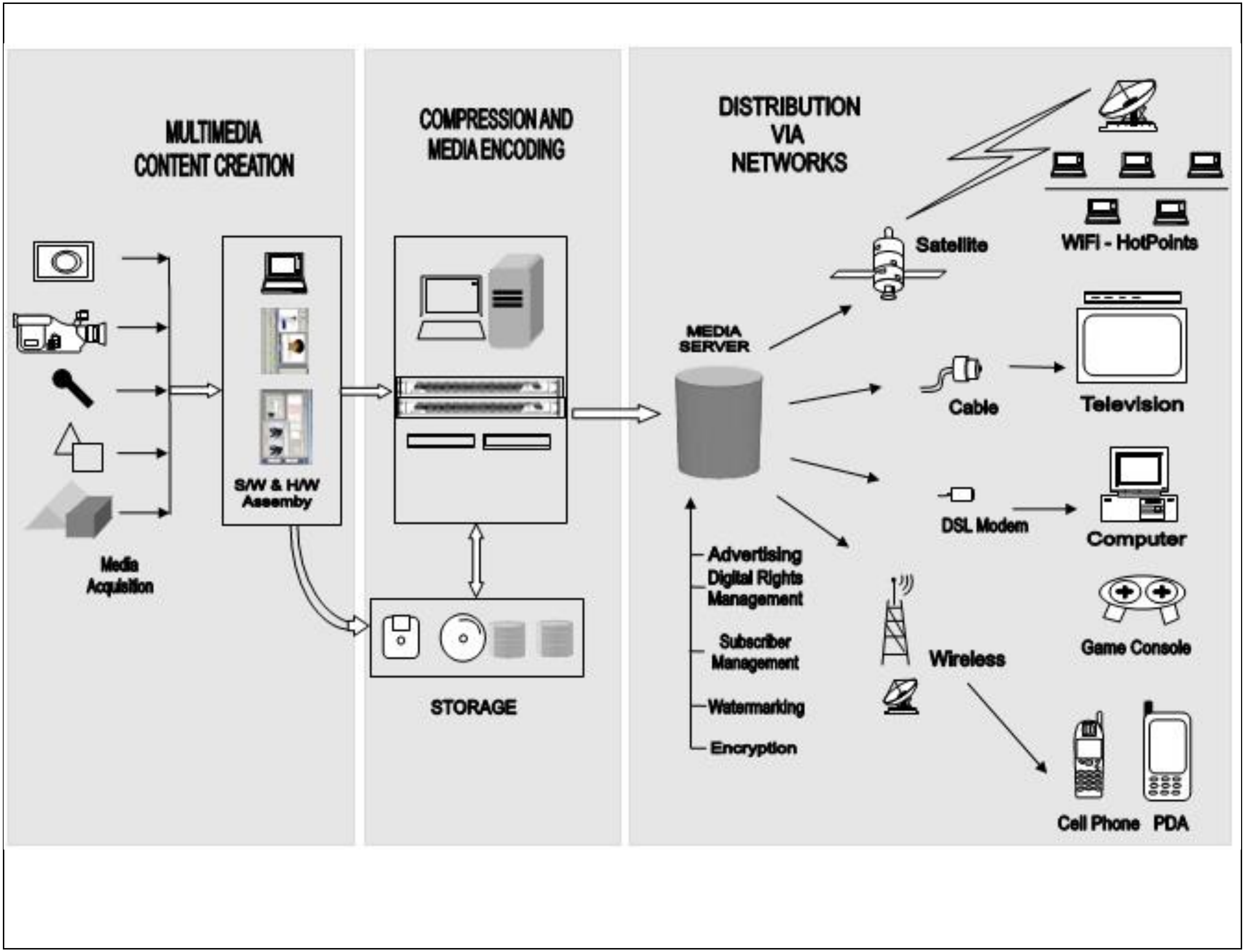
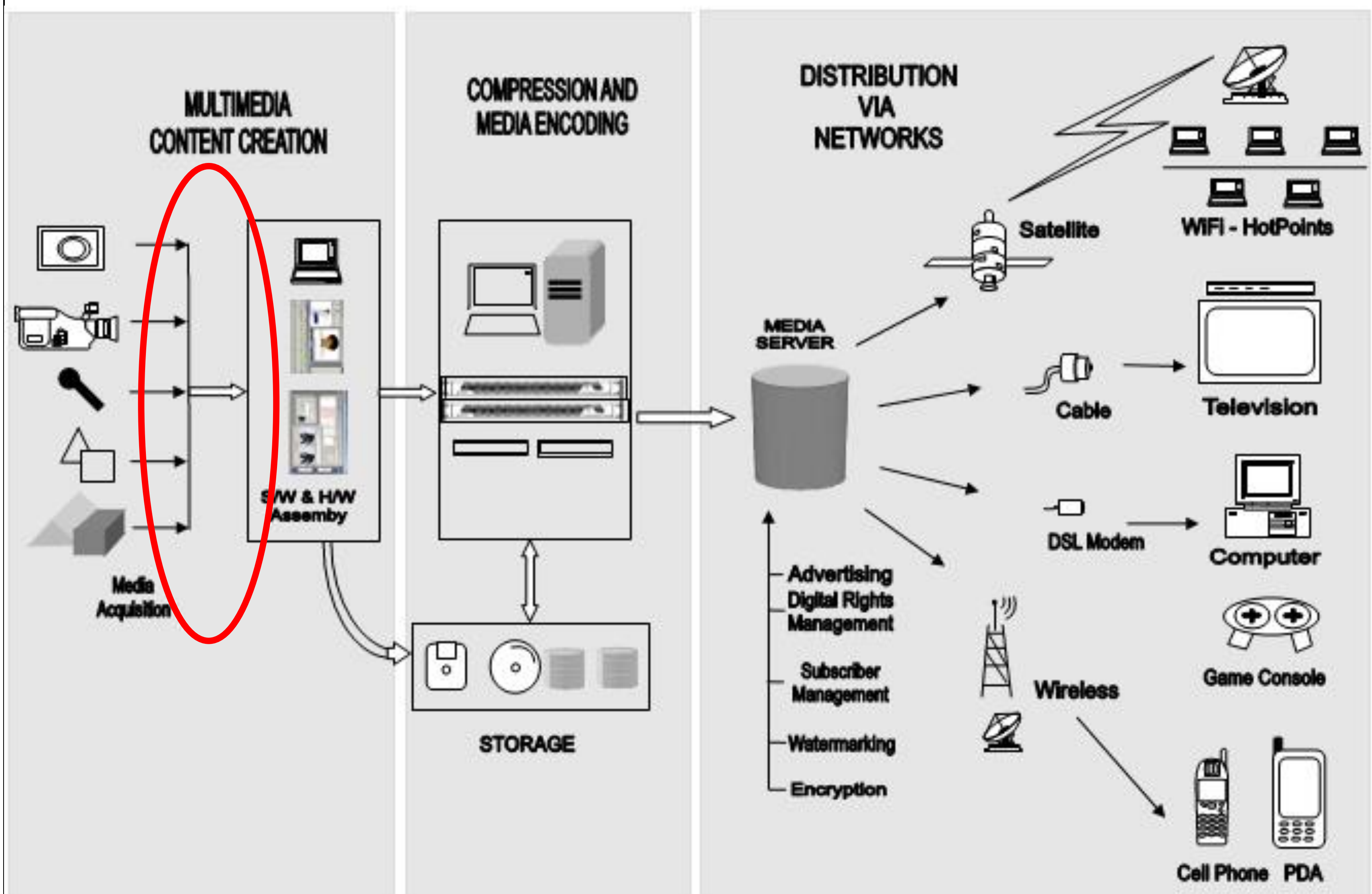
DIGITAL DATA ACQUISTION & MEDIA BASICS



MULTIMEDIA
CONTENT CREATION
COMPRESSION AND
MEDIA ENCODING
DISTRIBUTION
VIA
NETWORKS
Media
Acquisition
S/W & H/W
Assemby
STORAGE
MEDIA
SERVER
Advertising
Digital Rights
Management
Subscriber
Management
Watermarking
Encryption
Satellite
WIFI - HotPoints
Cable
Television
DSL Modem
Computer
Game Console
Wireless
Cell Phone
PDA



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LECTURE SUBTOPICS

Issues in Digitizing a Signal

- **Signal Sampling**
- **Quantization**
- **Bit Rate**

What do you lose in the digitization process?
Why do you lose it?
What can you do to avoid (minimize) the loss.

Filtering and Subsampling

Acquisition of media and formats

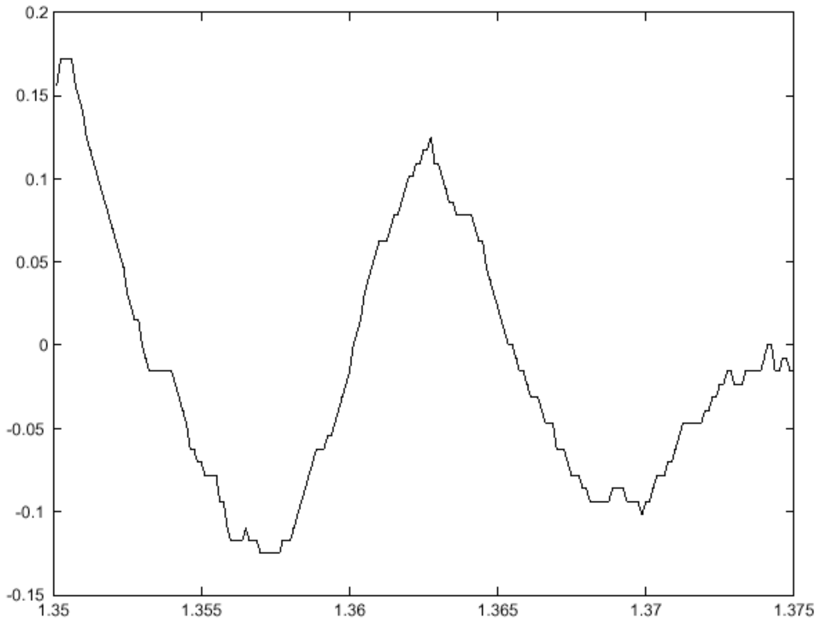
Video Progressive and Interlaced

Digital Component Video Formats

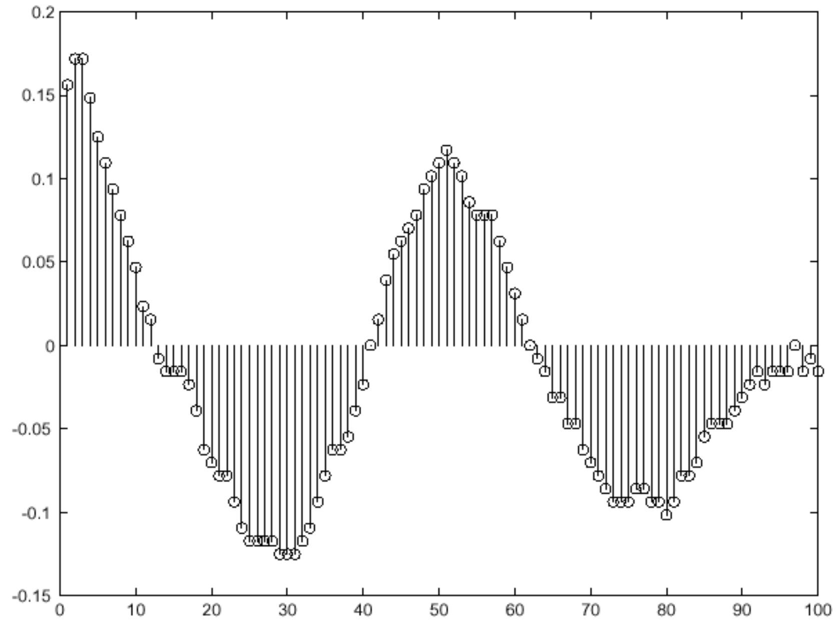
Aspect ratios

EXAMPLE SIGNALS

Analog Signal



Digital Signal



SAMPLING

For a signal $x(t)$,

$x_s(n)=x(nT)$ **where T is the sampling period**

$F=1/T$ **is the sampling frequency.**

The inverse transformation is called Interpolation

$x(t)$ ***from*** $x_s(n)$

Issues

- **If the sampled signal is interpolated, how do you ensure that you get back the original signal**
- **How fast should we sample**

QUANTIZATION

The value at every sampled location is digitized.

The digital domain has a finite bit representation

The sampled value is approximated to the nearest digital value.

OR Formally -

$x_q(n)=Q(x_s(n))$, *where Q* is a rounding function which maps the values of $x_s(n)$ into *N* levels with a quantization step Δ.

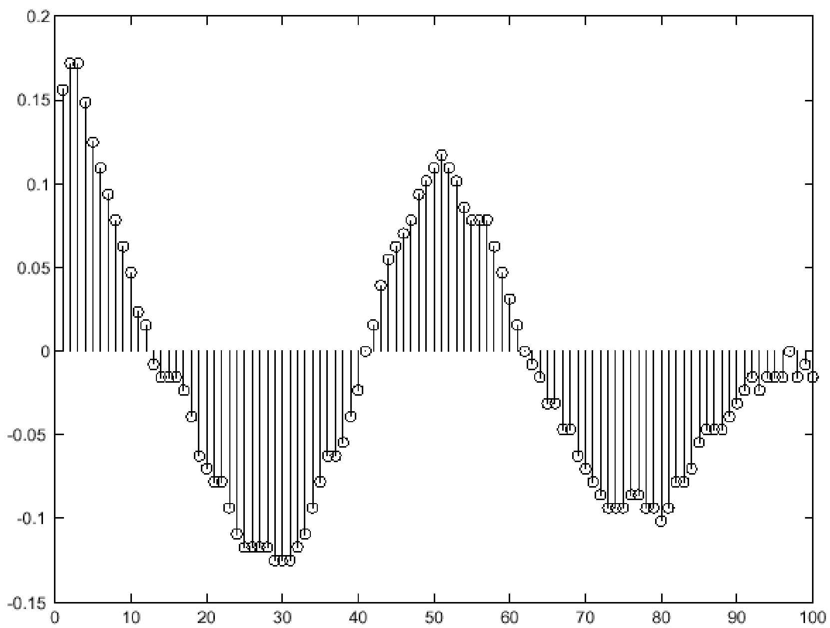
Typically, $N=2^b$ so that we need *b* bits to represent one quantized sample.

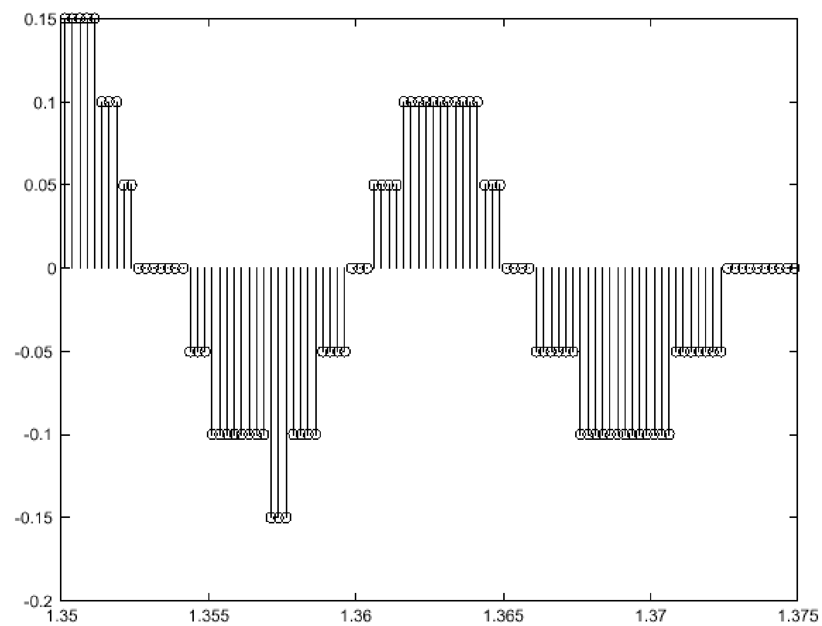
Issues

What is the correct quantization step?

Quantization errors may result!

QUANTIZATION EXAMPLE IN 1D



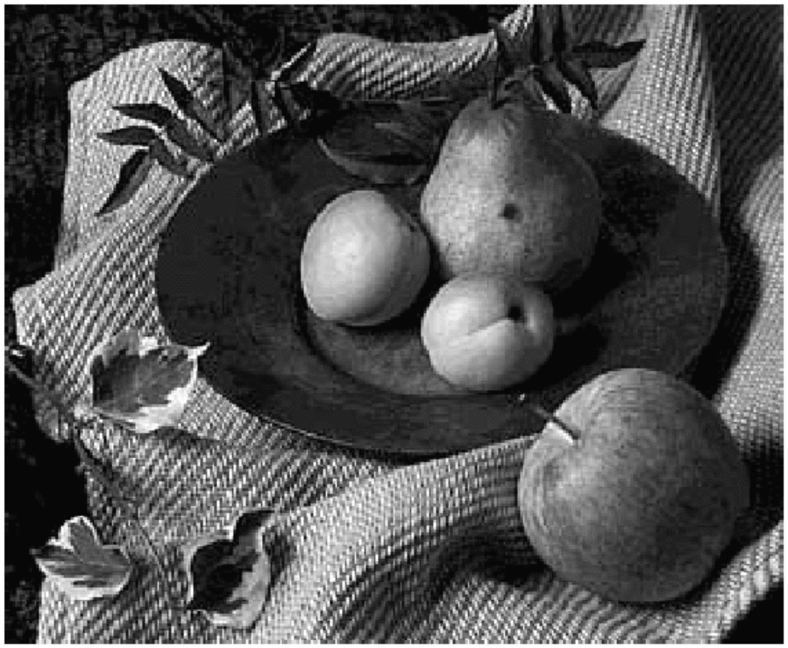


QUANTIZATION EXAMPLE IN 2D (1)

6 bits

5 bits

QUANTIZATION EXAMPLE IN 2D (2)

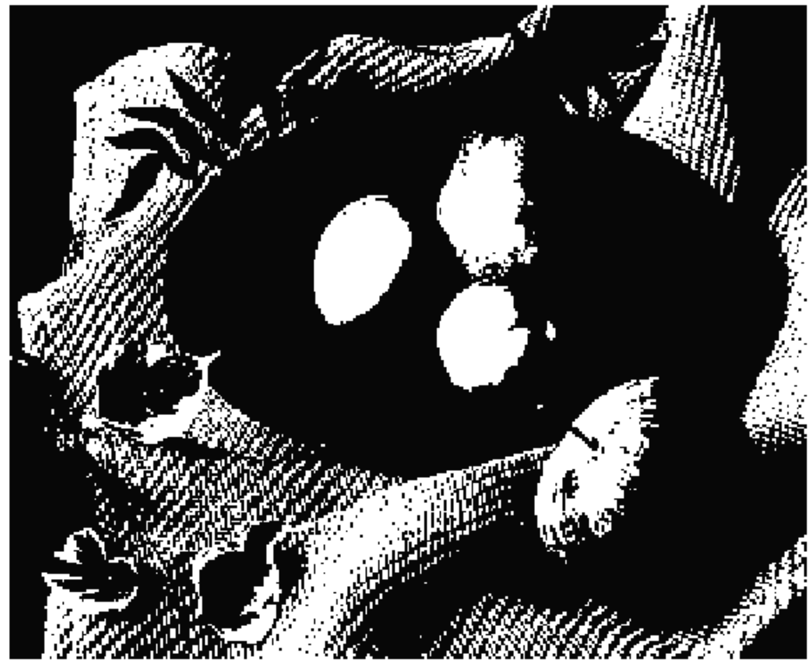


4 bits

3 bits

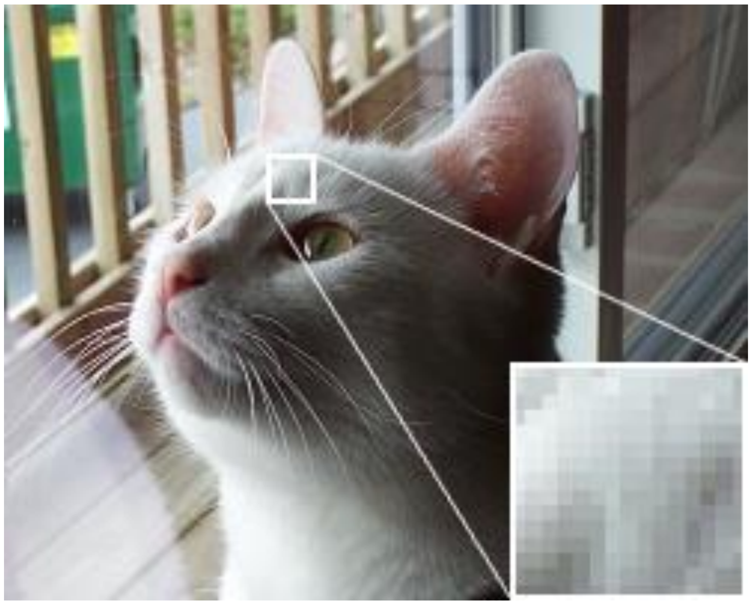
QUANTIZATION EXAMPLE IN 2D (3)

2 bits

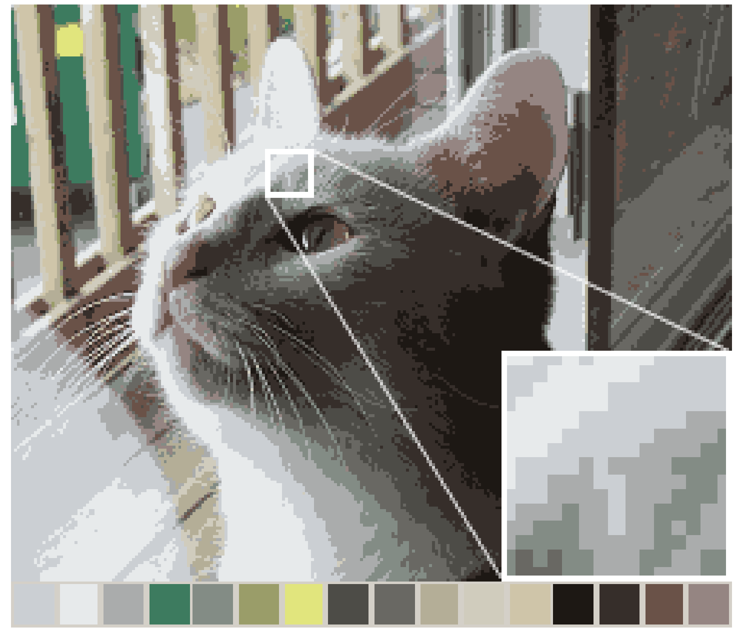


1 bits

COLOR QUANTIZATION IN IMAGES



24 bit RGB Color
(8 bits per channel)



16 Colors

BIT RATE

How many bits do you get per second?

Bit rate = (number of samples per second) x (bits per sample)

Bit rate relates to the network through put

Examples of bitrate

- **Audio – CD Bitrate**
  Sampling frequency: F= 44.1 KHz
  Quantization with 16 bits
  Bit-rate = 705.6 Kb/s (per channel)

As sampling rate increases, bit rate increases

As quantization bits used increase, bit rate increases

BIT RATE

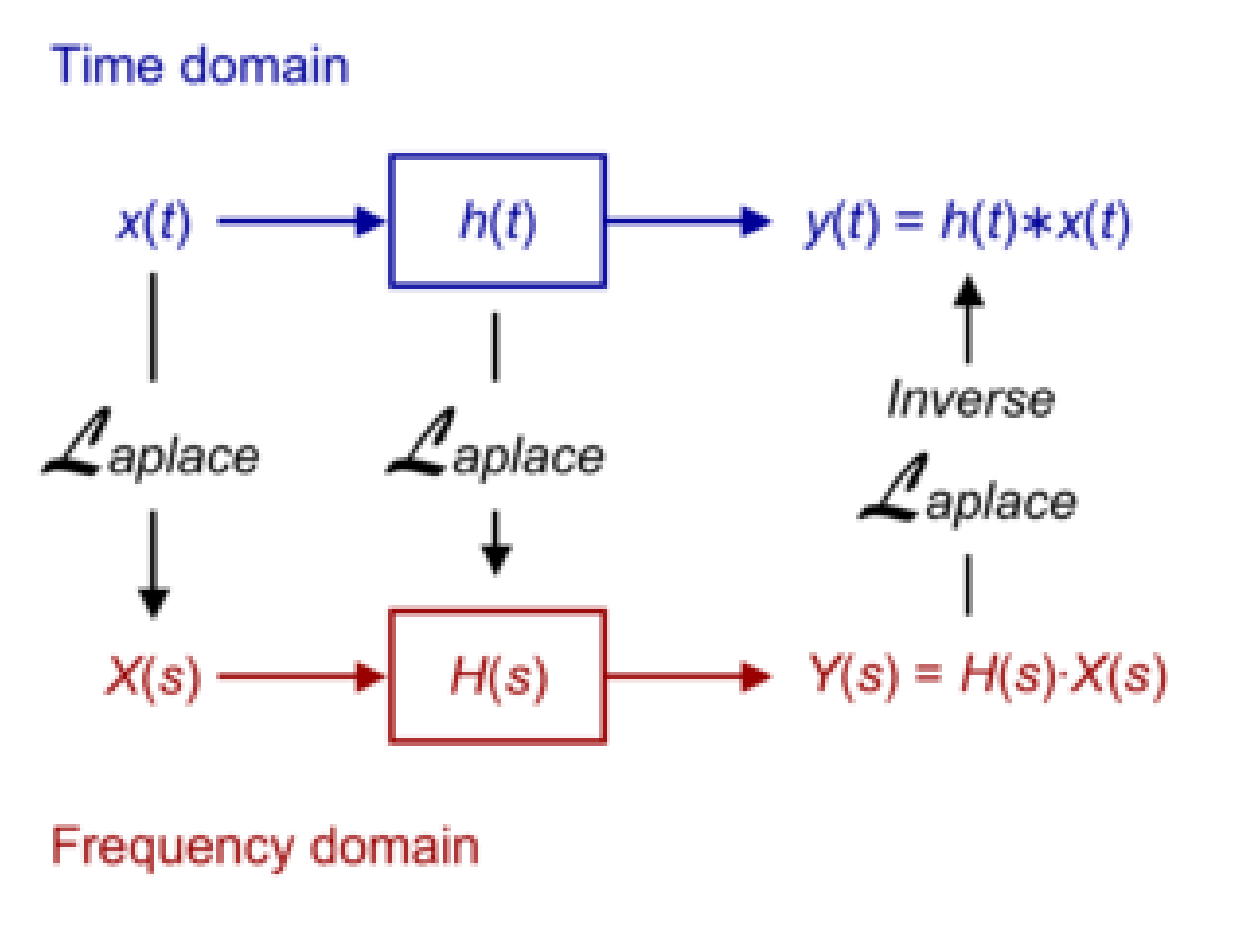
Signal	Sampling Rate	Quantization	Bit Rate
Speech	8 KHz	8 bits per sample	64Kbps
Audio CD	44.1 KHz	16 bits per sample	706 Kbps (mono) 1.4 Mbps (stereo)
Teleconferencing	16 KHz	16 bits per sample	256 Kbps
AM Radio	11 KHz	8 bits per sample	88 Kbps
FM Radio	22 KHz	16 bits per sample	352 Kbps (mono) 704 Kbps (stereo)
NTSC TV image frame	Width – 486 Height – 720	16 bits per sample	5.6 Mbits per frame
HDTV (1080i)	Width – 1920 Height – 1080	12 bits per pixel on average	24.88 Mbits per frame

SOME THEORY

Linear Time Invariant Systems

- **Can be completely characterized by impulse response**
- **Impulse Response Vs Transfer Function**
- **Time Domain View: The output of the system is the convolution of the input with the system's impulse response**
- **Frequency Domain View: The frequency transform output of the system is the product of the transfer function and the frequency transform of the input**

TIME DOMAIN VS FREQUENCY DOMAIN



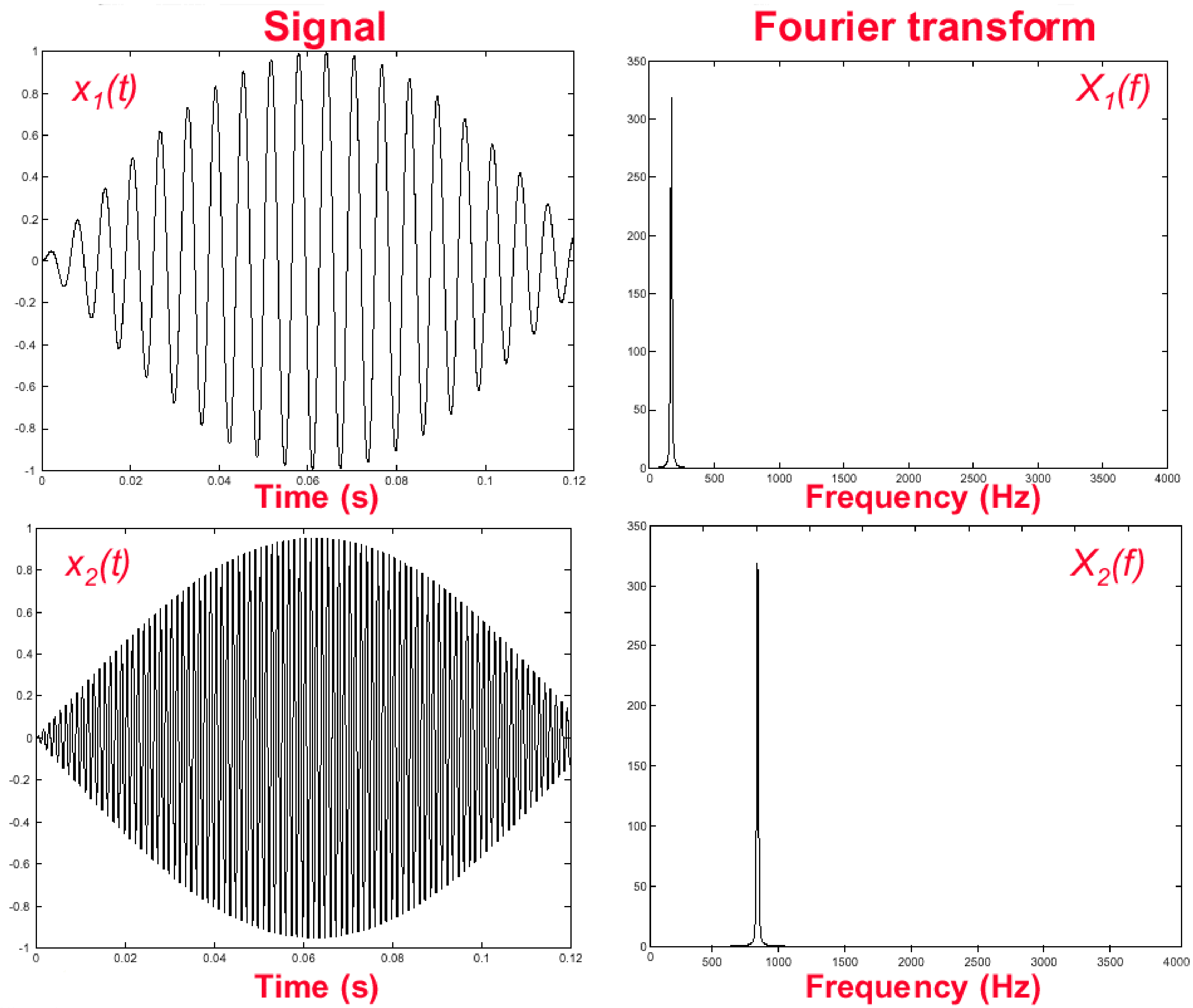
WHAT'S THE CORRECT SAMPLING RATE?

If *F* is too large *(T* is too small), we obtain too high a bit-rate

If *F* is too small *(T* is too large), too much information is lost in the sampling process

We want to capture as much information as necessary to represent the signal correctly

the *minimum sampling rate* for "correct" sampling depends on the frequency characteristics of the signal


Signal
Fourier transform
$x_1(t)$
$X_1(f)$
Time (s)
Frequency (Hz)
$x_2(t)$
$X_2(f)$
Time (s)
Frequency (Hz)

NYQUIST'S SAMPLING THEOREM

Let $x(t)$ have a maximum frequency F. Then we can "perfectly" interpolate the signal $x(t)$ from its sampled version $x_s(n)=x(nT)$ only if the sampling period T is less than $1/(2F)$

In other words, the sampling frequency should be at least 2F for a signal whose maximum frequency is F - Otherwise – aliasing

ALIASING EXAMPLES

Spatial Aliasing in one dimension

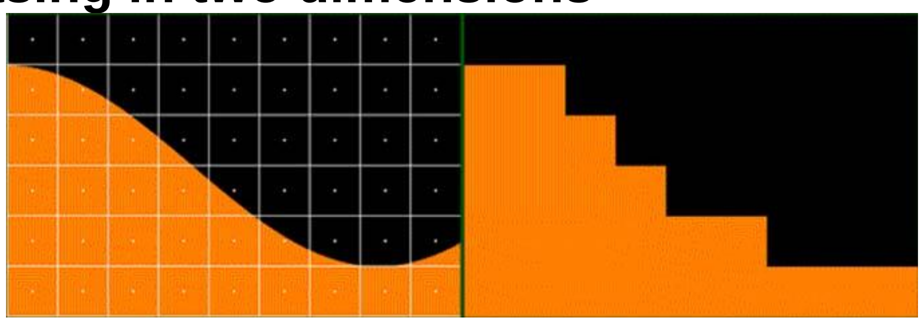
Example of a sinusoidal function in 1D

Audio aliasing (single frequency)

Audio without aliasing –

and with aliasing


Spatial Aliasing in two dimensions



Spatial Aliasing

Spatial Aliasing - moiré lines

Temporal Aliasing

Revolving Light **A real example**

OTHER EXAMPLES

Convolution –
http://www.jhu.edu/signals/lecture1/frames.html

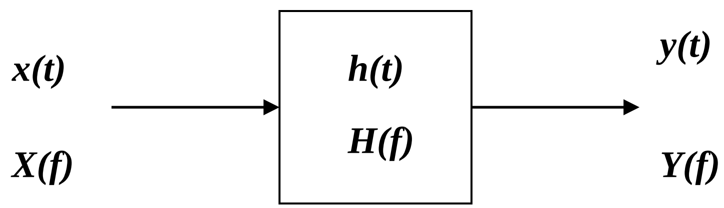
Fourier Transform -
http://www.jhu.edu/signals/sampling/index.html

BANDLIMITED SIGNALS AND FILTERS

Fourier Transform *X(f)* of a signal *x(t)*: describes how the "energy" of *x(t)* distributes among frequencies *f*

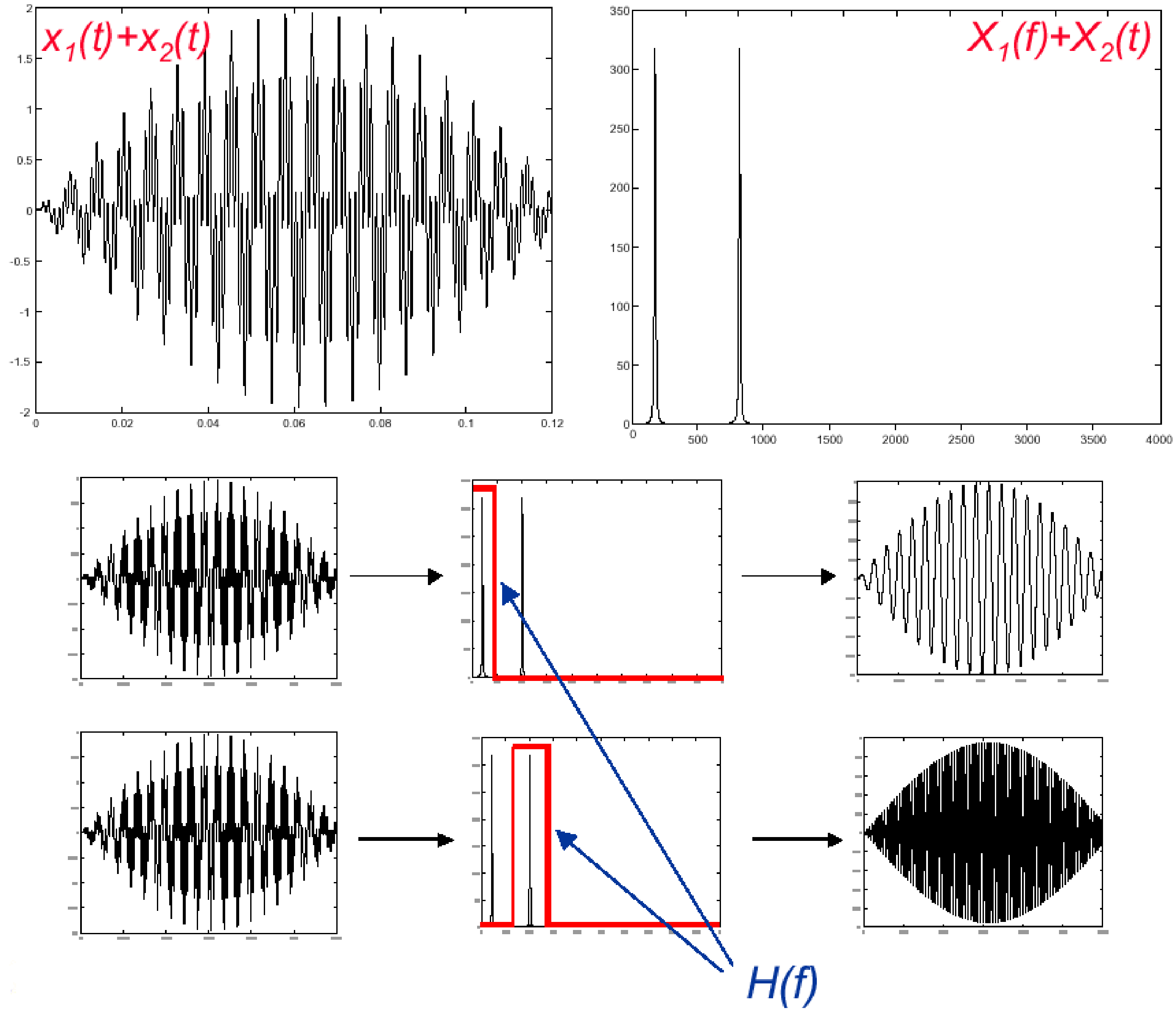
If the highest frequency in X(f) is B, we say x(t) is Band Limited to B

A "*filter*" is an operator characterized by its frequency response H(f):



- **The Fourier transform of *y(t)* is *Y(f)=H(f)X(f)***
- **Therefore, the band B_y of *y(t)* is < the band B_h of the filter**
- **Filters can be low-pass, band-pass or high-pass**

Signal   Fourier transform



Original

Low-pass filtered

High-pass filtered

EXAMPLES USING FILTERS IN COMPRESSION

Audio Filtering Example

Cut-off frequency of microphone is 100KHz. We should sample at 200KHz. If Quantized at 16 bits per sample -> 3 Mbs!

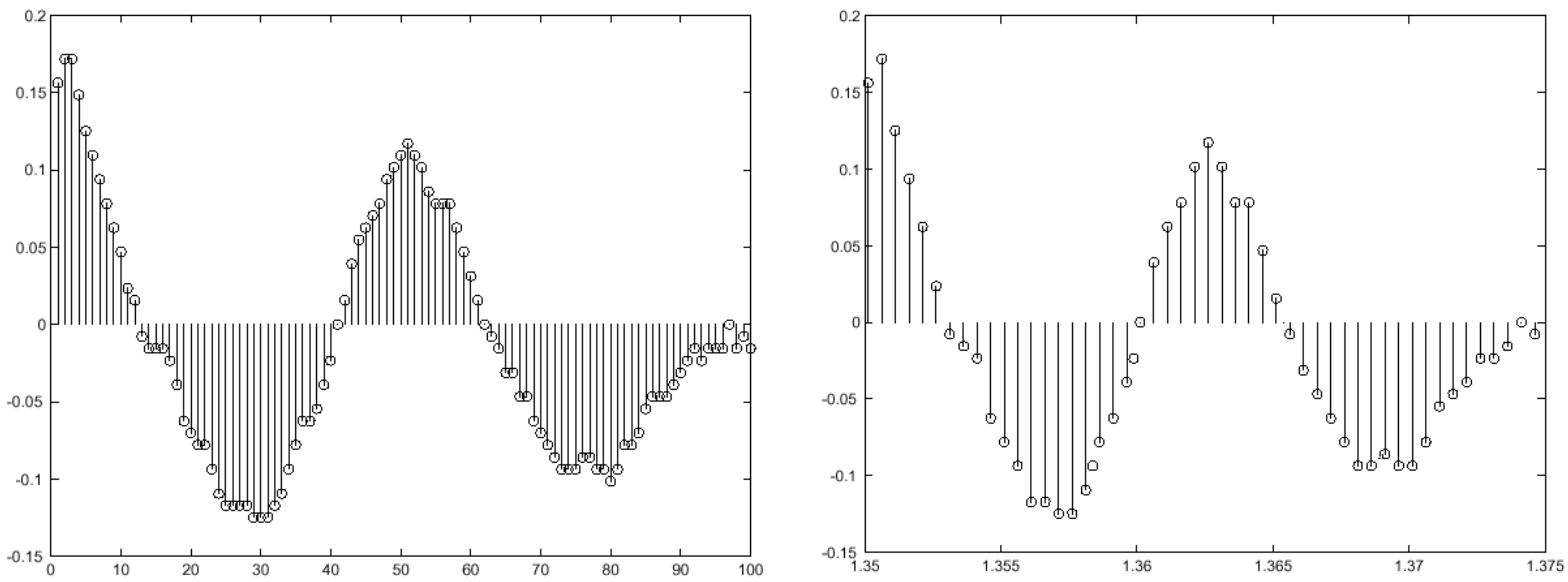
Our hearing system can only detect frequencies up to ~20KHz.

Prefilter the signal

Use a low-pass filter with cut-off frequency B=20KHz. Then, we sample the signal at 40KHz producing only 640 Kb/s

SUBSAMPLING (DECIMATION)

Given *x (n)*, subsampling by *M* means generating a signal *y (n) = x (Mn)*.



SUBSAMPLING EXAMPLE

Example: A continuous signal *x(t)*, band-limited to B=4KHz is sampled without aliasing with *F*=10 KHz. Suppose now we subsample the resulting signal by 2.

This is equivalent to sampling the original signal with rate F=5KHz (which gives *aliasin*g)

Solution: digital low-pass filter before subsampling.

STATISTICAL DEFINITIONS

Mean or Expectation of the signal *x (n)*, for a large sample space M is defined as

$$\mu_x = \left(\sum_{n=1}^{n=M} x(n) \right) \Big/ M$$

The Variance of the signal *x(n)* is defined as

$$\sigma_X^2 = \left(\sum_{n=1}^{n=M} \left(x(n) - \mu_X \right)^2 \right) \Big/ M$$

The power of the quantization error, σ_e^2 is the variance of the signal *e(n) = x $_q$ (n)-x(n)*

The signal-to-quantization noise ratio (measured in dB)
SNR = 10 log $_{10}(\sigma_x^2 / \sigma_e^2)$

ORIGINAL IMAGE

SUBSAMPLED BY 2

Without prefiltering

With prefiltering

SUBSAMPLED BY 4

Without prefiltering

With prefiltering

MEDIA REPRESENTATIONS

Audio Signals – Time Varying Signals (amp @ t)

Images – 2D Signal (color @ x, y)

Video Signals – 3D Signals (color @ x, y, t)

Graphics –

- **Inherently Digital**
- **2D graphics objects**
- **3D graphical objects**

VIDEO SIGNALS

Video is obtained via *raster scannin*g, which transforms a 3-D color signal (function of x, *y* and t) into a one-dimensional signal for transmission

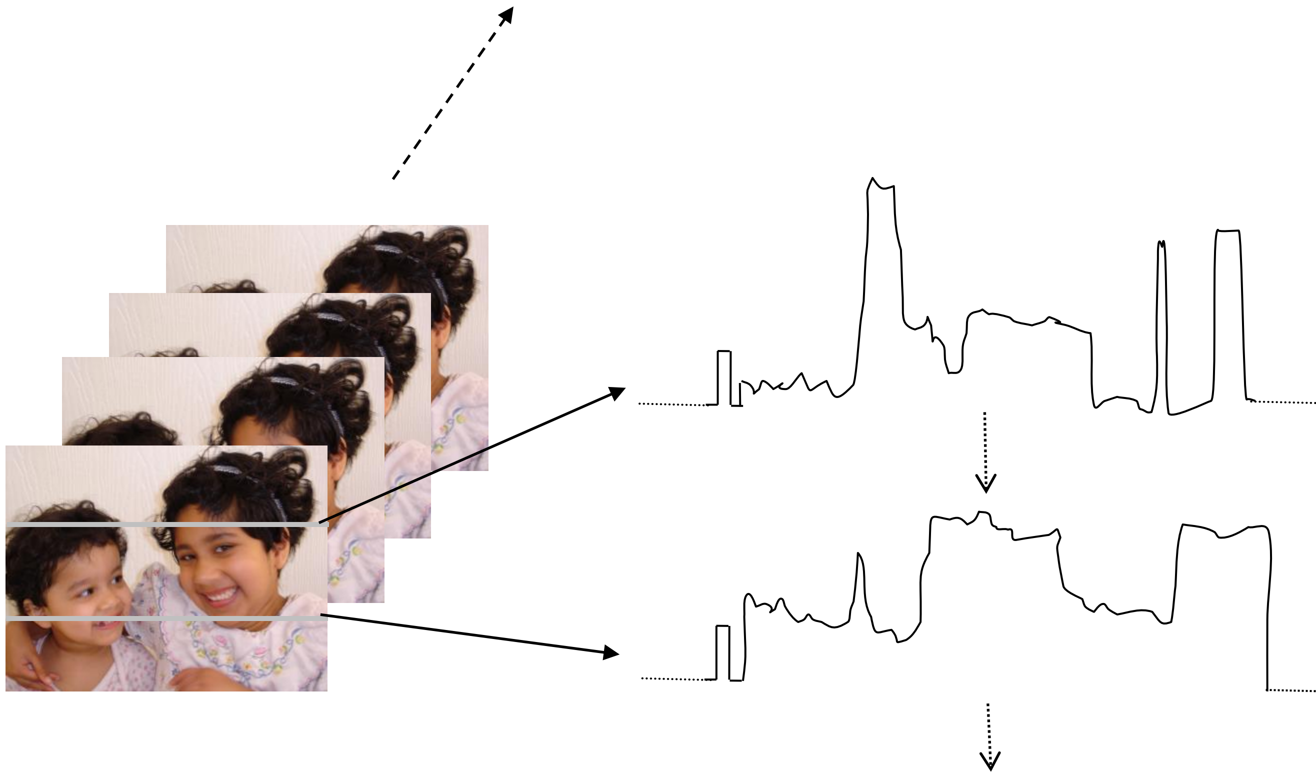
Scanning is a sampling operation:

Samples in time: *Frames*
Samples along *y* (vertical direction): *Lines*
Samples along x (horizontal direction): *Pixels*

Scanning is done using two formats

- **Progressive Scanning**
- **Interlaced Scanning**

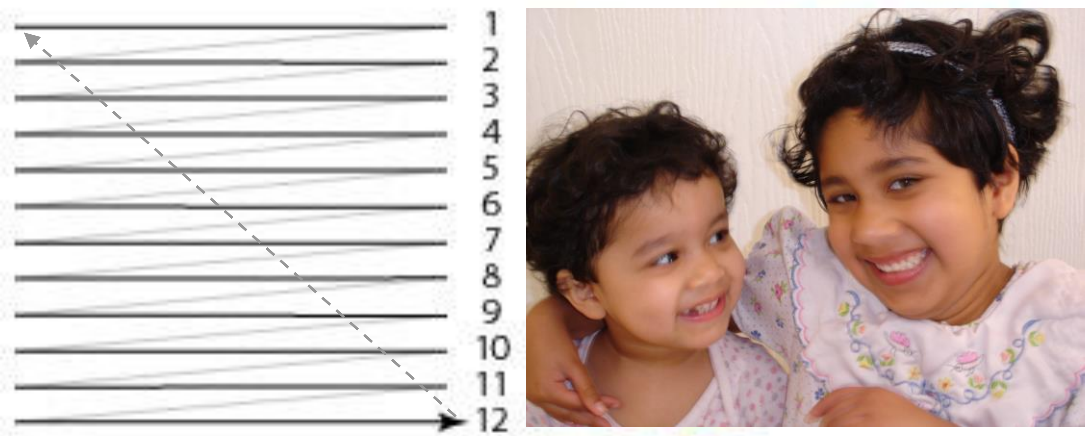
ANALOG VIDEO



History of Television and Analog Video

PROGRESSIVE SCANNING

Rows are scanned left to right and top to bottom

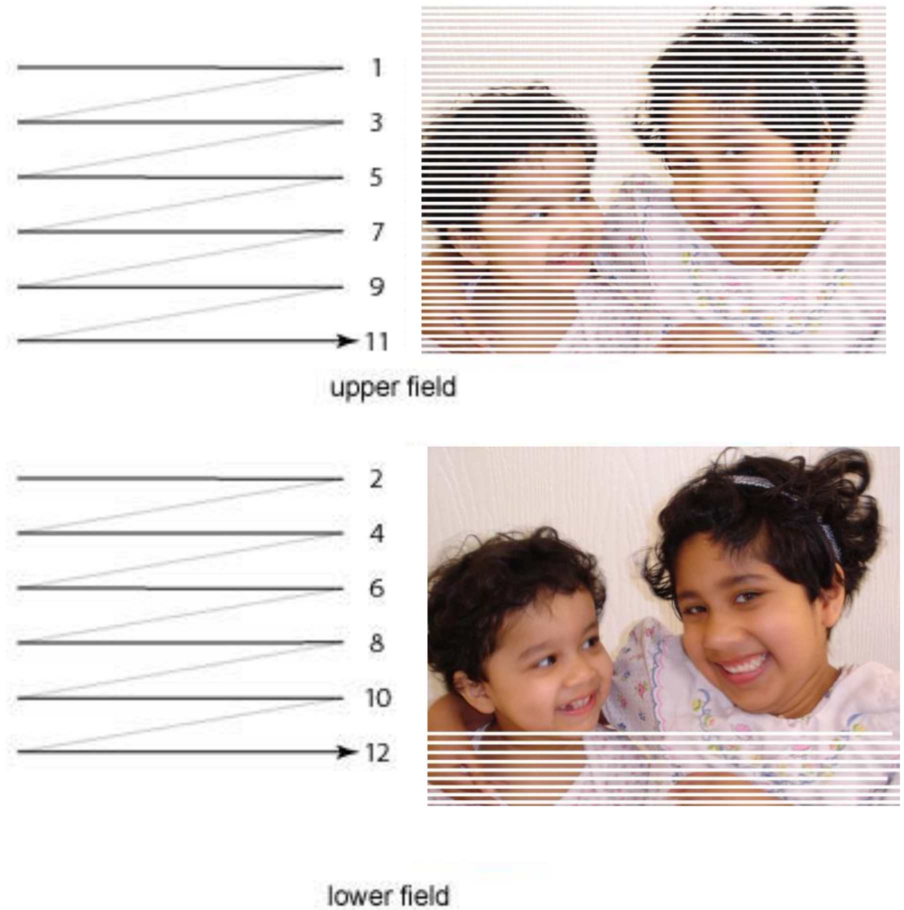


INTERLACED SCANNING

Each frame is scanned twice (two fields)
First, scan all even lines
then, scan all odd lines

- **Slow-moving objects can be perceived with high spatial resolution**
- **fast-moving objects can be perceived at high frame rate**

INTERLACED SCANNING EXAMPLE



LUMINANCE AND CHROMINANCE

In color video, we have 3 signals:

1 signal of *luminance*

2 signals of *chrominance*

The three signals are composed together to form a color image.

If only the *luminance* **signal is received: grayscale image**

CHROMINANCE SUBSAMPLING SCHEMES

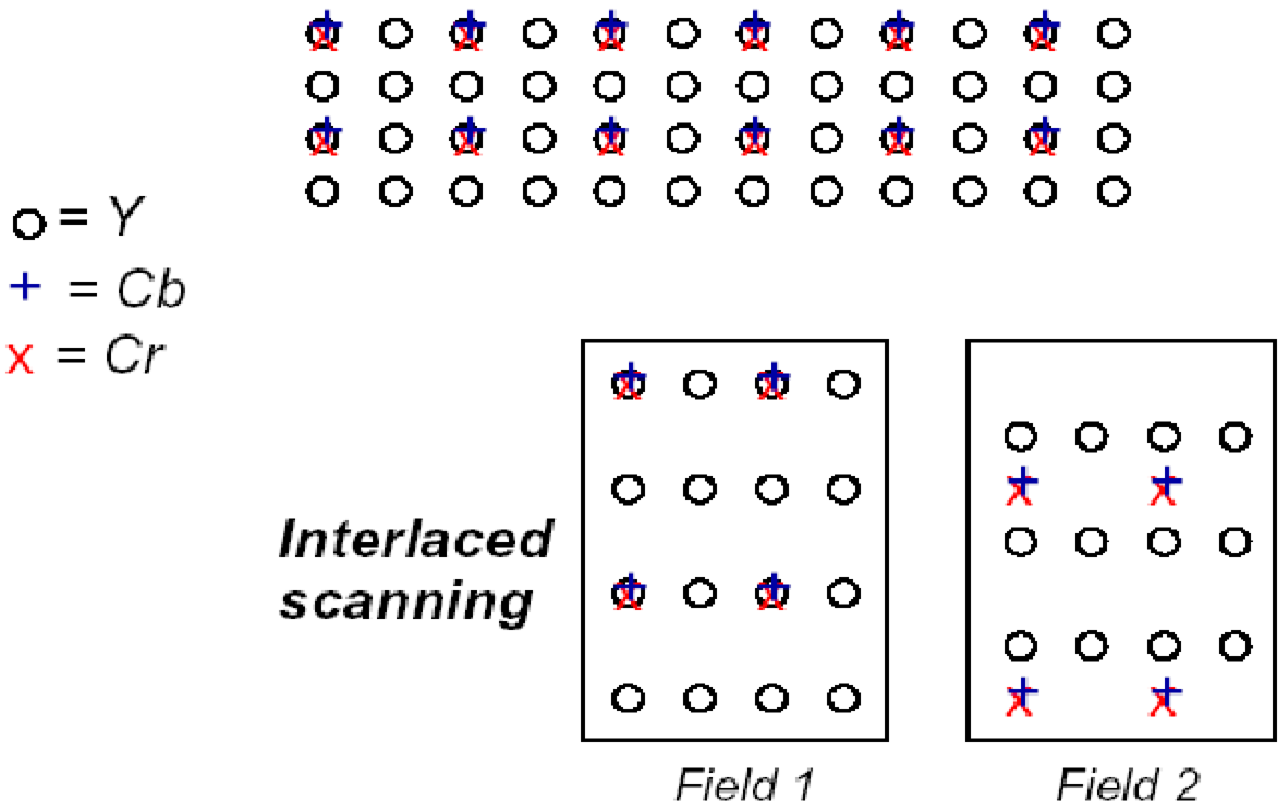
Human visual system is less sensitive to the *Chrominance* **channels than to** *Luminance* **channel**

We can *subsample* the chrominance channels without noticeable loss of detail

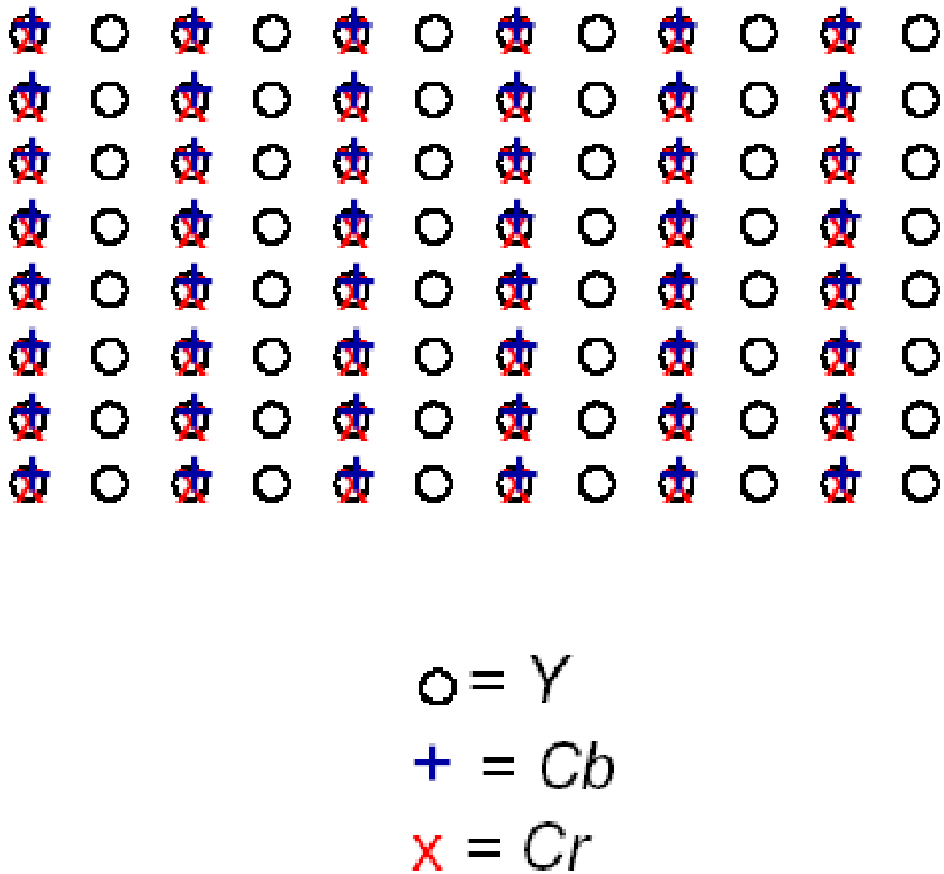
Color subsampling schemes:

- *4:2:0* **(a.k.a.** *4:1:1***): 1 sample of each chrominance channel every 4 samples of luminance**
- *4:2:2:* **1 sample of each chrominance channel every 2 samples of luminance**

4:2:0 SUBSAMPLING SCHEME



4:2:2 SUBSAMPLING SCHEME



EQUIVALENT BITS/PIXEL

Assume luminance and the two channels of chrominance are quantized with 8 bits/sample

4:2:0 **- For every 4 pixels, we have 4 samples of luminance and 1 sample each of chrominance.**

- **Overall, $4 \cdot 8+8+8=48$ bits per 4 pixels.**
- **On average, $48/4=12$ bits per pixel.**

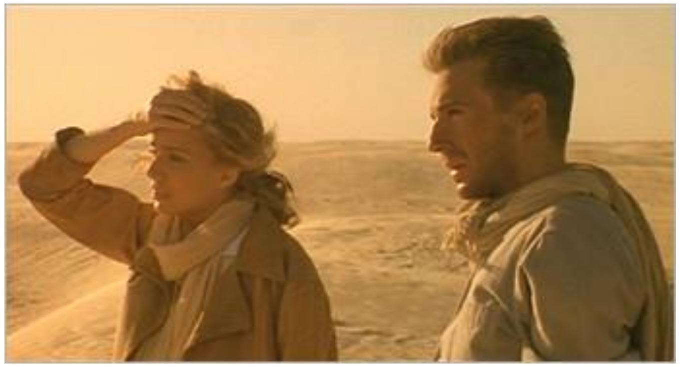
4:2:2 **- For every 2 pixels, we have 2 samples of luminance and 1 sample each of chrominance.**

- **Overall, $2 \cdot 8+8+8=32$ bits per 2 pixels.**
- **On average, $32/2=16$ bits per pixel.**

IMAGE ASPECT RATIOS

Image Aspect Ratio: ratio of width to height in the image

- **Typically 4:3 for standard TV**
- **HDTV has 16:9**
- **Cinemascope has 47:20!**



PIXEL ASPECT RATIOS

Pixel Aspect Ratio: ratio width to height of a pixel, assuming it is a rectangle

- **Computers have square pixels, ratio = 1**
- **NTSC Wide Screen 16:9, ratio = 1.2**

Example:

Image Aspect Ratio = 4:3; N_l=486; N_p=720;
Then Pixel Aspect Ratio = (4/3)(486/720)=0.9

SEAM CARVING

http://www.youtube.com/watch?v=qadw0BRKeMk

STILL IMAGE FORMATS

Format name	Lines/frame	Pixels/line	Bits/Pixel
FAX	2200	1700	1
VGA	480	640	8
XVGA	768	1024	24

VIDEO FORMATS

Format Name	Lines per Frame	Pixels per Line	Frames per Second	Interlaced?	Sub sampling scheme	Image Aspect Ratio
CIF	288	352		N	4:2:0	4:3
QCIF	144	176		N	4:2:0	4:3
SQCIF	96	128		N	4:2:0	4:3
4CIF	576	704		N	4:2:0	4:3
SIF-525	240	352	30	N	4:2:0	4:3
SIF-625	288	352	25	N	4:2:0	4:3
CCIR 601 NTSC (DV, DVB, DTV)	480	720	29.97	Y	4:2:2	4:3
CCIR 601 PAL/SECAM	576	720	25	Y	4:2:0	4:3
EDTV (576p)	480 / 576	720	29.97	N	4:2:0	4:3 / 16:9
HDTV (720p)	720	1280	29.97	N	4:2:0	16:9
HDTV (1080i)	1080	1920	59.94 (field rate)	Y	4:2:0	16:9
HDTV (1080p)	1080	1920	29.97	N	4:2:0	16:9
Digital Cinema (2K)	1080	2048	24	N	4:4:4	47:20
Digital Cinema (4K)	2160	4096	24	N	4:4:4	47:20

VIDEO FORMATS – BIT RATE COMPUTATION

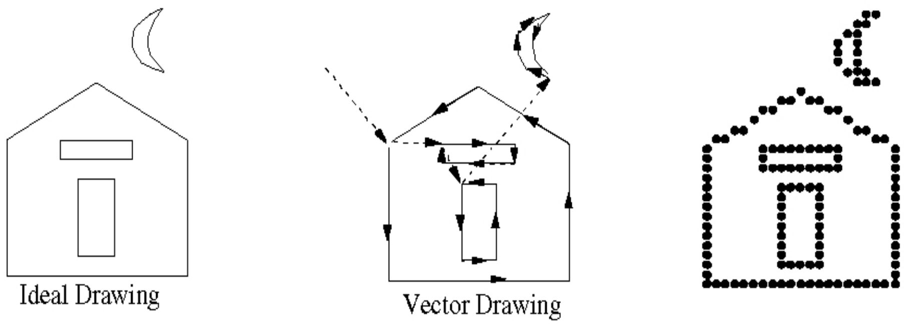
Bit-rate for interlaced HDTV format is calculated as

- **N_l =1080 lines per frame,**
- **N_p =1920 pixels per line,**
- **N_{FPS} =29.97 frames/second**
- **P = 12 bits per pixels (luminance + chrominance)**

$N_l N_p N_{FPS} \cdot 12$ **= 745,749,504 bits/s.**

GRAPHICS

Representation - vector and raster



Graphical object in 2D/3D