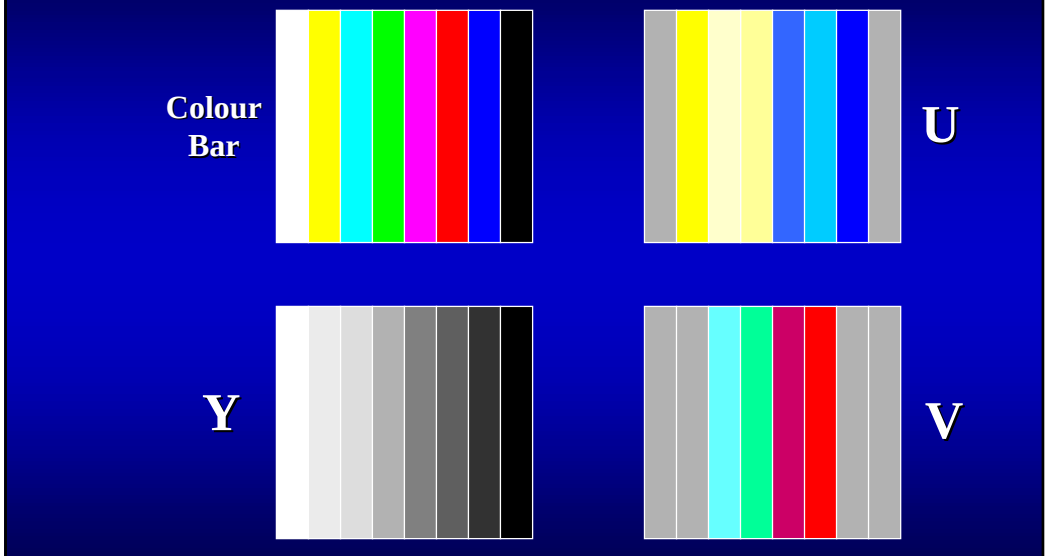
66

What makes a Colour Bar - RGB



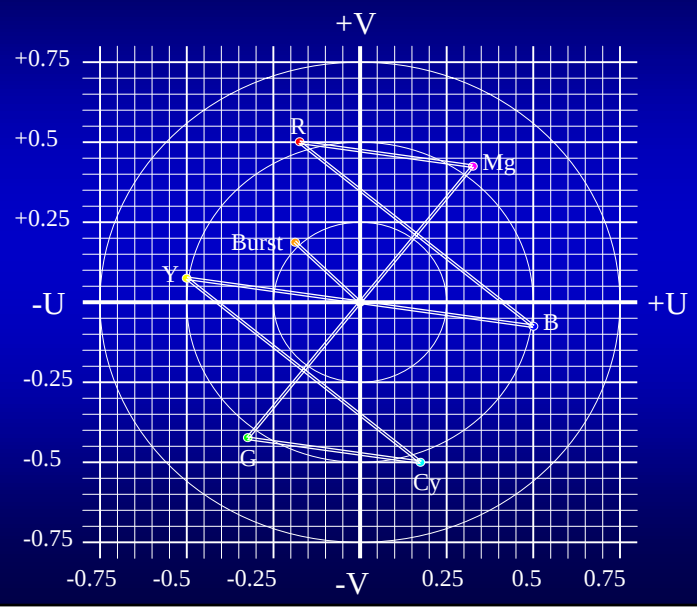
67

Component Colour Bar - YUV



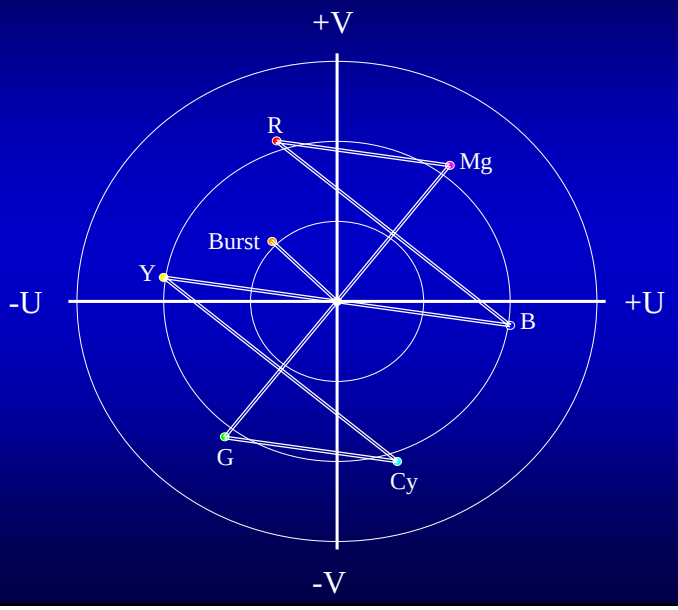
68

Plotting U & V Coordinates



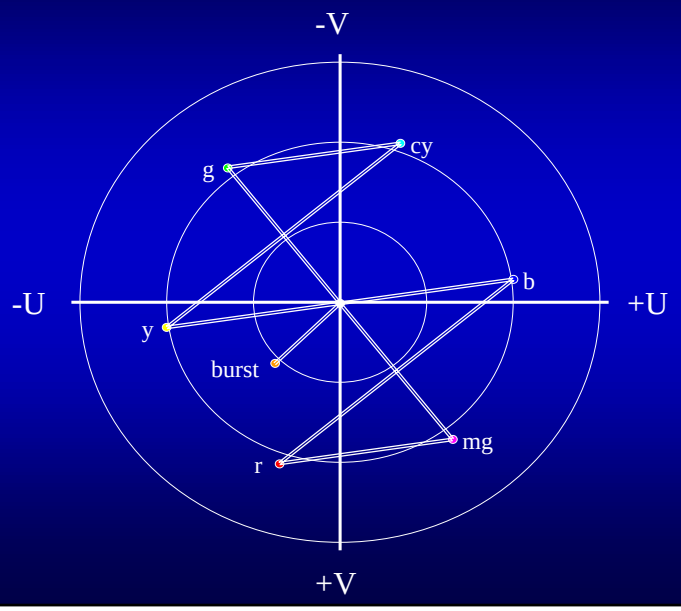
69

Line A Chrominance Vectors



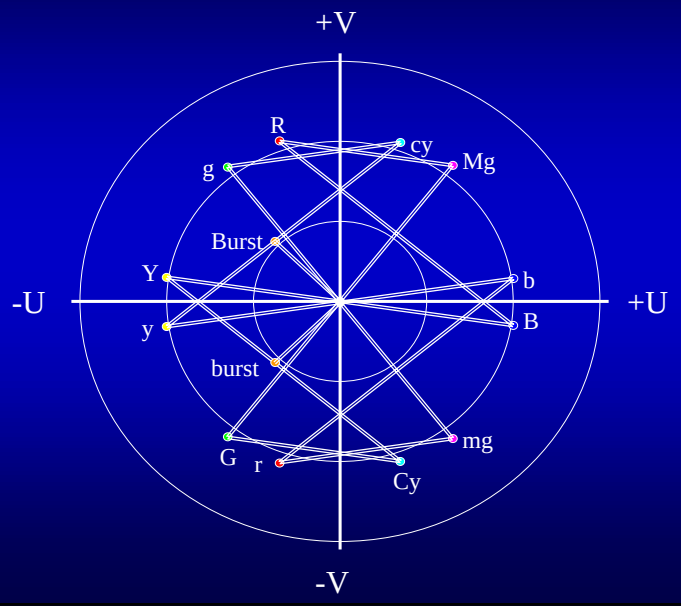
70

Line B Chrominance Vectors



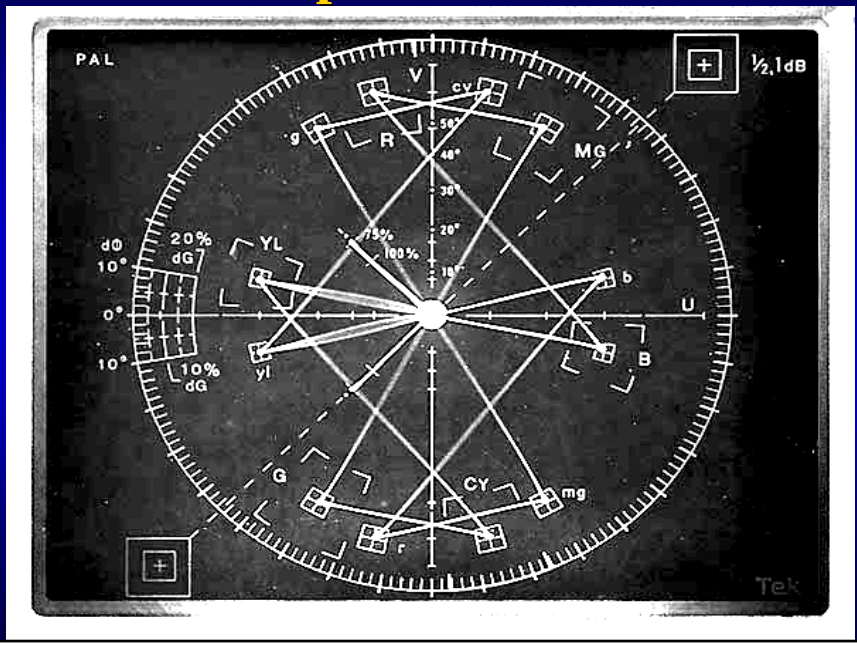
71

PAL Chrominance Vectors



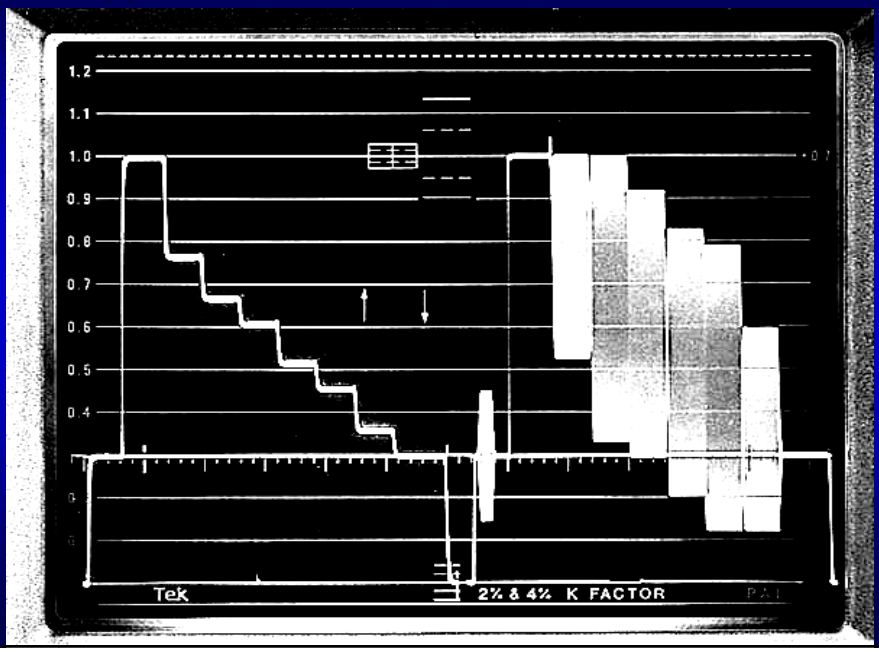
72

Vectorscope - PAL Colour Bar



73

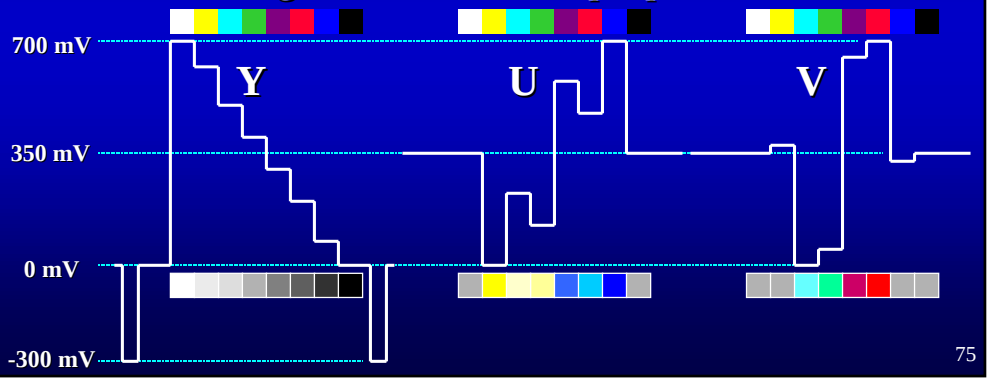
Waveform Monitor - PAL CB



74

Component Video

- Video distributed as separate Y U V Components
- Y signal is 700 mV for Video Black-White
- Y Signal carries Sync at -300 mV
- U & V signals are 700 mV pk-pk. 350 mV at 0



75

Coax

- Video Signals are transmitted on Coaxial Cable
- 75 Ohm Coax - RG-59 or RG-178
- Video is usually 1 Volt Peak to Peak
- Terminated with 75 Ohms at end of run
- High impedance loop through taps are used
- To split video must us a Distribution Amplifier
- For Component signals all coaxes must be the same length otherwise mistiming of the video components will occur

76

Standard Definition Television SDTV

- The current television display system
- 4:3 aspect ratio picture, interlace scan
- Australia/Europe
  - 625 lines - 720 pixels x 576 lines displayed
  - 50 frames/sec 25 pictures/sec
  - 414720 pixels total
- USA/Japan
  - 525 lines - 704 pixels x 480 lines displayed
  - 60 frames/sec 30 pictures/sec
  - 337920 pixels total

77

Enhanced Definition Television EDTV

- Intermediate step to HDTV
- Doubled scan rate - reduce flicker
- Double lines on picture - calculated
- Image processing - ghost cancelling
- Wider aspect ratio - 16:9
- Multi-channel sound

78

High Definition Television - HDTV

- Not exactly defined - number of systems
- System with a higher picture resolution
- Greater than 1000 lines resolution
- Picture with less artefacts or distortions
- Bigger picture to give a viewing experience
- Wider aspect ratio to use peripheral vision
- Progressive instead of interlaced pictures

79

HDTV Parameters - AS 4599

- HDTV Defined as a MPEG-2 stream which is compliant with MP@HL encoding.
- HDTV sample rate:
  - Less than 62 668 800 samples per second
  - Greater than 10 368 000 samples per second
- Systems with less than 10 368 000 samples per second are defined as SDTV

Max Sample Density	Max Sample Rate	Max Total Bit Rate	Max VBV Buffer	Profile & Level
1920/1152/60	62 668 800	80 Mb/s	9 781 248	MP@HL
720/576/30	10 369 000	15 Mb/s	1 835 008	MP@ML

80

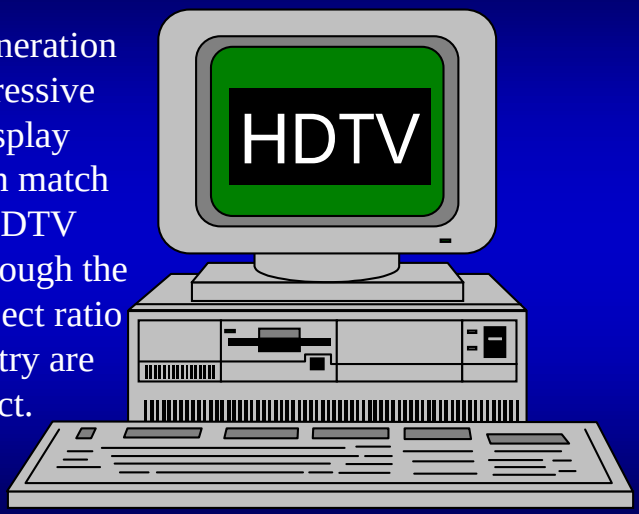
HDTV
Have We Heard This Before?

- The first TV system had just 32 lines
- When the 405 line system was introduced it was called HDTV!
- When 625 line black & white came along it was called HDTV!
- When the PAL colour system was introduced it was called HDTV by some people.
- Now we have 1000+ line systems and digital television - guess what? Its called HDTV!

81

Do You Use A PC?

All Current Generation PCs use Progressive Scan and display Pictures which match or exceed HDTV resolutions although the pixel pitch, aspect ratio and colorimetry are not correct.



82

Video Formats - SDTV - 50 Hz

Pixel x Line	Pixels/Picture	Bitrate Mb/s
704 x 576	405,504	5.0 - 15.0
544 x 576	313,344	3.5 - 8.0
352 x 576	202,752	2.5 - 4.0
544 x 288	156,672	1.5 - 3.0
352 x 288	101,376	1.0 - 2.5

All these formats are Interlaced

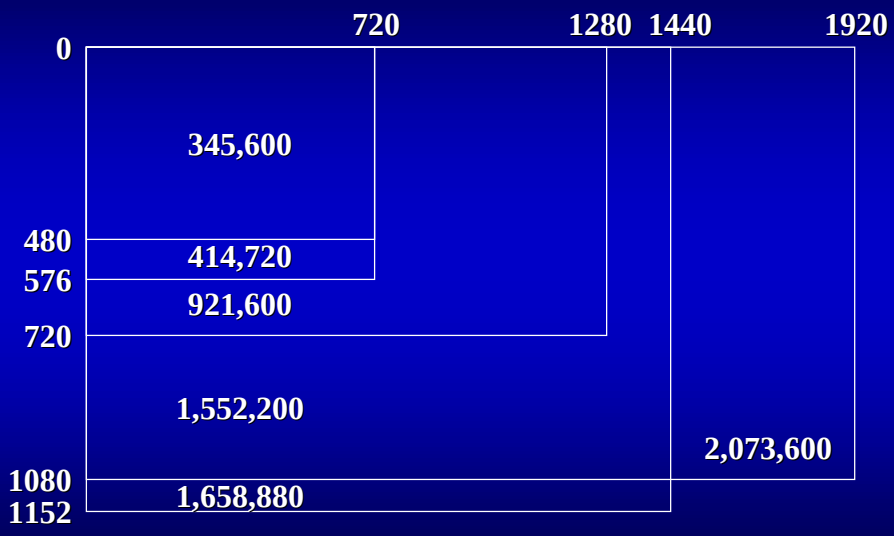
83

Video Formats - HDTV - 50 Hz

Pixel x Line	Pixels/Picture	Bitrate Mb/s
1920 x 1080 I	2,073,600	19 - 25
1920 x 1035 I	1,987,200	18 - 25
1440 x 1152 I	1,658,880	15 - 20
1280 x 720 I/P	921,600	8 - 11
720 x 576 I/P	414,720	6 - 15
720 x 480 I/P	345,600	5 - 12

84

HD Video Formats



85

Common Image Format CIF

- 1920 pixels x 1080 lines is now the world CIF.
- All HDTV systems support this image format and then allow conversion to any other display formats that are supported by the equipment.
- In Australia we have adopted the CIF for our HDTV production format. The Recommended Video format is 1920 x 1080 Interlaced at 50 Hz with a total line count of 1125 lines.

86

Chromaticity

- SDTV needs compatibility with legacy displays, so default SDTV chromaticity in DVB is:
  - same as PAL for 25Hz
  - same as NTSC for 30Hz
- HDTV has unified world-wide chromaticity and no legacy displays
  - default is BT.709 for both 25Hz and 30Hz
  - simulcast allows mixture of legacy chromaticity for SDTV and BT.709 for HDTV

87

BT-709 Colorimetry

- HDTV uses a different colour space to SDTV
- HDTV display Phosphors not same as SDTV
- BT-709 defines the parameter values for HDTV
- HDTV has a slightly different colour equation

$$Y = 0.2126\,R + 0.7152\,G + 0.0722\,B$$

Colour Difference Signals

$$U = 0.539\,(B - Y)$$

$$V = 0.635\,(R - Y)$$

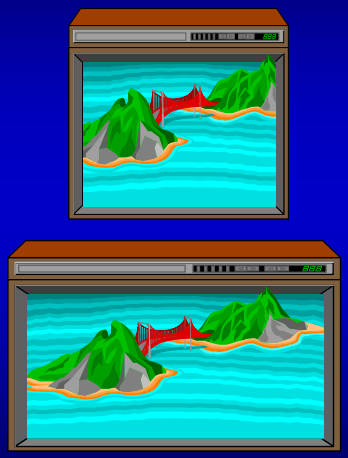
88

Digital Television

Why digital?

To Overcome Limitations of Analog Television

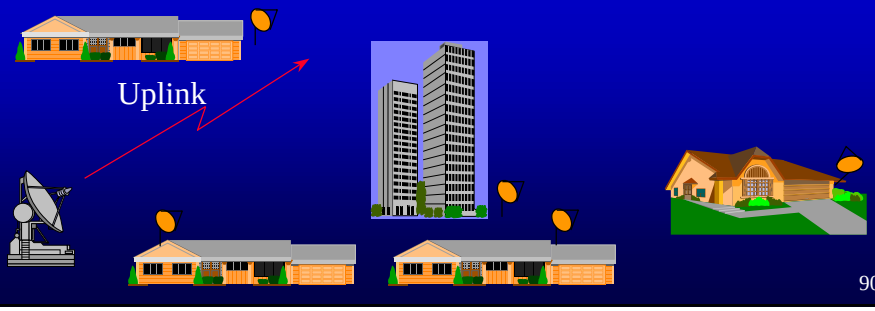
- Noise free pictures
- Higher resolution images Widescreen / HDTV
- No Ghosting
- Multi-channel, Enhanced Sound Services
- Other Data services.



89

Digital Television - Types

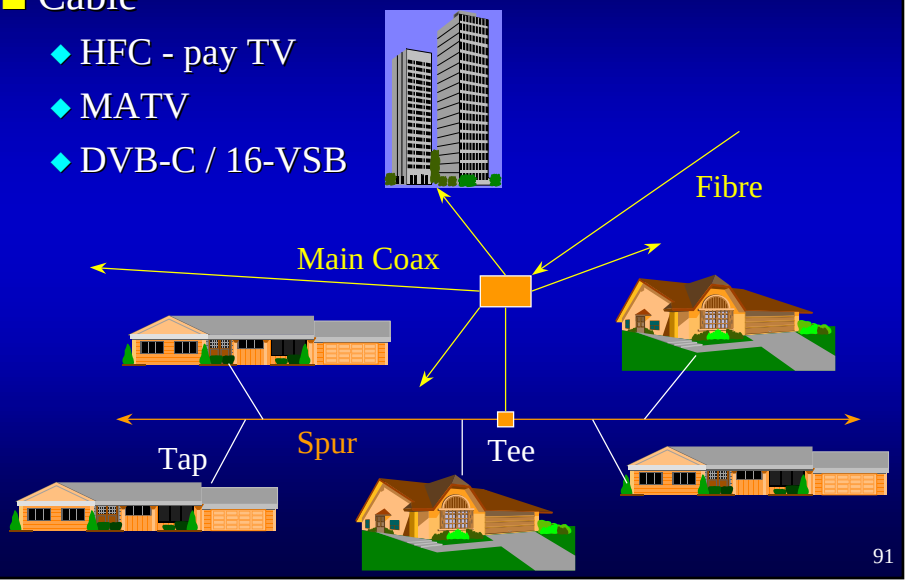
- Satellite (DBS)
  - DVB-S
  - Program interchange
  - Direct view / pay TV
  - SMATV



90

Digital Television - Types

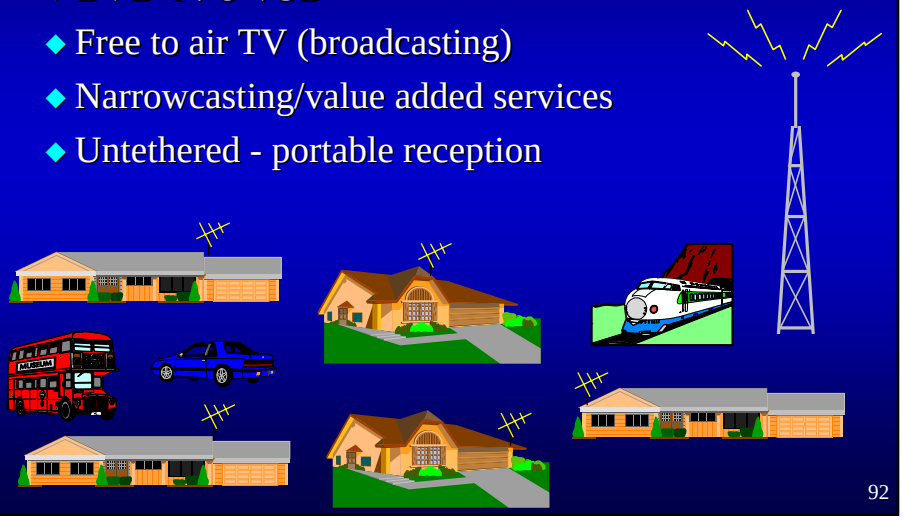
- Cable
  - HFC - pay TV
  - MATV
  - DVB-C / 16-VSB



91

Digital Television - Types

- Terrestrial (DTTB)
  - DVB-T / 8-VSB
  - Free to air TV (broadcasting)
  - Narrowcasting/value added services
  - Untethered - portable reception



92

Digital Terrestrial Television Broadcasting - DTTB

- Regional free to air television
- Replacement of current analog PAL broadcast television services
- Operating in adjacent unused “taboo” channels to analog PAL service
- Carries a range of services
  HDTV, SDTV, audio, teletext, data
- Providing an un-tethered portable service

93

University of Canberra
Advanced Communications Topics

Elements of Digital Television

Lecture 3
Enabling Technologies
Sampling and Compression

by: Neil Pickford

94

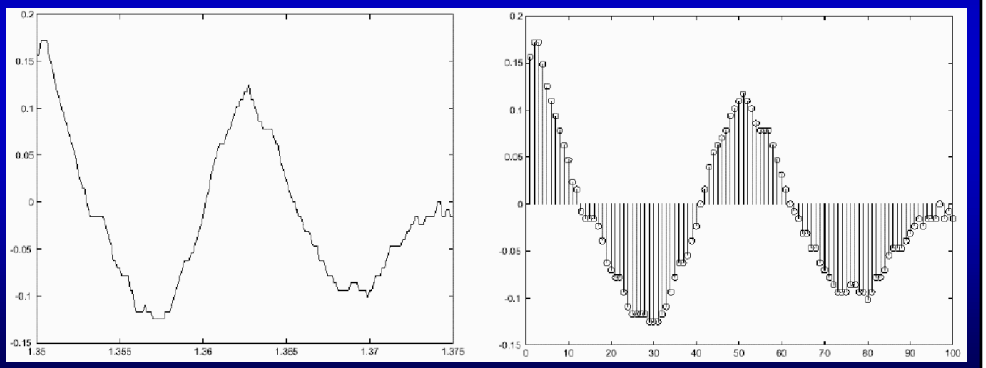
Enabling Technologies

- Source digitisation (Rec 601 digital studio)
- Compression technology (MPEG, AC-3)
- Data multiplexing (MPEG)
- Transmission technology (modulation)

95

Digital Sampling

- Digitising Analog waveforms results in large amounts of digital data.
- Must sample above the Nyquist Rate.

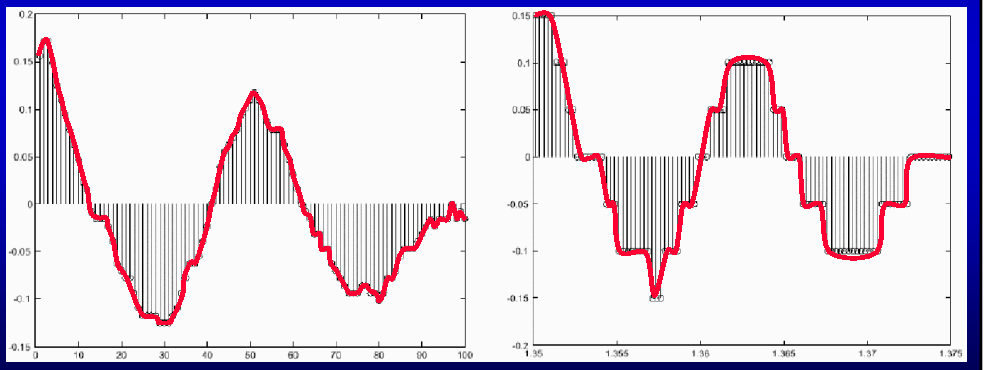


Analog Signal Sampled Signal

96

Digital Quantisation

- In Order to reduce the data load Quantisation may be used to approximate the original signal.
- Appropriate Filtering can restore course detail.



Digitised Samples Quantised Result

97

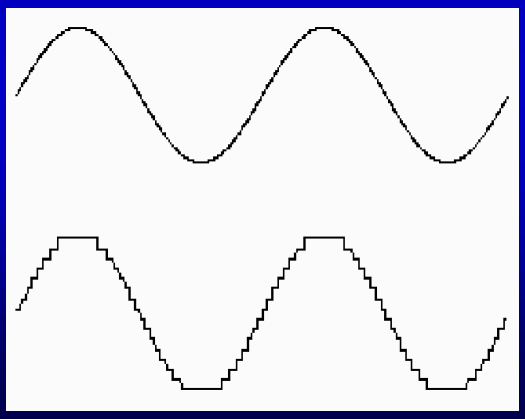
Problems with Image Digitisation

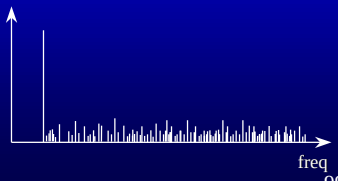
- Quantisation Noise:
  - Rounding introduces high frequency random perturbations in the resultant signal
- Banding:
  - Insufficient number of quantisation steps used
  - Large steps in signal rather than gradual changes
- Aliasing:
  - Caused by an insufficient number of samples
  - Introduction of artifacts due to mixing with sampling rates

98

Quantisation Noise

- Random High frequency noise is introduced

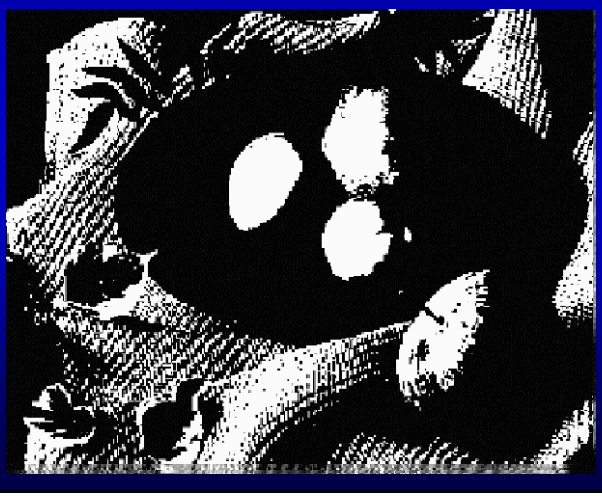




99

Banding

- Individual Pixel sample at too low a resolution
- Results in contouring or banding in the image

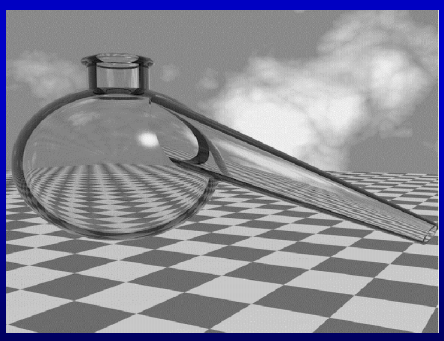


1 Bit/Pixel

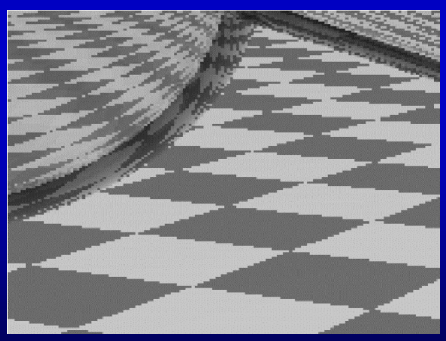
100

Aliasing

- Interaction of Capture and Display device sampling rates.
- Sampling at too low a resolution for display



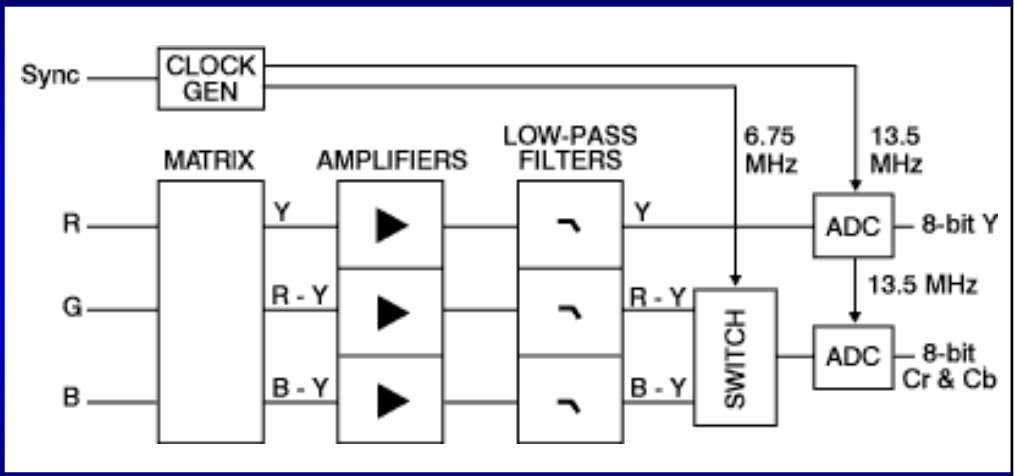
Original Image



Section Magnification

101

Digitising Video - Rec BT-601

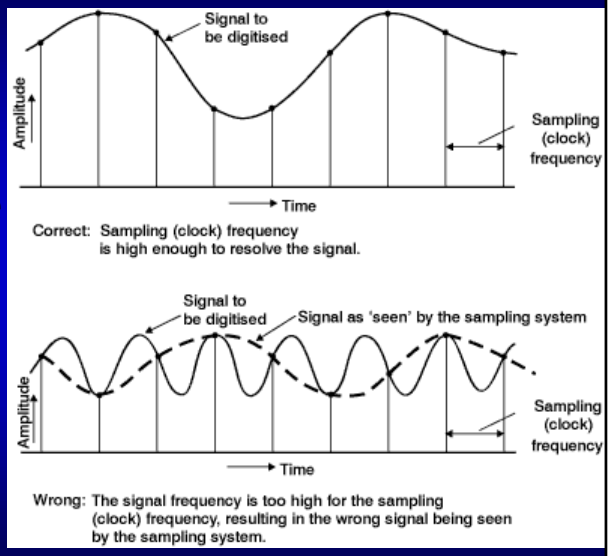


Output 27 MHz - Y Cr Y Cb Y Cr Y Cb ……..
10 bit x 27 MHz = 270 Mbit/s

102

Rec BT-601 - Sampling

- Nyquist Rate for SDTV 11 MHz
- 13.5 MHz base sampling rate.
- Chrominance sample rate 6.75 MHz
- 8 or 10 bit component samples



103

Parallel BT-656

- First Rec 656 connection format to be used.
- Uses 110 Ohm twisted pairs for data and clock
- ECL level signalling @ 27 MHz
- Width: 10 bits NRZ data + 1 clock pair
- Uses standard DB-25 Female on Equipment
- All cables are DB-25 Male to Male pin for pin
- All cables have overall shield to prevent EMI
- Max length without a DA 50 m, with EQ 200 m

104

SDI - Serial BT-656

- Serial Data Interface - Current version of 656
- Uses standard 75 Ohm video coax Cabling
- 1300 nm Optical fibre interface also defined
- 270 Mb/s Serial data stream of 10 bit data
- X^9+X^4+1 scrambling used for data protection
- Encoding polarity free NRZI 800 mV pk-pk
- 4 channel Audio can be encoded into ancillary data areas during the blanking period

105

Sampling

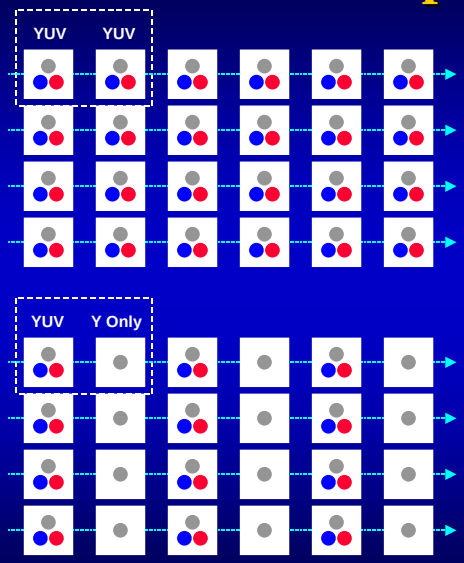
- Digital video requires sampling of the Analog image information.
- Highest quality achieved when sampling Component video signals.
- For SDTV a basic luminance sampling frequency of 13.5 MHz has been adopted.
- Various methods exist to sample the complete colour image information

4:2:2 **4:4:4**
4:1:1 **4:2:0**

106

4:4:4 & 4:2:2 Sampling

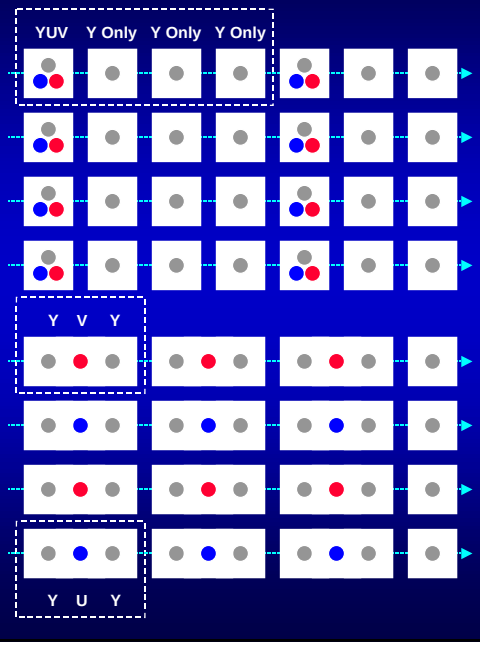
YUV Sampling Points 13.5 MHz



107

4:1:1 & 4:2:0 MPEG-1 Sampling

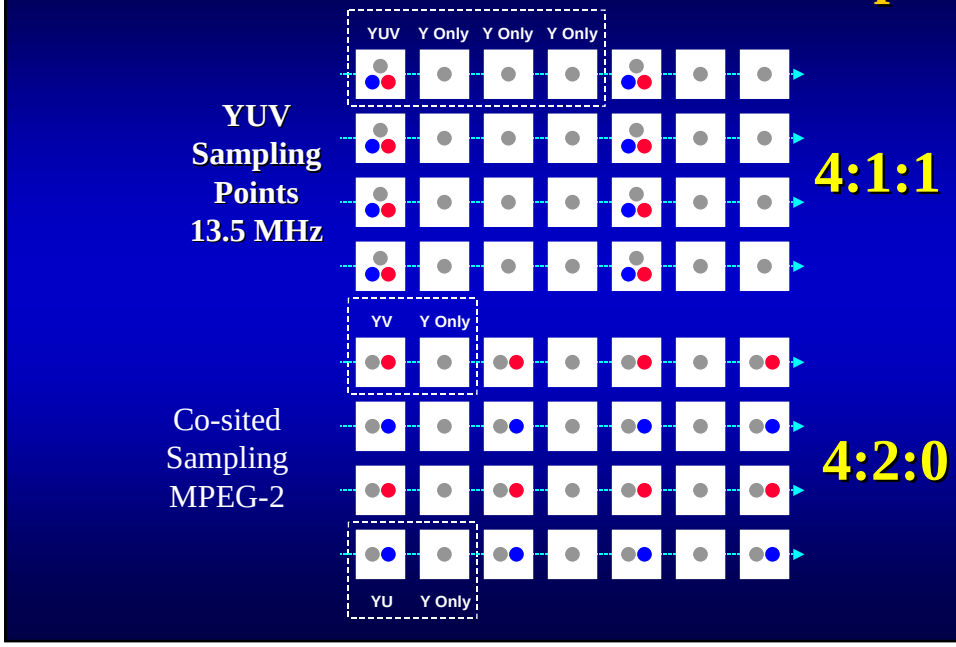
YUV Sampling Points 13.5 MHz



JPEG/JFIF
H.261
MPEG-1

108

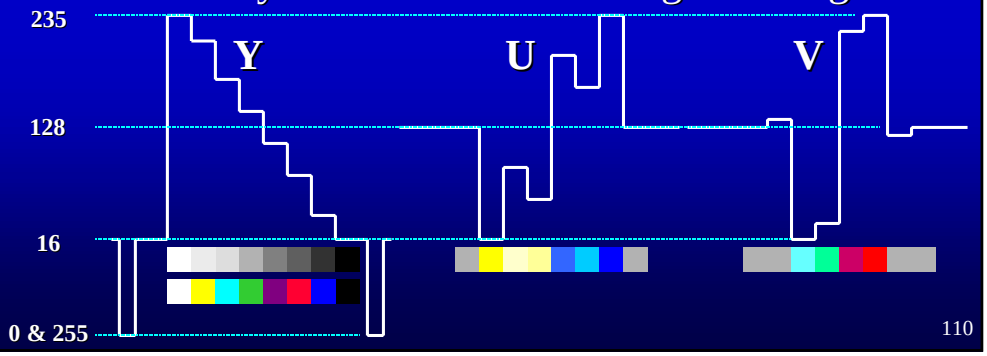
4:1:1 & 4:2:0 MPEG-2 Sampling



109

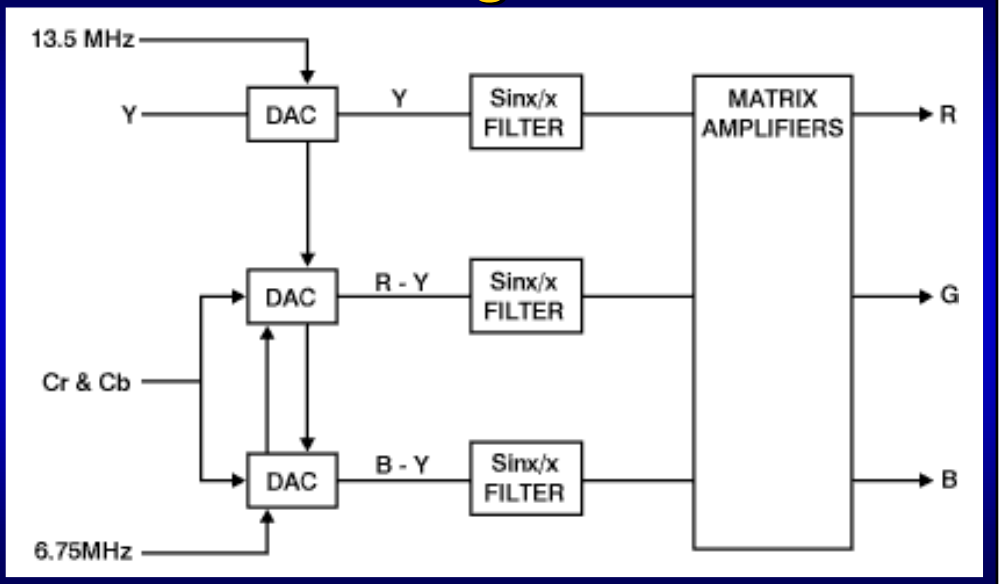
Rec BT-601/656

- Digital Standard for Component Video
- 27 MHz stream of 8 / 10 bit 4:2:2 Samples
- 8 bit range 219 levels black to white (16-235)
- Sync/Blanking replaced by SAV & EAV signals
- Ancillary data can be sent during Blanking



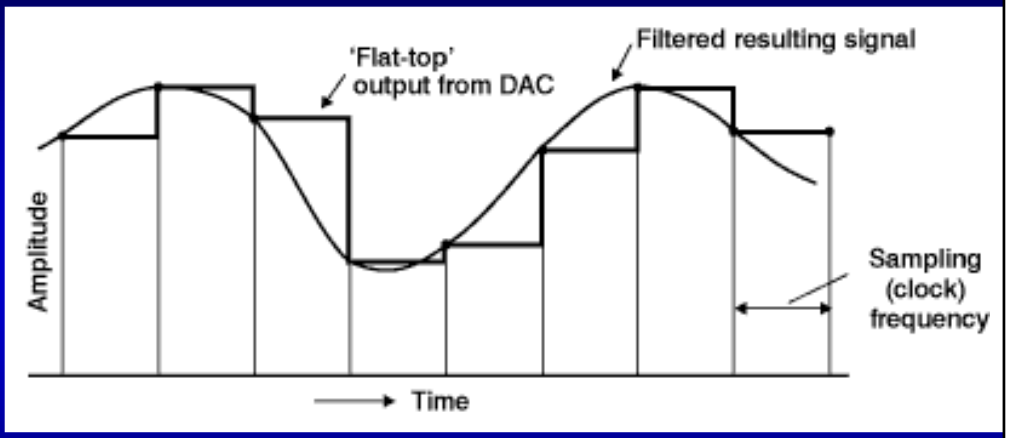
110

Decoding Rec BT-601



111

Rec BT-601 - Filtering



Multiple A/D and D/A conversion generations should be avoided

112

Enabling Technologies

- Source digitisation (Rec 601 digital studio)
- Compression technology (MPEG, AC-3)
- Data multiplexing (MPEG)
- Transmission technology (modulation)

113

Video Bitrate - HDTV

- **2 M pixels * 25 pictures * 3 colours * 8 bits**

= 1.24416 G bits / sec for Interlace Scan

or

= 2.4833 G bits / sec for Progressive

We need to Compress this a bit!

114

Compression Technology

- When low bandwidth analog information is digitised the result is high amounts of digital information.

5 MHz bandwidth analog TV picture

≡

170 - 270 Mb/s digital data stream

- 270 Mb/s would require a bandwidth of at least 140 MHz to transport
- Compression of the information is required

115

Compression - Types

- Two types of compression available

1 - Entropy Coding
  - Independent of Content
  - Loss-less compression
  - 2 to 5 times

2 - Source Coding
  - Based on Content
  - Lossy compression
  - 5 to 250 times

} Hybrid Coding

116

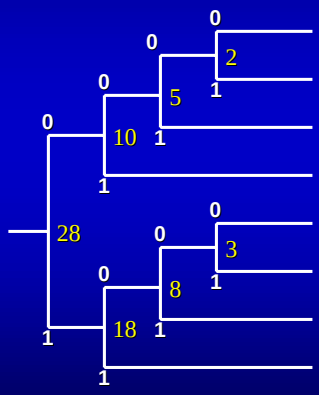
Compression - Loss-less Types

- Picture differences - temporal
- Lookup tables
- Run length data coding - GIF
  - 10100010001001001101 = 1 + 4x0100 + 1101
    - 21 bits source = 12 bits compressed
  - 01 11 31 31 31 21 01 11
    - 21 symbols source = 16 symbols compressed
- Huffman coding - PKZIP
  - Assumption: A Known Probability of Symbols
    - Short codes for common blocks
    - Longer codes for uncommon blocks

117

Loss-less - Huffman Coding Tree

AEHDEHHDAHHHFDHBHDCHEGHEDACE



Symbol	Prob.	Code	Level
B	1	0000	4
F	1	0001	4
A	3	001x	3
E	5	01xx	2
G	1	1000	4
C	2	1001	4
D	5	101x	3
H	10	11xx	2

28 x 3 bits = 84 bits ⇨ 4+4+12+10+4+4+15+20 = 73 bits

118

Compression - Lossy Types

- Fractal coding
- Quantisation - rounding
- Companding
- Prediction & Interpolation
- Motion vectors
- Discrete cosine transform (DCT)

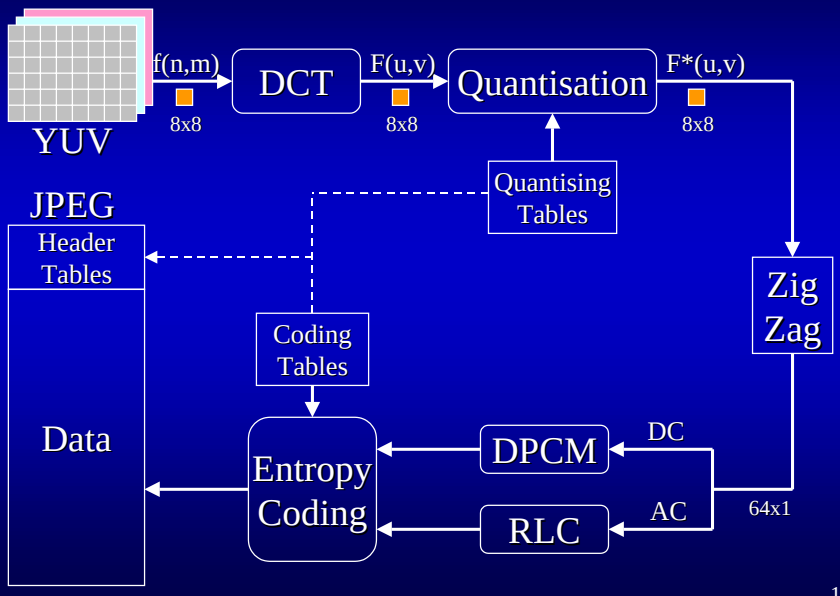
119

JPEG Compression

- Joint Photographic Experts Group
  - General Purpose Image Compression Standard
    - Lossy and Lossless coding
    - Still images: Grey scale and colour
    - Various Applications
  - Multiple Modes of Operation
    - Sequential encoding: Single scan top to bottom, left to right
    - Progressive encoding: Multiple Scans (bits or coefficients)
    - Lossless encoding: Uses only predictive techniques
    - Hierarchical encoding: Multiple resolution levels
  - Transform Coding: Discrete Cosine Transform (DCT)
    - Close to optimal for still images, well known, fast algorithm

120

JPEG Compression Overview



121

JPEG Notes

- Image is separated into components
  - YUV, CMYK - up to 255 components
  - Possible to sub-sample each component
  - Compression is run on each component separately
- Typically uses 8x8 pixel blocks as macroblocks for compression
- Pixel Resolution
  - Lossless Modes: 2 to 16 bits per pixel
  - Lossy Modes: 8 to 12 bits per pixel

122

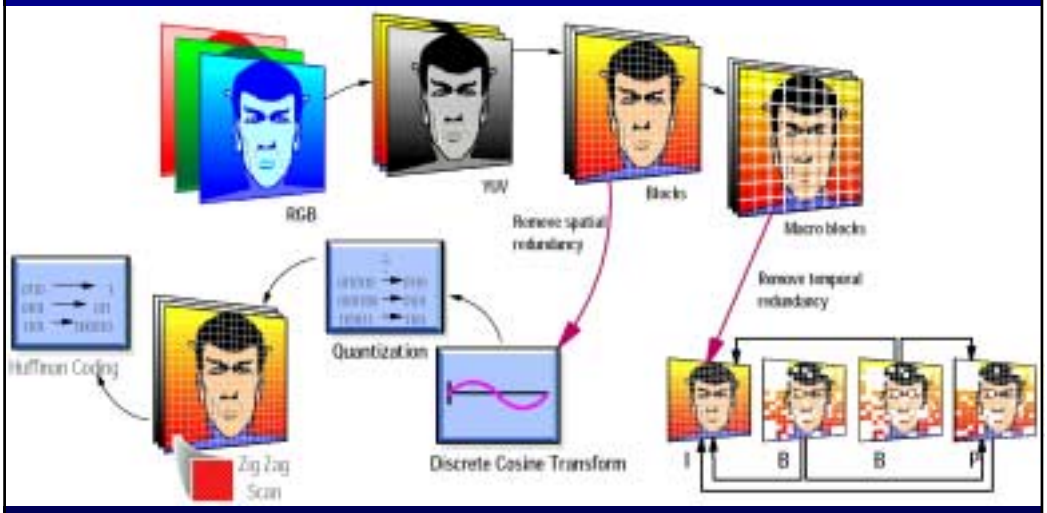
Approaches to Image Compression

- Intraframe compression treats each frame of an image sequence as a still image. (JPEG)
  - Intraframe compression, when applied to image sequences, reduces only the spatial redundancies present in an image sequence.
- Interframe compression employs temporal predictions and thus aims to reduce temporal as well as spatial redundancies, increasing the efficiency of data compression.
  - Example: Temporal motion-compensated predictive compression.

123

Overview of MPEG Compression

MPEG exploits Spatial and Temporal Image Redundancy



124

University of Canberra
Advanced Communications Topics

Elements of Digital Television

Lecture 4
Digital Compression of Audio and Video

by: Neil Pickford

125

MPEG-1: General Remarks - 1

- MPEG-1 standard simultaneously supports both interframe and intraframe compression modes.
- MPEG-1 standard considers:
  - Progressive-format video only:
  - Luminance plus two chroma channel representation. where chroma channels are subsampled by a factor of 2 in both directions;
  - 8 bit/pixel video
- Otherwise, appropriate pre- and post- processing steps should be carried out.

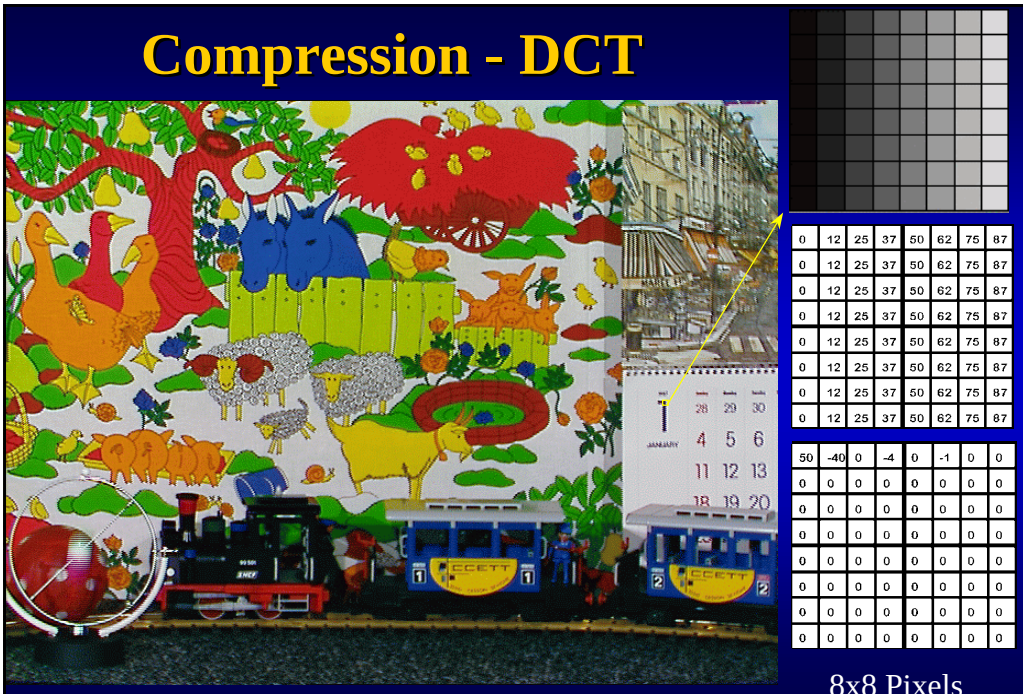
126

MPEG-1: General Remarks - 2

- MPEG-1 standardised a syntax for the representation of encoded bit-stream and a method of DECODING.
- MPEG-1 does NOT specify the encoder topology
- The standard syntax supports the operations of:
  - Discrete Cosine Transformation (DCT),
  - Motion-compensated prediction,
  - Quantisation, and
  - Variable Length Coding (VLC).

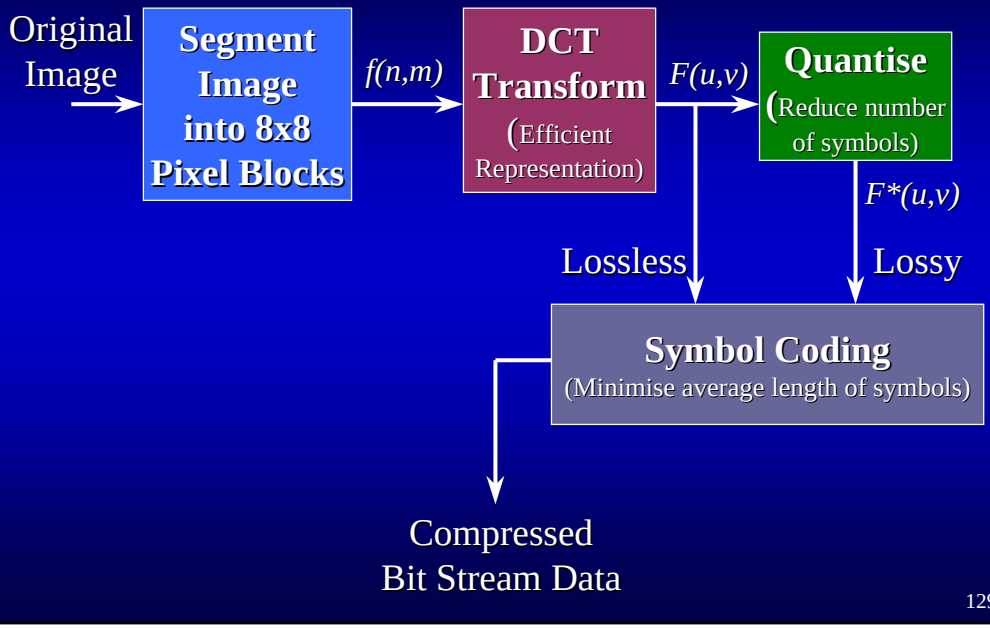
127

Compression - DCT



128

Steps of Intra Frame Compression



129

Discrete Cosine Transformation (DCT)

- DCT can be applied to various sample block sizes
- For MPEG DCT is applied to 8 x 8 Blocks of Luminance and Chrominance data.

$$F(u,v) = \frac{1}{4}C(u)C(v)\sum_{m=0}^{7}\sum_{n=0}^{7} f(m,n)\cos\left(\frac{\pi(2m+1)u}{16}\right)\cos\left(\frac{\pi(2n+1)v}{16}\right)$$

where $u,v,m,n = 0,1,\ldots,7$, *and*

$C(w) = 1/\sqrt{2}$ *for* $w = 0$; *and* $C(w) = 1$ *otherwise.*

130

DCT - Original Spatial Pixels

Spatial 8 x 8 Pixel Values

$f(m,n)$

	m = 0	1	2	3	4	5	6	7
n = 0	55	55	109	109	109	109	109	109
n = 1	55	55	109	109	109	109	109	109
n = 2	55	55	109	109	109	109	109	109
n = 3	55	55	109	109	109	109	109	109
n = 4	55	55	55	55	55	55	55	55
n = 5	55	55	55	55	55	55	55	55
n = 6	55	55	55	55	55	55	55	55
n = 7	55	55	55	55	55	55	55	55

131

DCT - Raw Values

Frequency Domain 8 x 8 Transform Values

NINT[$F(u,v)$]

	u = 0	1	2	3	4	5	6	7
v = 0	602	-69	-50	-24	0	16	21	14
v = 1	147	-63	-45	-22	0	15	19	12
v = 2	0	0	0	0	0	0	0	0
v = 3	-52	22	16	8	0	-5	-7	-4
v = 4	0	0	0	0	0	0	0	0
v = 5	34	-15	-11	5	0	3	4	3
v = 6	0	0	0	0	0	0	0	0
v = 7	-29	12	9	4	0	-3	-4	-2

NINT = Nearest INteger Truncation

132

Why use transform Coding?

- The purpose of transformation is to convert the data into a form where compression is easier
- Transformation yields energy compaction
  - Facilitates reduction of irrelevant information
- The transform coefficients can now be quantised according to their statistical properties.
  - This transformation will reduce the correlation between the pixels (decorrelate X, the transform coefficients are assumed to be completely decorrelated (Redundancy Reduction).

133

How Do Transforms Work?

- Basic Fourier Analysis
  - Waveform is composed of simpler sinusoidal functions
  - Providing enough of the waveform is sampled, component frequencies can be determined that approximate the original waveform
- The component frequencies are the basis of the original waveform.
  - Basis waveforms change with each type of transform.

134

2D DCT Basis Function

$$\Psi_{mn}(x,y) = \frac{k_m k_n}{\sqrt{XY}} \cos\left(\pi n \frac{x}{X}\right) \cos\left(\pi m \frac{y}{Y}\right)$$

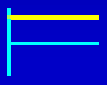
$$k_i = \begin{cases} 1 & i = 0 \\ \sqrt{2} & i > 0 \end{cases}$$

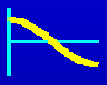
135

1D DCT Basis Function

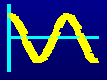
For Simplicity the 2D Basis function can be reduced to a 1D function that is applied in both x and y dimensions

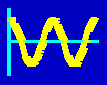
$$\Psi = \cos\left(\frac{\pi n x}{X}\right)$$

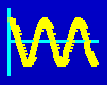
$x = 0$ 

$x = 1$ 

$x = 2$

$x = 3$ 

$x = 4$ 

$x = 5$ 

$x = 6$

$x = 7$

136

4 x 4 - DCT Basis Block Pattern

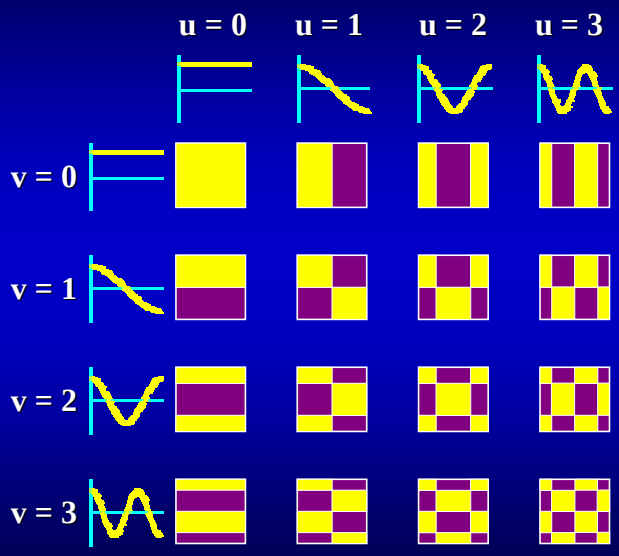
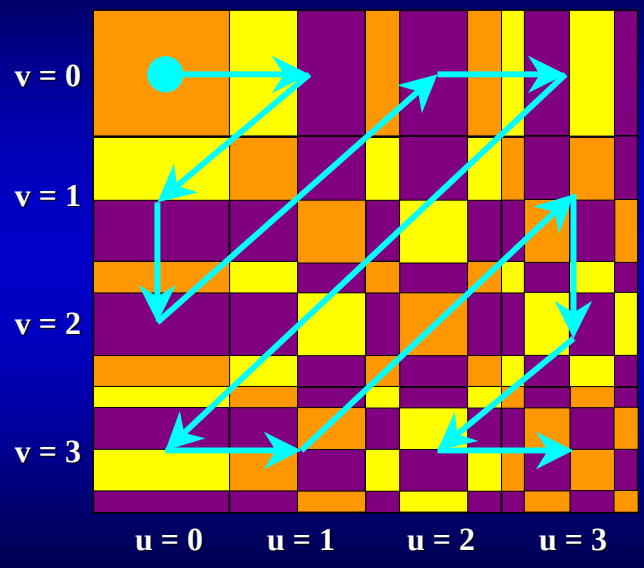


Diagram Simplified by 1 bit Quantising the pattern

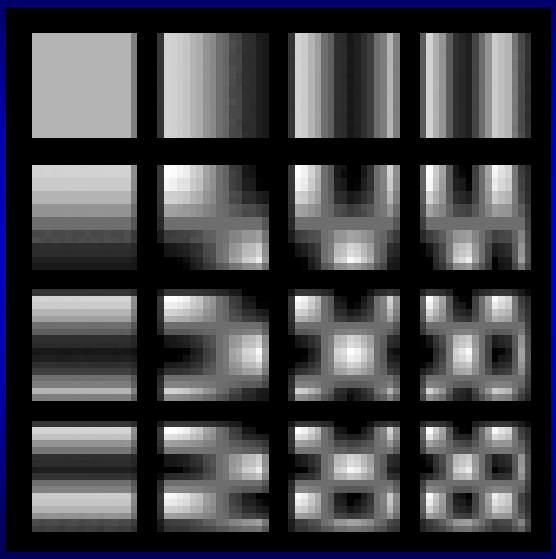
137

DCT Block Scan Sequence



138

4 x 4 DCT Patterns



139

Quantisation - DC Coefficient

- The DCT coefficients are uniformly quantised.
- DC and AC Coefficients are treated differently.
- The DC Coefficient
  - The DC coefficient is divided by 8, and the result is truncated to the nearest integer in [-256 255] range.
  - **F*(0,0) = NINT[F(0,0)/8]**

140

Quantisation - AC Coefficients

- Each AC coefficient, F(U, V) is first multiplied by 16 and the result is divided by a weight. w(u, v). times the quantiser_scale.
- **F*(u,v) =**
  NINT[16 * F(u,v)/w(u,v) * quantiser_scale].
- The result is then truncated to [-256,255] range.
- The 8 x 8 array of weights, w(u,v), is called the quantisation matrix.
- The parameter quantiser_scale facilitates adaptive quantisation.

141

MPEG-1 Quantisation Matrix

w(u,v)

8	16	19	22	26	27	29	34
16	16	22	24	27	29	34	37
19	22	26	27	29	34	34	38
22	22	26	27	29	34	37	40
22	26	27	29	32	35	40	48
26	26	29	32	35	40	48	58
26	27	29	34	38	46	56	69
27	29	35	38	46	56	69	83

Default Matrix

Matrix can be downloaded

Weights are 8 bit integers

142

DCT Example - Original Image

55	55	109	109	109	109	109	109
55	55	109	109	109	109	109	109
55	55	109	109	109	109	109	109
55	55	109	109	109	109	109	109
55	55	55	55	55	55	55	55
55	55	55	55	55	55	55	55
55	55	55	55	55	55	55	55
55	55	55	55	55	55	55	55

143

Example - Raw DCT Coefficients

602	-69	-50	-24	0	16	21	14
147	-63	-45	-22	0	15	19	12
0	0	0	0	0	0	0	0
-52	22	16	8	0	-5	-7	-4
0	0	0	0	0	0	0	0
34	-15	-11	5	0	3	4	3
0	0	0	0	0	0	0	0
-29	12	9	4	0	-3	-4	-2

144

Example - Quantised DCT - QS=2

75	-35	-21	-9	0	5	6	3
74	-32	-16	-7	0	4	4	3
0	0	0	0	0	0	0	0
-19	8	5	2	0	-1	-2	-1
0	0	0	0	0	0	0	0
10	-4	-3	1	0	1	1	0
0	0	0	0	0	0	0	0
-9	3	2	1	0	0	0	0

Quantiser_scale = 2

145

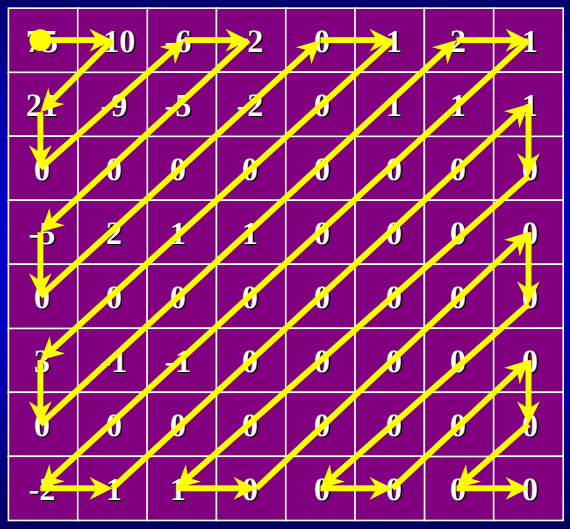
Example - Quantised DCT - QS=7

75	-10	-6	-2	0	1	2	1
21	-9	-5	-2	0	1	1	1
0	0	0	0	0	0	0	0
-5	2	1	1	0	0	0	0
0	0	0	0	0	0	0	0
3	-1	-1	0	0	0	0	0
0	0	0	0	0	0	0	0
-2	1	1	0	0	0	0	0

Quantiser_scale = 7

146

Example - 8 x 8 Scan Sequence



Quantiser_scale = 7

147

Example - Inverse DCT - Result

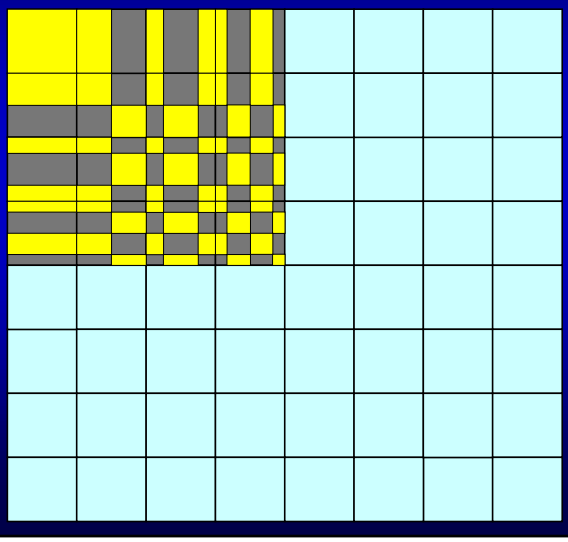
Received 8 x 8 pixel block at the Decoder

59	59	105	107	107	110	107	107
56	59	105	108	107	108	106	107
56	62	105	110	107	107	106	107
57	64	100	108	107	106	103	102
54	50	61	57	55	56	59	60
55	52	56	58	54	55	57	55
55	55	56	56	54	54	56	55
52	55	56	59	54	53	56	55

Quantiser_scale = 7

148

Assignment 2 - Draw accurately the full 8x8 DCT Basis block set



Name:

Due: 31/05/02

Simplified basis block Diagram by 1 bit Quantising the basis pattern

149

Quantised Data Stream

Quantiser_scale = 2

75 -35 74 0 -32 -21 -9 -16 0 -19 0 8 0 -7 0 5 0 0 5 0 10 0 -4 0 2
0 4 6 3 4 0 0 0 -3 0 -9 3 0 1 0 -1 0 3 0 -2 0 0 0 2 1 0 1 0 -1 0 1 0
0 0 0 0 0 0 0 0

Quantiser_scale = 4

75 -17 37 0 -16 -11 -4 -8 0 -9 0 4 0 -4 0 2 0 0 2 0 5 0 -2 0 1 0 2 3 2
2 0 0 0 -2 0 -4 2 0 1 0 -1 0 1 0 -1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0

Quantiser_scale = 7

75 -10 21 0 -9 -6 -2 -5 0 -5 0 2 0 -2 0 1 0 0 1 0 3 0 -1 0 1 0 1 2 1
1 0 0 -1 0 -2 1 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0

Quantiser_scale = 16

75 -4 9 0 -4 -3 -1 -2 0 -2 0 1 0 -1 0 1 0 0 1 0 1 0 -1 0 0 0 1 1 0 1
0 0 0 0 0 -1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

150

Spatially-Adaptive Quantisation

- Spatially-adaptive quantisation is implemented by the quantiser_scale, that scales the w(u,v) values
  - The quantiser_scale is allowed to vary from one "macroblock" to another within a picture to adaptively adjust the quantisation on a macroblock basis.
  - The quantiser_scale is chosen from a specified set of values on the basis of spatial activity of the block (e.g., macroblocks containing busy, textured areas are quantised relatively coarsely), and on the basis of buffer fullness in constant bitrate applications.

151

Coding: AC Coefficients

- Coding is based on the fact that most of the quantised coefficients are zero and hence it is more efficient to represent the data by location and value of the non-zero coefficients.
- The quantised AC coefficients are scanned in a zigzag fashion and ordered into symbol = [Run, level] pairs and then coded using variable length (Huffman) codes (VLC) (longer codes for less frequent pairs and vice versa).
  - (The VLC tables are standardised.)

152

Example - Run Level Coding

- Level: is the value of a non-zero coefficient;
- Run: is the number of zero coefficients preceding it.

Run	Level
0	-10
0	21
1	-9
0	-6
0	-2
0	-5
1	-5
1	2

Run	Level
1	-2
1	1
2	1
1	3
1	-1
1	1
1	1
0	2

Run	Level
0	1
0	1
2	-1
1	-2
0	1
5	1
5	1
EOB	

63 DCT coefficients represented by 47 symbols

Quantiser_scale = 7

75 -10 21 0 -9 -6 -2 -5 0 -5 0 2 0 -2 0 1 0 0
1 0 3 0 -1 0 1 0 1 2 1 1 0 0 -1 0 -2 1 0 0 0 0
0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

153

Coding: DC Coefficients

- Redundancy among quantised DC coefficients of 8 x 8 blocks is reduced via differential pulse coded modulation (DPCM).
- The resultant differential signal ([-255, 255] range) is coded using variable length codes.
  - Standard VLC tables are specified.
  - These tables are the only standard tables in MPEG-1 that make a distinction between luminance and chrominance components of the data.)

154

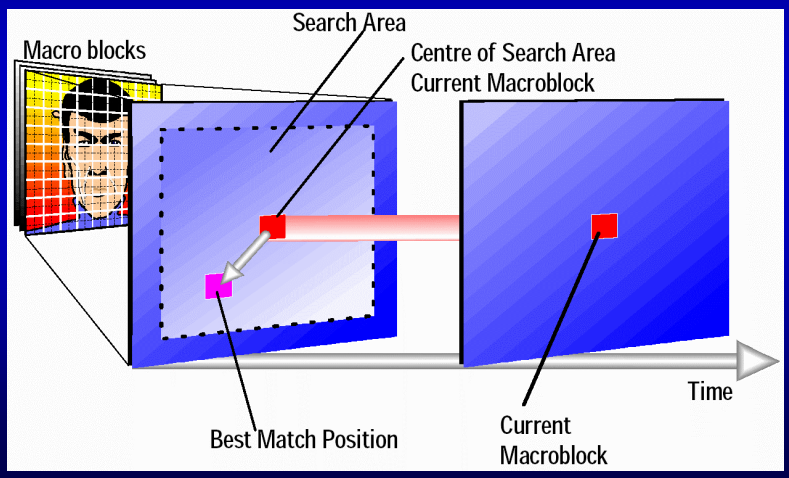
Motion Compensation & Prediction

- Inter-Frame compression exploits temporal redundancy between successive frames
- If adjacent frame macro blocks are the same then don't retransmit the macroblock. (Signal Same)
- Search to see if the same macroblock exists in the next frame. If it does then only transmit it's new coordinates (a motion vector).
- If a macroblock has multiple locations then transmit (motion vectors)
- Only if the block is completely new then intraframe compress it. (DCT)

155

Inter-Frame Compression

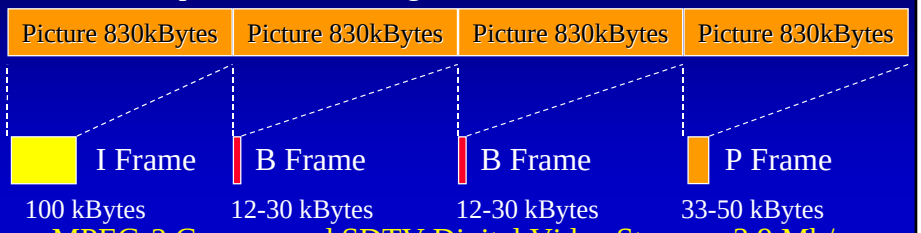
- This is where significant compression is achieved
- Search area size dependent on processing power



156

MPEG-1 - I, P & B Frames

Uncompressed SDTV Digital Video Stream - 170 Mb/s

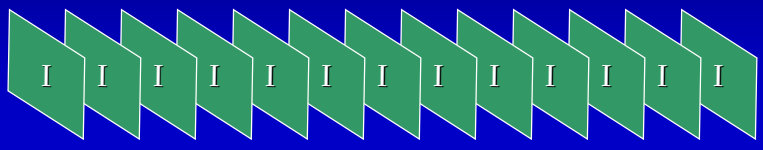


MPEG-2 Compressed SDTV Digital Video Stream - 3.9 Mb/s

- **I** - Intra picture coded without reference to other pictures. Compressed using spatial redundancy only
- **P** - Predictive picture coded using motion compensated prediction from past I or P frames
- **B** - Bidirectionally predictive picture using both past and future I or P frames

157

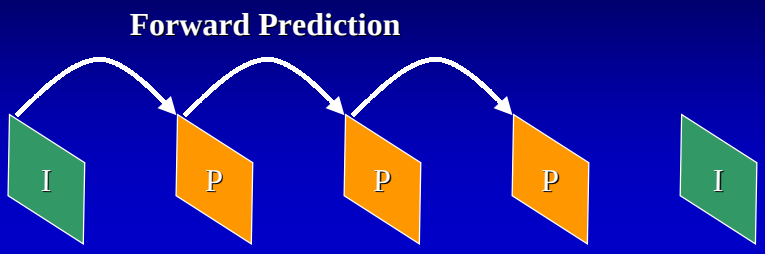
I Frames



- Intraframe Compression
  - Frames marked by (I) denote the frames that are strictly intraframe compressed.
  - The purpose of these frames, called the "I pictures", is to serve as random access points to the sequence.

158

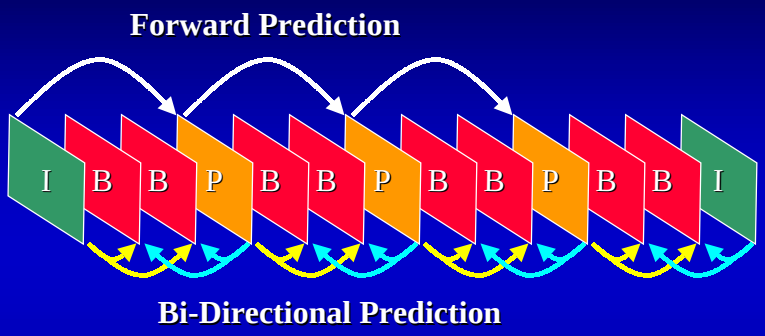
P Frames



- P Frames use motion-compensated forward predictive compression on a block basis.
  - Motion vectors and prediction errors are coded.
  - Predicting blocks from closest (most recently decoded) I and P pictures are utilised.

159

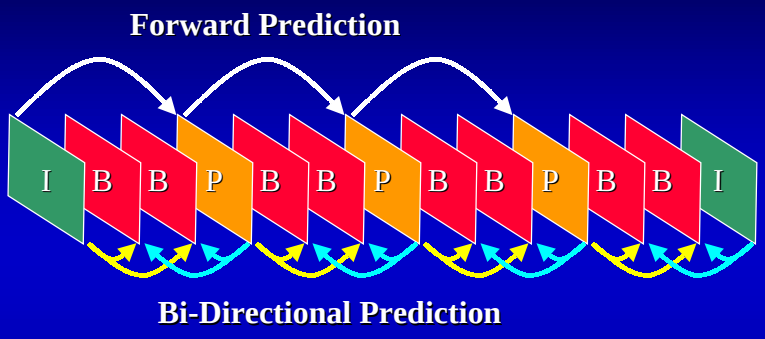
B Frames



- B frames use motion-compensated bi-directional predictive compression on a block basis.
  - Motion vectors and prediction errors are coded.
  - Predicting blocks from closest (most recently decoded) I and P pictures are utilised.

160

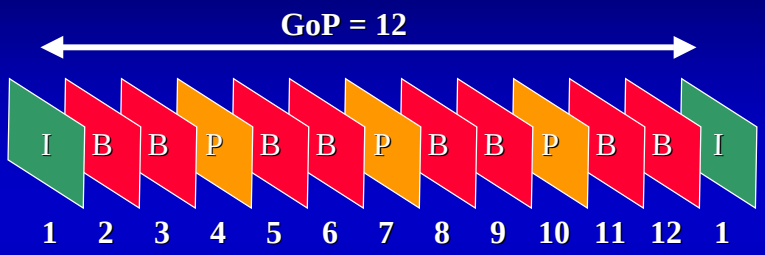
In Case of Poor Predictions



- In both P and B pictures, the blocks are allowed to be intra compressed if the motion prediction is deemed to be poor.

161

Group of Pictures

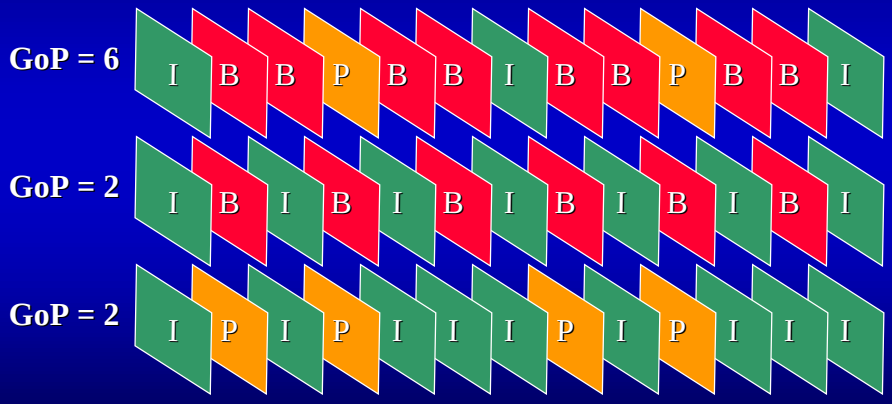


- Relative number of (I), (P), and (B) pictures can be arbitrary.
- Group of Pictures (GoP) is the Distance from one I frame to the next I frame

162

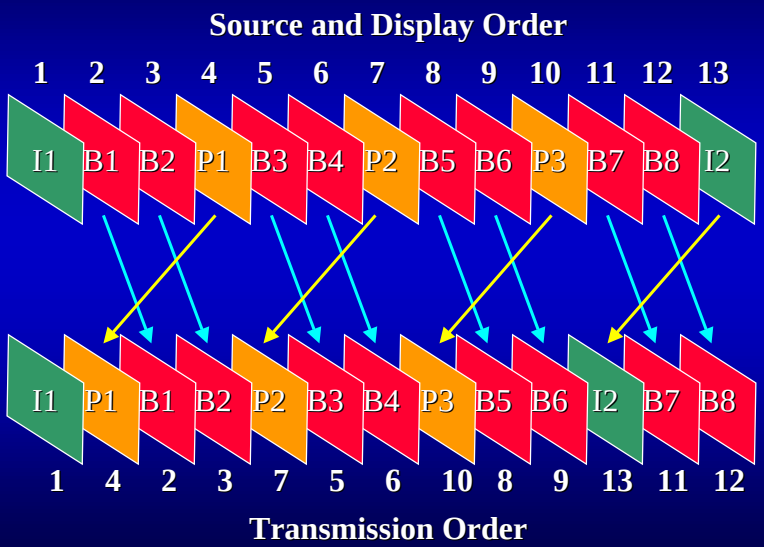
Some Other Frame Patterns

- An I picture is mandatory at least once in a sequence of 132 frames (period_max= 132)



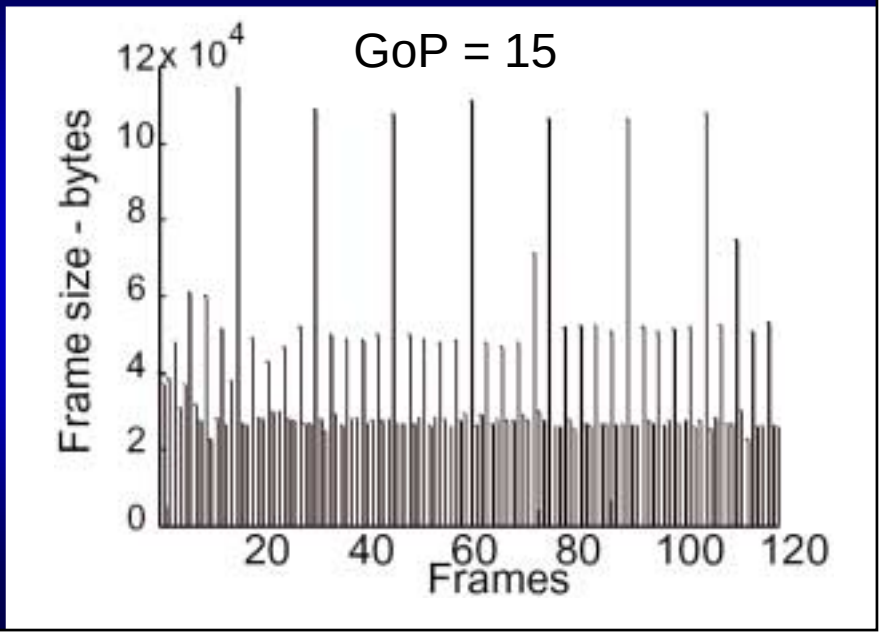
163

Frame Transmission Sequence



164

MPEG Typical Frame Size

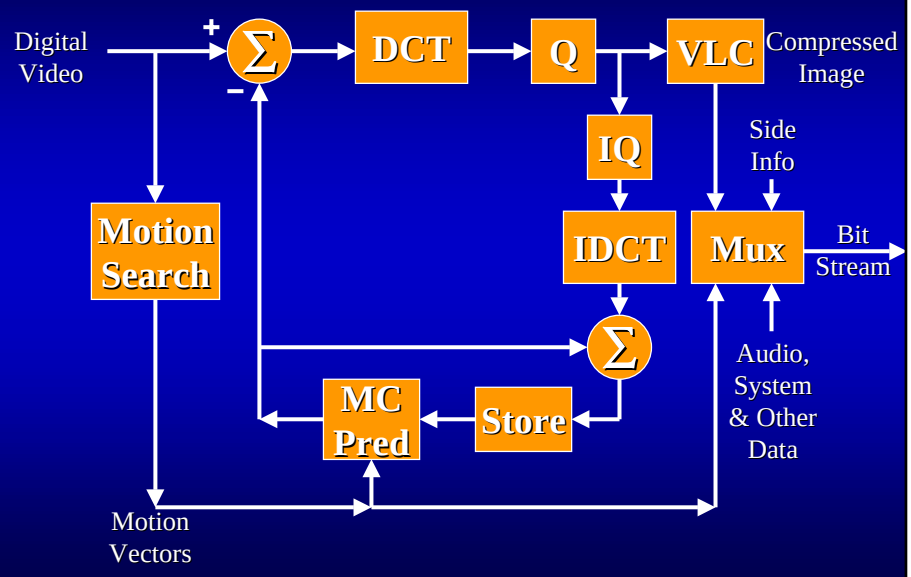


MPEG Encoder

- A typical MPEG encoder includes modules for:
  - Motion estimation
  - Motion-compensated prediction (predictors and framestores)
  - Quantisation and de-quantisation
  - DCT and IDCT
  - Variable length coding
  - a Multiplexer
  - a Memory buffer
  - a Buffer regulator

166

Simplified MPEG Encoder

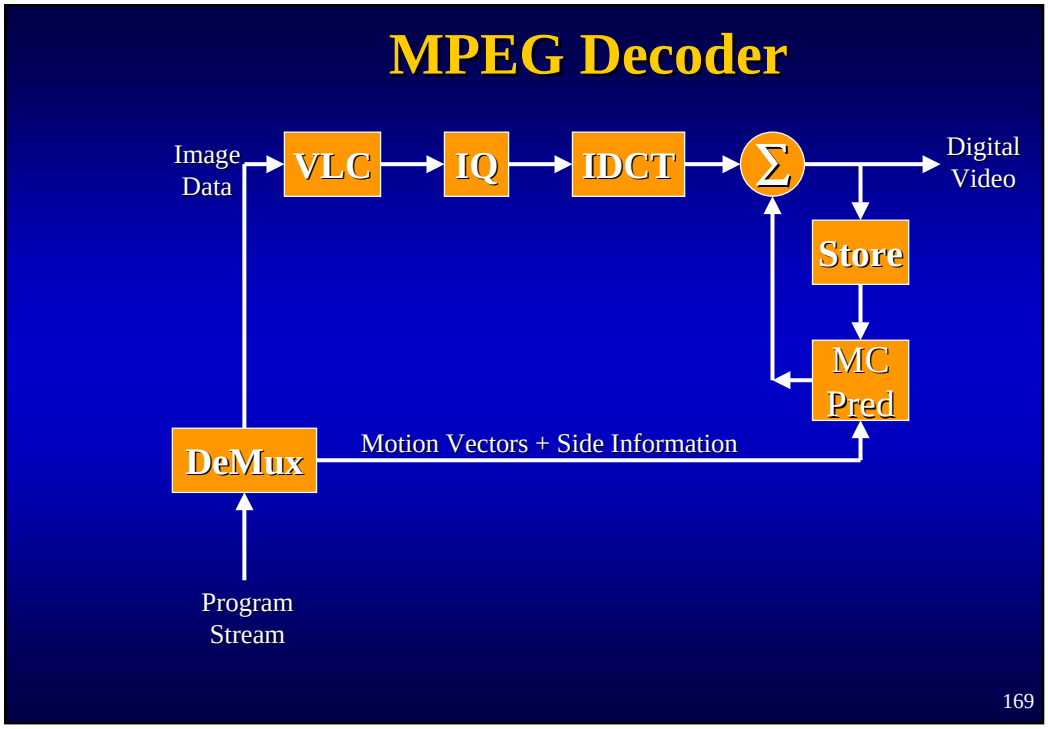


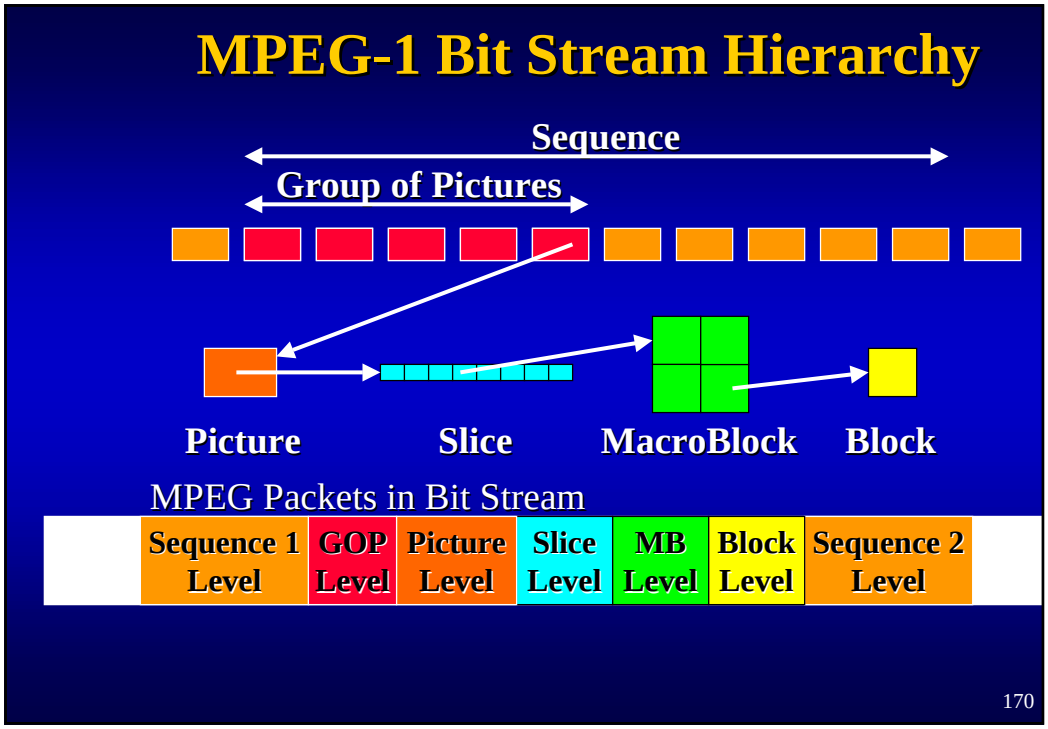
167

MPEG Decoder

- The decoder basically reverses the operations of the encoder.
- The incoming bit stream (with a standard syntax) is demultiplexed into:
  - DCT coefficients
  - Side information
    - Displacement vectors
    - Quantisation parameter, etc.
- In the case of B pictures, two reference frames are used to decode the frame.

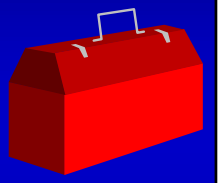
168


MPEG Decoder
Image Data
VLC
IQ
IDCT
Σ
Digital Video
Store
MC Pred
DeMux
Motion Vectors + Side Information
Program Stream
169


MPEG-1 Bit Stream Hierarchy
Sequence
Group of Pictures
Picture
Slice
MacroBlock
Block
MPEG Packets in Bit Stream
Sequence 1 Level
GOP Level
Picture Level
Slice Level
MB Level
Block Level
Sequence 2 Level
170

MPEG-2 - Formats ML & HL

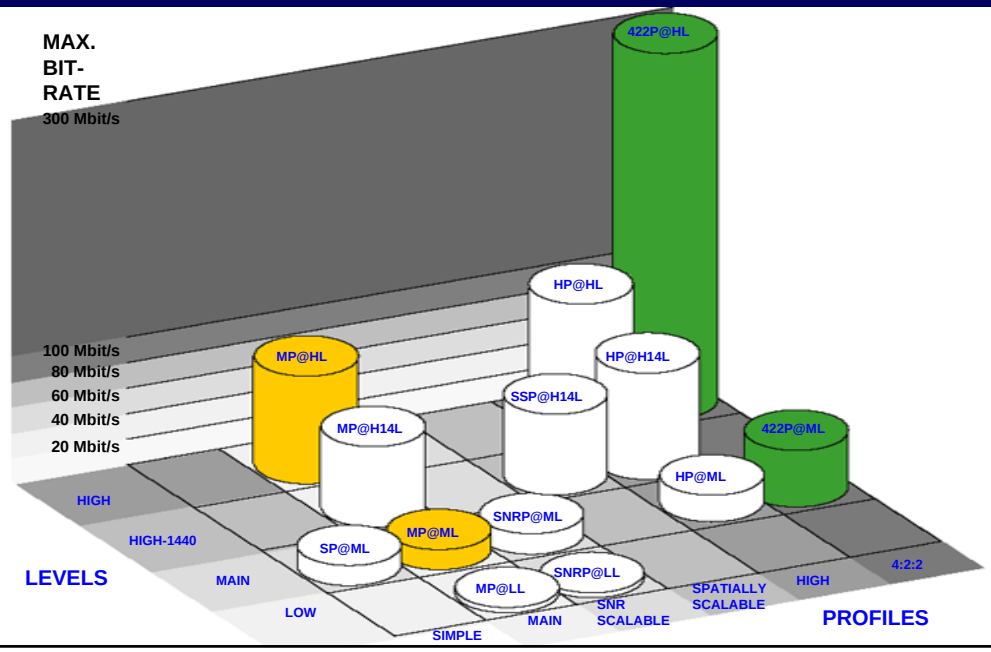
- MPEG-2 defines profiles & levels
  - They describe sets of compression tools
- DTTB uses main profile.
- Choice of levels
- Higher levels include lower levels



Level	resolution	
Low level (LL)	360 by 288	SIF
Main level (ML)	720 by 576	SDTV
High level (HL)	1920 by 1152	HDTV

171

MPEG Profiles and Levels



MP@ML

MP@HL

It is preferable that all decoders sold in Australia be MP@HL capable allowing all viewers access to HD resolution when it becomes commonly available

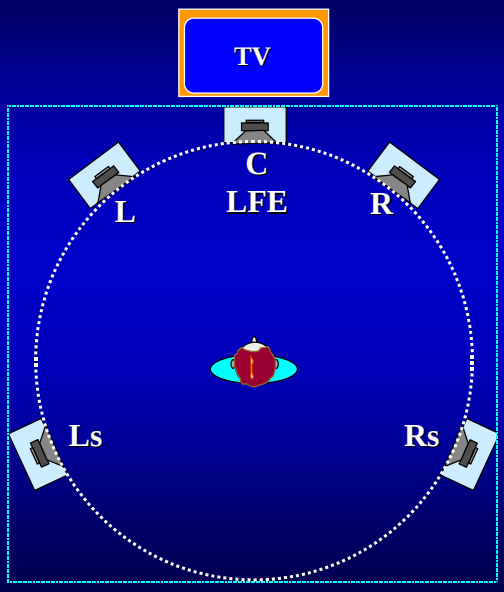
173

Digital Audio - Multichannel

- Two sound coding systems exist for Digital TV
  - MPEG 1 & 2
  - Dolby AC-3
- Cover a wide variety of Audio Applications
  - DVB
  - VCD and S-VCD
  - DAB, DBS, DVD
  - Cinema (Film)
  - Computer Operating Systems (Windows)
  - Professional (ISDN codecs, tapeless studio, ….)

174

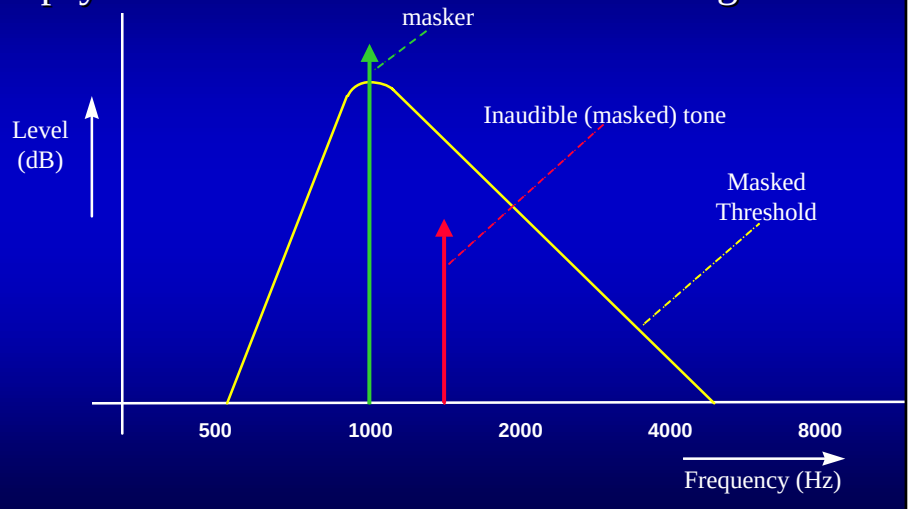
Multichannel Sound



175

Masking

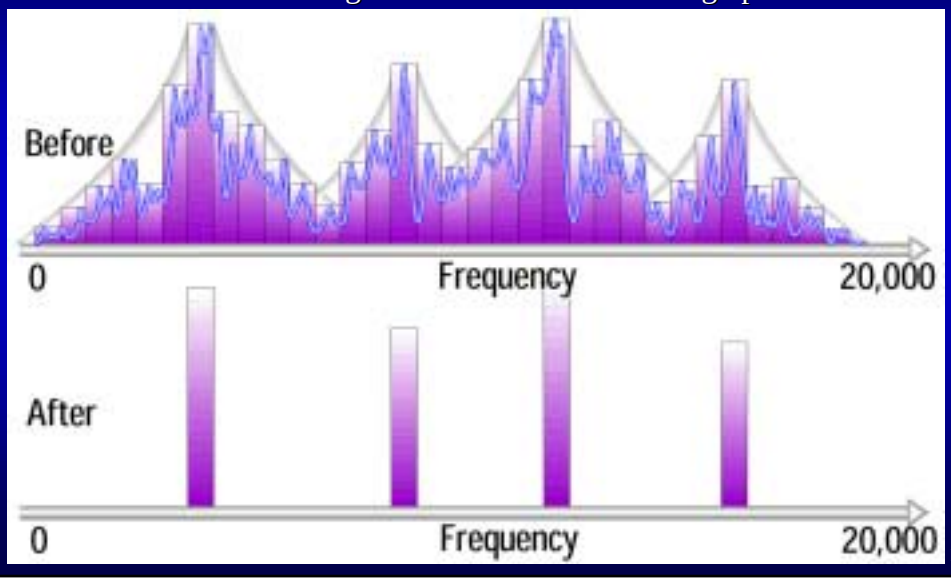
- Both use perceptual audio coding that exploits a psychoacoustic effect known as masking



176

Sub-Band Masking

- Relies on masking of tones either side of a high power tone

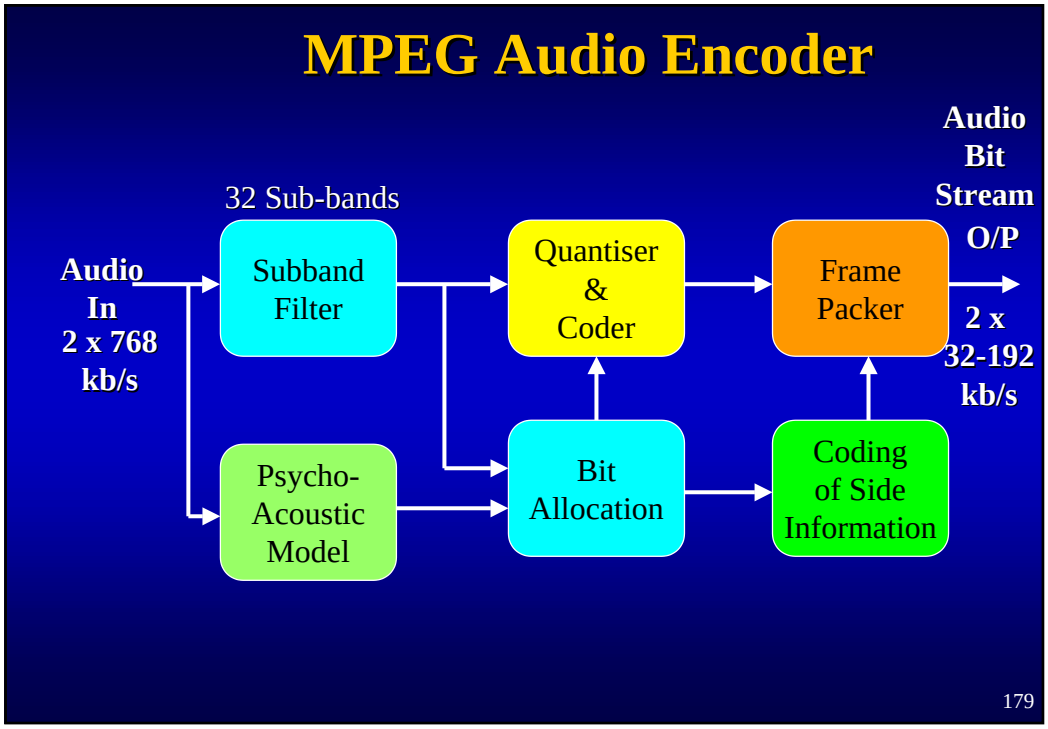


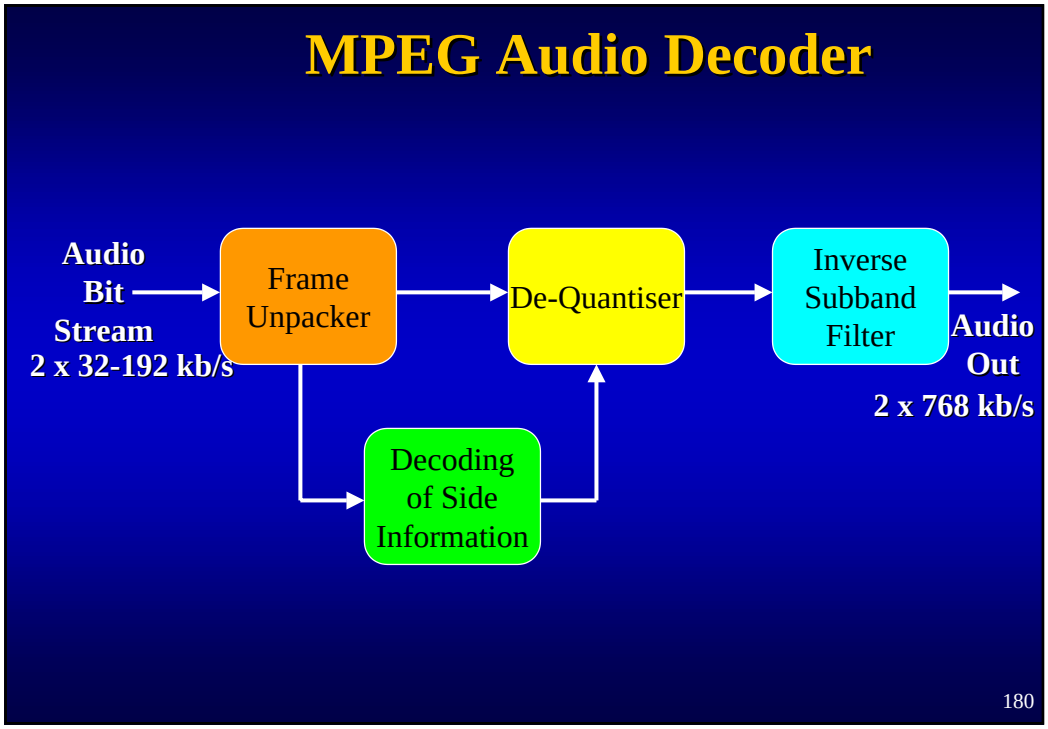
177

Multichannel Sound - MPEG 1/2

- MPEG Audio Layer II was developed in conjunction with the European DVB technology
  - Uses Musicam Compression with 32 sub bands
  - MPEG 1 is basic Stereo 2 channel mode
  - MPEG 2 adds enhancement information to allow 5.1 or 7.1 channels with full backwards compatibility with the simple MPEG 1 decoders
  - MPEG 1 is compatible with Pro-Logic processing.
  - Bitrate 224 kb/s MPEG 1
  - Bitrate 480 - 512 kb/s MPEG 2 5.1

178


MPEG Audio Encoder
Audio In 2 x 768 kb/s
32 Sub-bands
Subband Filter
Quantiser & Coder
Frame Packer
Audio Bit Stream O/P
2 x 32-192 kb/s
Psycho-Acoustic Model
Bit Allocation
Coding of Side Information
179

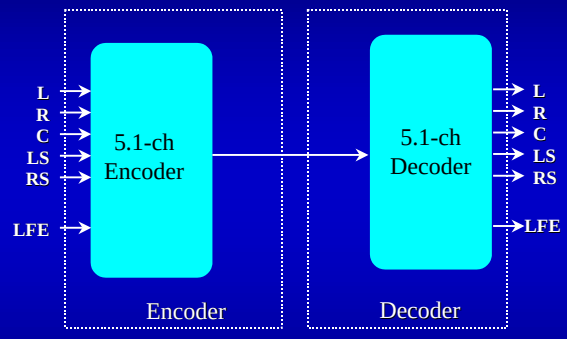

MPEG Audio Decoder
Audio Bit Stream 2 x 32-192 kb/s
Frame Unpacker
De-Quantiser
Inverse Subband Filter
Audio Out 2 x 768 kb/s
Decoding of Side Information
180

Multichannel Sound - Dolby AC-3

- Dolby AC-3 was developed as a 5.1 channel surround sound system from the beginning.
  - Compression Filter bank is 8 x greater than MPEG 2 (256)
  - Must always send full 5.1 channel mix
    One bitstream serves everyone
  - Decoder provides down-mix for
    Mono, Stereo or Pro-Logic
  - Listener controls the dynamic range,
    Audio is sent clean
  - Bitrate 384 kb/s or 448 kb/s
  - Dialogue level passed in bit-stream

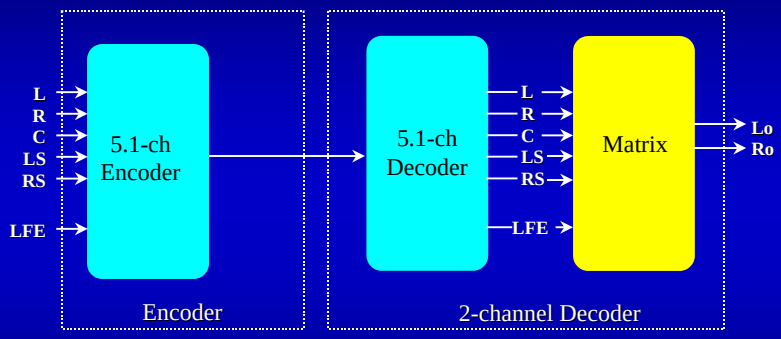
181

AC-3 Multichannel Coder



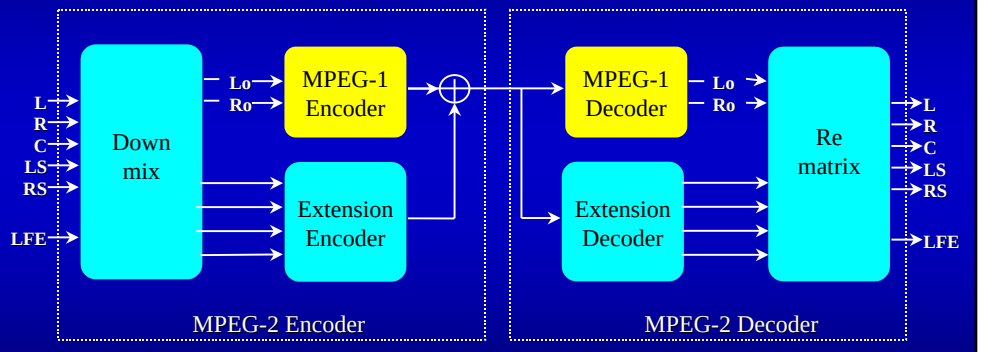
182

AC-3 Stereo Decoder



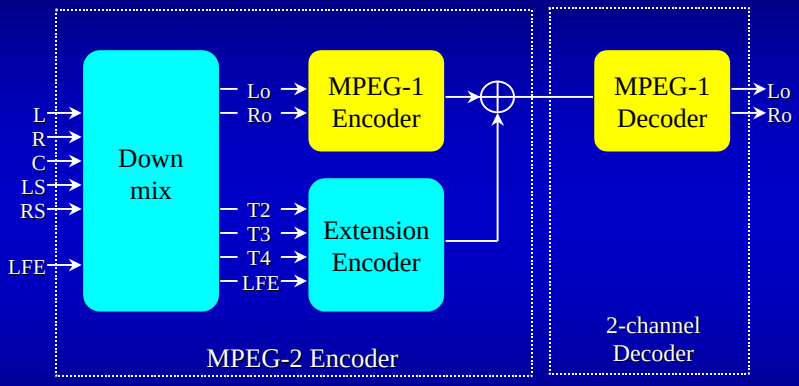
183

MPEG-2 Multichannel Coder concept



184

Low cost 2-channel decoder



185

Enabling Technologies

- Source digitisation (Rec 601 digital studio)
- Compression technology (MPEG, AC-3)
- Data multiplexing (MPEG)
- Transmission technology (modulation)

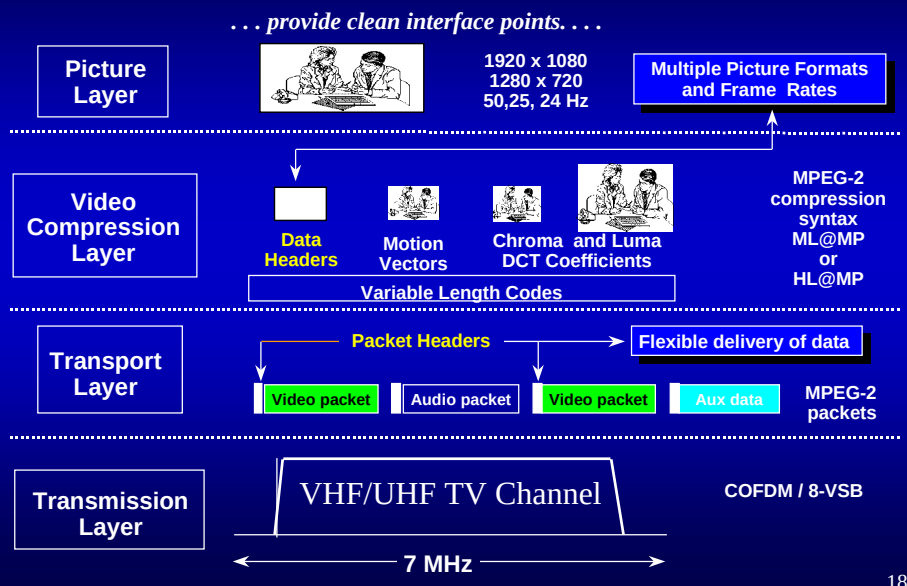
186

MPEG-2

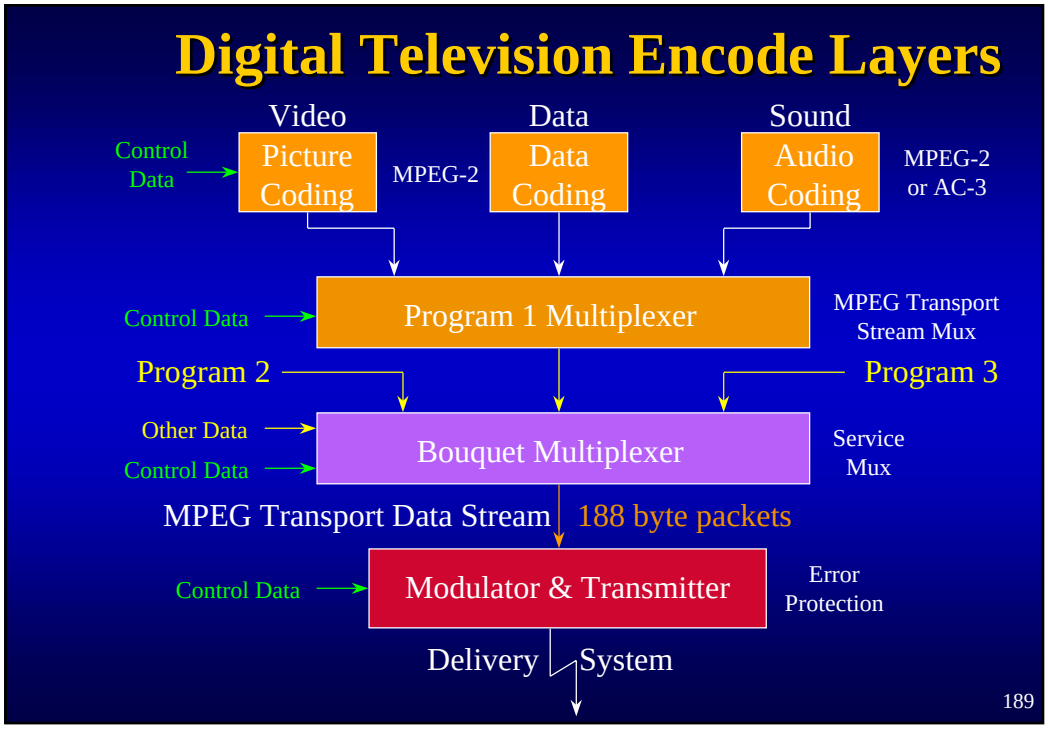
- Compresses source video, audio & data
- Segments video into I, P & B frames
- Generates system control data
- Packetises elements into data stream
- Multiplexes program elements - services
- Multiplexes services - transport stream
- Organises transport stream data into 188 byte packets

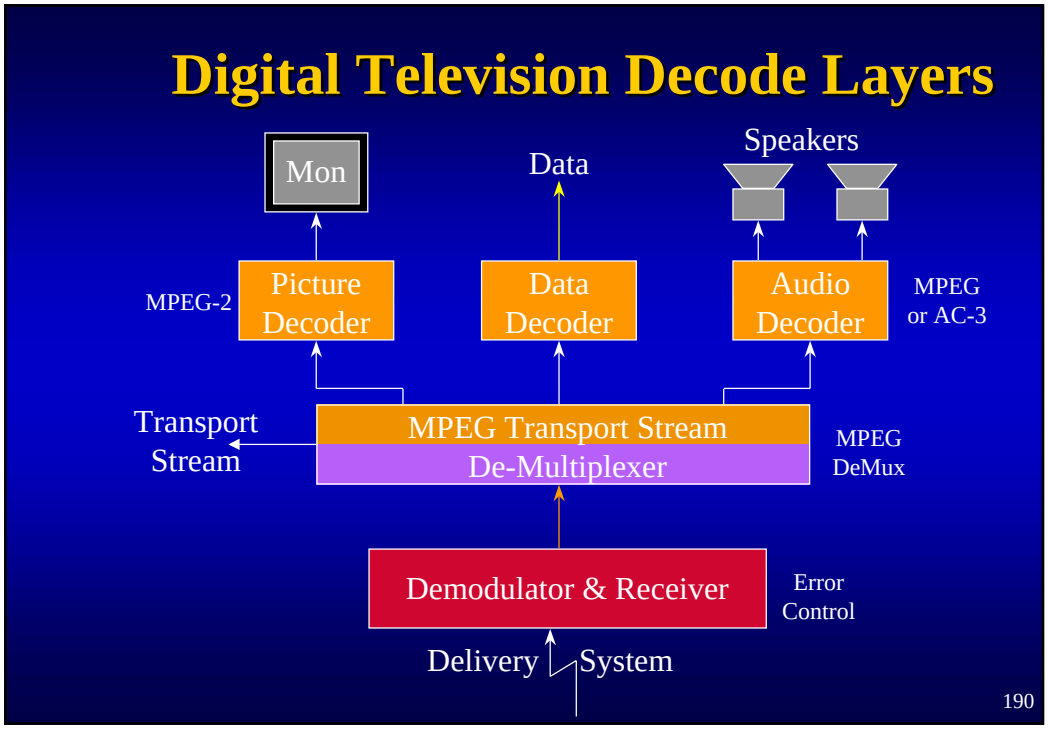
187

Digital Terrestrial TV - Layers



188


Digital Television Encode Layers
Video
Data
Sound
Control Data
Picture Coding
MPEG-2
Data Coding
Audio Coding
MPEG-2 or AC-3
Control Data
Program 1 Multiplexer
MPEG Transport Stream Mux
Program 2
Program 3
Other Data
Control Data
Bouquet Multiplexer
Service Mux
MPEG Transport Data Stream
188 byte packets
Control Data
Modulator & Transmitter
Error Protection
Delivery System
189


Digital Television Decode Layers
Mon
Data
Speakers
MPEG-2
Picture Decoder
Data Decoder
Audio Decoder
MPEG or AC-3
Transport Stream
MPEG Transport Stream
De-Multiplexer
MPEG DeMux
Demodulator & Receiver
Error Control
Delivery System
190

Set top Box (STB) - Interfacing

- Domestic and Professional interfaces still to be defined
- Transport Stream via IEEE 1394 (Firewire)
- Baseband Audio & RGB/YUV Video signals.
- STB can convert between line standards so you do not have to have a HD display.
- Display and transmitted information must be at same Frame/Field rate. (25/50)

191

DTTB - Content & Services

- DTTB was designed to carry video, audio and program data for television
- DTTB can carry much more than just TV
  - Electronic program guide, teletext
  - Broadband multimedia data, news, weather
  - Best of internet service
  - Interactive services
  - Software updates, games
- Services can be dynamically reconfigured

192

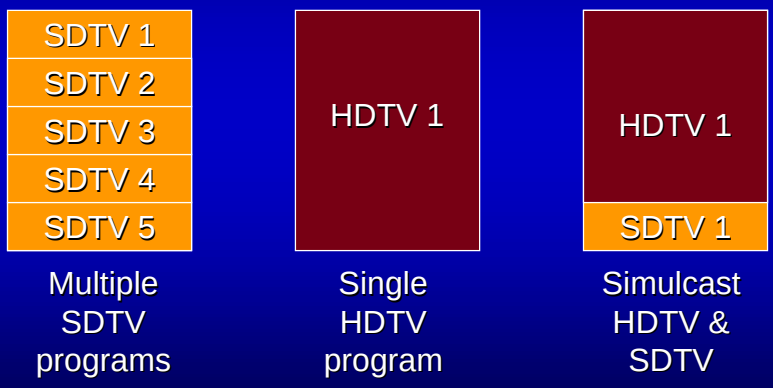
DVB Data Containers

- MPEG Transport Stream is used to provide DVB "data containers" which may contain a flexible mixture of:
  - Video
  - Audio
  - Data services
- Streams with variable data rate requirements can be Statistically Multiplexed together.
  - Allows Six 2 Mb/s programs to be placed in a 8 Mb/s channel

193

Examples of DVB Data Containers

Channel bandwidth can be used in different ways:



194

Video Program Capacity

For a payload of around 19 Mb/s

- 1 HDTV service - sport & high action
- 2 HDTV services - both film material
- 1 HDTV + 1 or 2 SDTV non action/sport
- 3 SDTV for high action & sport video
- 6 SDTV for film, news & soap operas

However you do not get more for nothing.

- **More services means less quality**

195

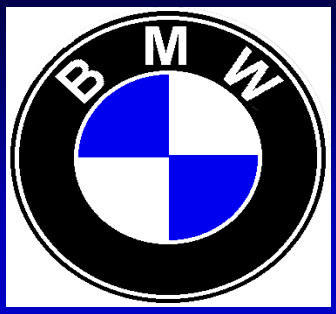
Fixed Bit Rate Multiplexing

- Most early digital services used fixed data rates for each of the component streams.
- The fixed rate had to allow for a high Quality of Service for demanding material.
- Fixed Data Rate was set to a high value for QoS
- Less demanding material is sent at a higher quality level.
- Works well with systems having similar material on the transport channels.

196

Spare Data Capacity

- Spare data capacity is available even on a fully loaded channel.
- Opportunistic use of spare data capacity when available can provide other non real time data services.
- Example: 51 second BMW commercial



The Commercial was shown using 1080 Lines Interlaced. 60 Mb of data was transferred during it. In the Final 3 seconds the BMW Logo was displayed allowing 3 Phone Books of data to be transmitted.

197

Statistical Multiplexing - 1

- Increases efficiency of a multi-channel digital television transmission multiplex by varying the bit-rate of each of its channels to take only that share of the total multiplex bit-rate it needs at any one time.
- The share apportioned to each channel is predicted statistically with reference to its current and recent-past demands.
- Data rate control fed back to the encoders from the multiplexer.

198

Statistical Multiplexing - 2

- More demanding material can request a higher data rate to maintain Quality of Service.
- More channels can be multiplexed together than an equivalent fixed rate system.
- Relies on demand peaks on only a few channels while other channels idle at a lower demand.

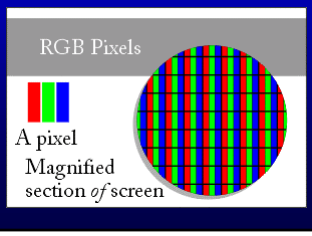
199

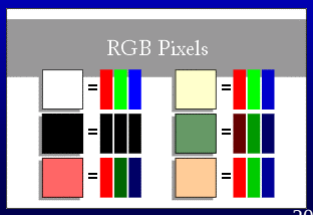
Enabling Technologies

- Source digitisation (Rec 601 digital studio)
- Compression technology (MPEG, AC-3)
- Data multiplexing (MPEG)
- Transmission technology (modulation)

200

Colour Reproduction





201