Chapter 2

Multimedia Fundamentals

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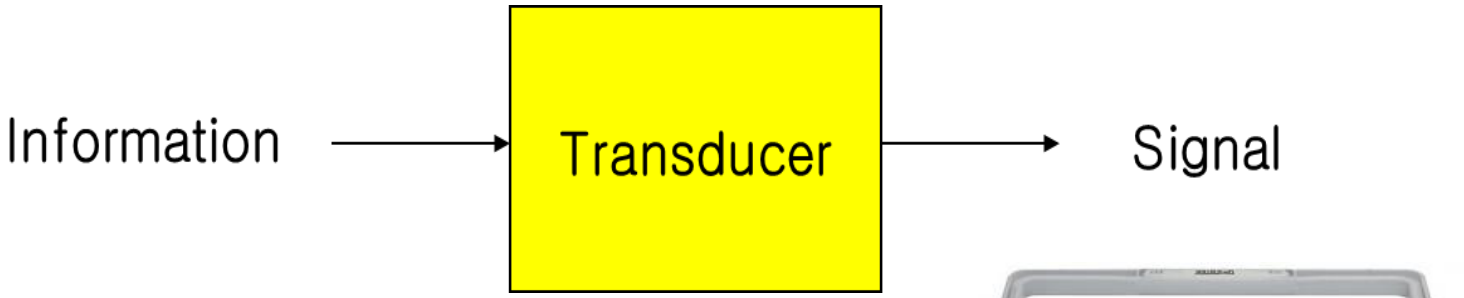
Contents

- Information and Signal
  - Analog and Digital
- Digitization of analog source
  - ADC and DAC
  - Bit rate
- Digital signal and spectrum
- Network

Information and Signal

- Signal
  - Physical realization of information in electrical waveform such as current or voltage
  - Signal itself carries information
  - ***All nature signal (speech, audio, image) exists in the analog form***

Information to signal transformation

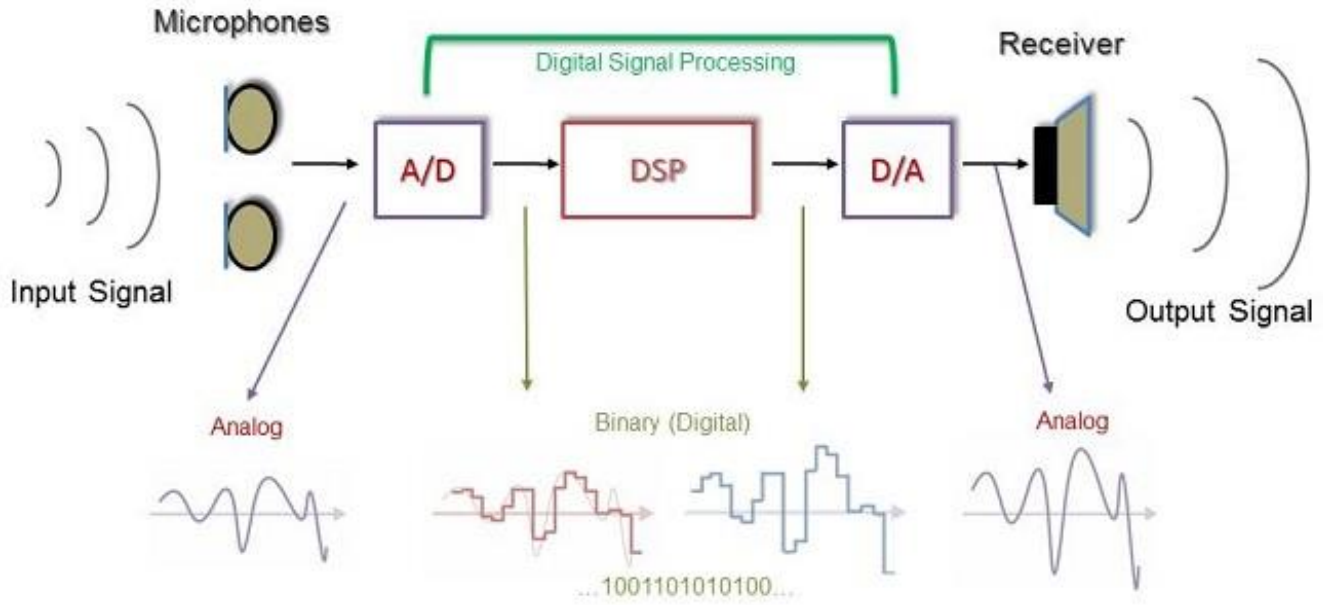


oscilloscope

Signal

- Possible to measure in electrical waveform in LAB
- Way of carrying out the information

Digital hearing aid system



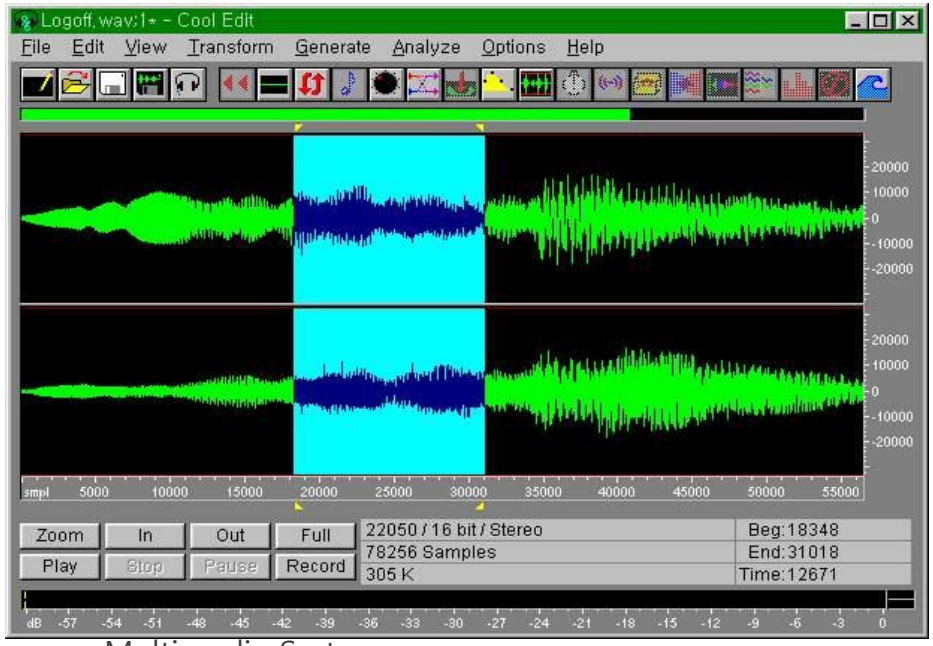
Classifying Signal

- Analog Signal (continuous-time signal)
  - Continuous waveform with respect to time
  - $x(t)$, $y(t)$
- Digital signal (discrete-time signal)
  - Discrete waveform with respect to time
  - Sampled version of analog signal $x[n]$, $y[n]$
  - 0,1 is called digital binary

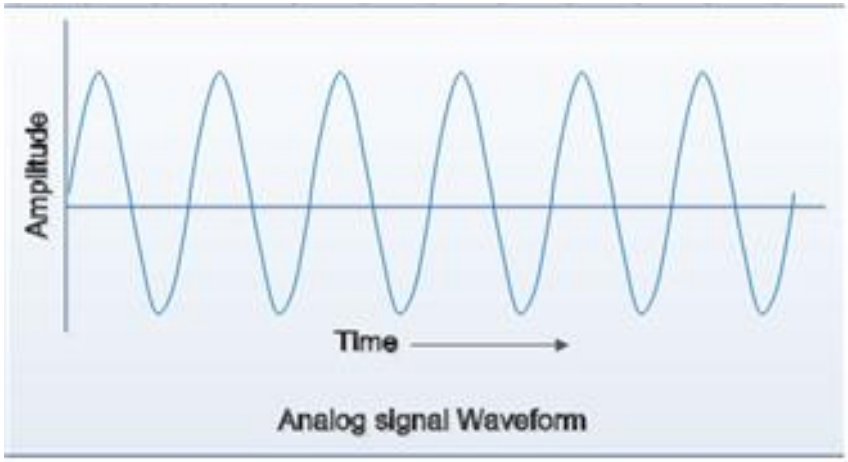
Multimedia Signal

- Signal classification
  - Time-varying: Audio, Spatial-varying : Image
  - Time, Spatial-varying: Moving Pictures = Video

  (spatial means 2D space)



Analog Signal



$$x(t) = A \cdot \sin(2\pi ft + \theta)$$

- Information lies on the amplitude
- ***A* - amplitude, *f* - frequency in Hz, *θ* - phase**

- **Amplitude -** strength of the signal
  - Speech and audio
    - Represents loudness or strength of the sound

      ⇒ SPL (sound pressure level)
    - SPL

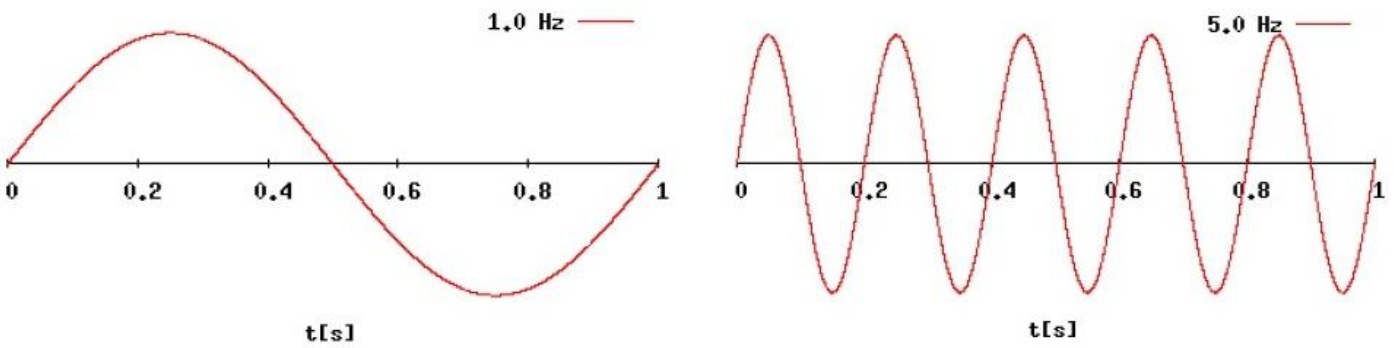
$$SPL\ (dB) = 20 \cdot \log_{10}\left(\frac{P}{P_0}\right)$$

      - P_0 is reference sound pressure. It is measured when we can barely hear the $1kHz$ sine tone. $P_0 = 2.5X10^{-5}N/m^2$
      - P is measuring sound pressure
  - Image: Strength or intensity of the light

Frequency (f)

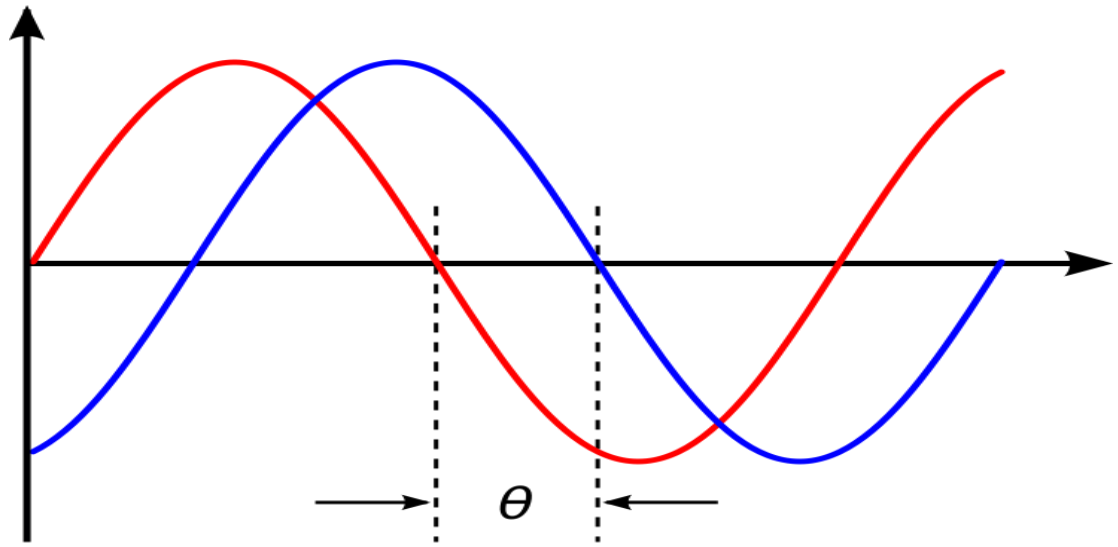
- Number of repetitions of same pattern in 1 sec (unit : Hz); Period (T) = 1 / f (unit : sec)

$f = 5kHz$

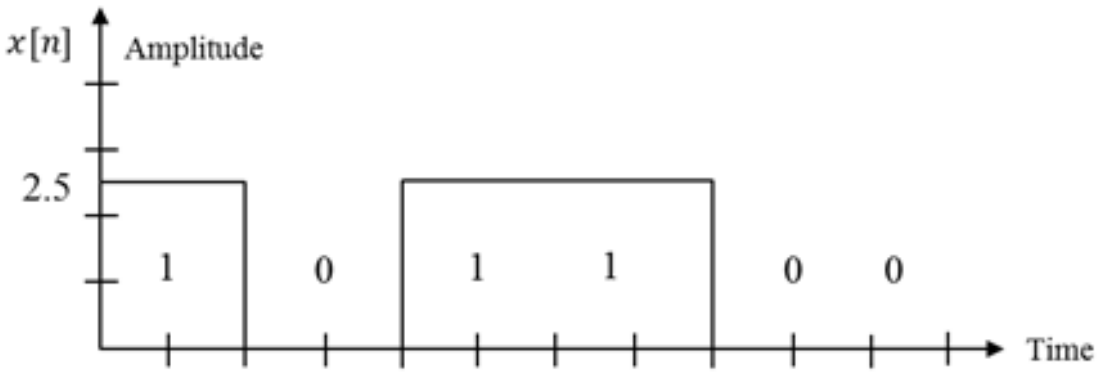


frequency	Time-domain waveform	Sound hearing
(a) $f = 1kHz$	relatively slow time-varying	relatively heard as low tone (pitch)
(b) $f = 5kHz$	relatively fast time-varying	relatively heard as high tone (pitch)

- Phase
  - Phase angle θ between two sinusoids



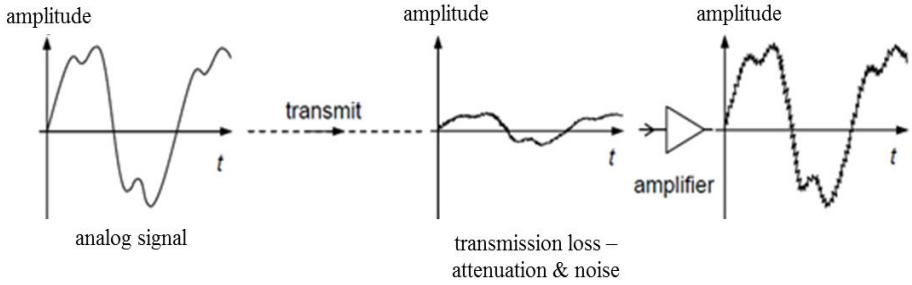
Digital Binary



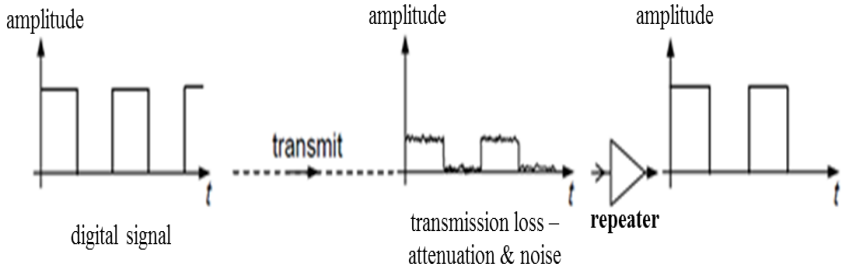
- Information lies on discerning ability between binary 0 and binary 1
- ***Does not matter with amplitude!!***

Advantage of DSP

- Allows **high quality of signal processing**
  - Digital Binary 0, 1 is highly robust to noise
  - Not sensitive to environmental factors such as temperature as in analog signal



Analog transmission



Digital transmission

- Possible to setup **programmable** digital system
  - Can easily change system functionality by slightly modifying the SW program in DSP Chip
  - Not possible with analog system, the hardware must be redesigned overall

- Possible to process **multimedia** data
  - Can easily combine different type of digital media such as speech, audio, image
  - Easy store, processing, transmission

- **Low cost digital IC Chip** is available
  - Getting more smaller and low cost
  - Low-powered chip is always desirable
- **Good security** messaging services using various coding technique

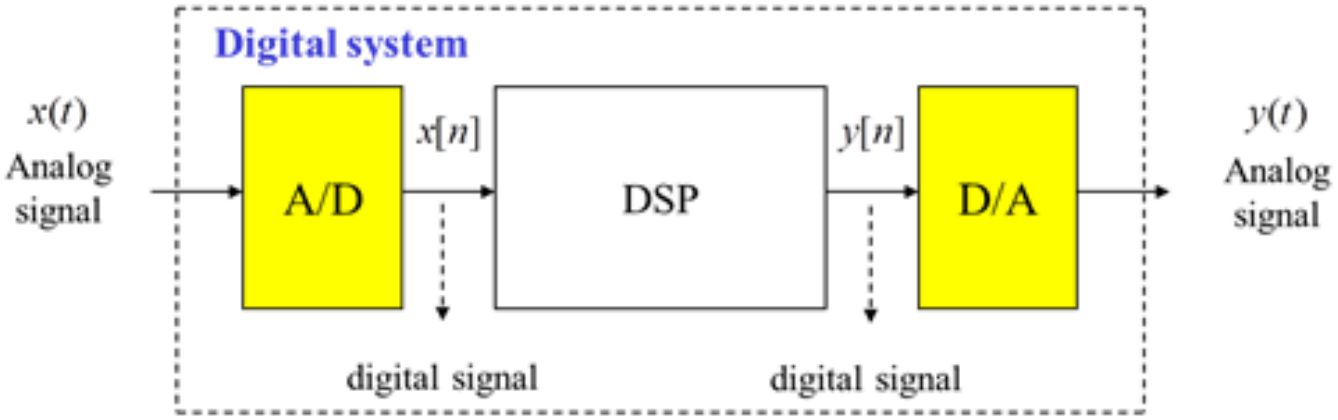
Weak point of DSP

- Need to process **huge amount of digital data** after A/D conversion
  - So always **data compression** with digital system

- Detection of digital signal require the communication system to be **synchronized**

Analog to Digital Conversion

- ADC



Two Steps in ADC

- Step 1) **Sampling** (Sample and Hold)
- Step 2) **Quantization** and Digitization

⇒ Digital binary sequence 0110…

⇒ Called

PCM (Pulse Code Modulation)

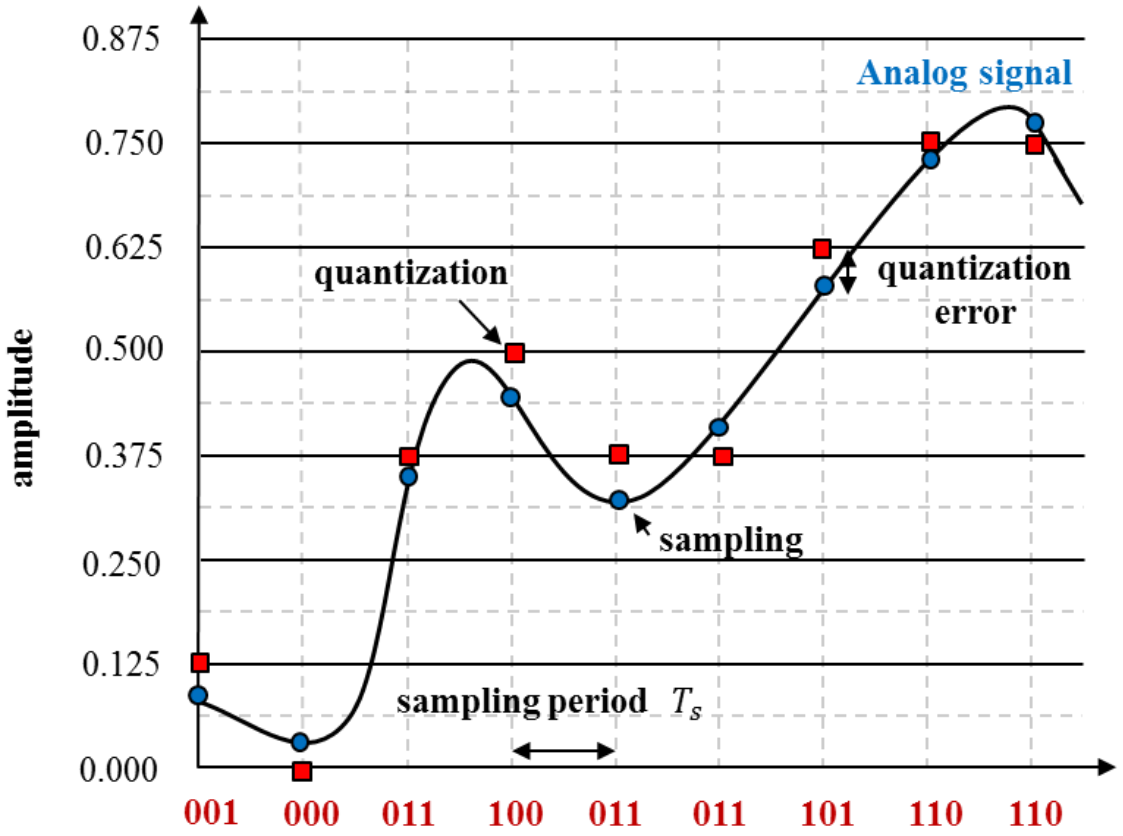
resulting binary = PCM code

- Sampling
  - Takes samples of analog signal at regular interval called **sampling period** T_s

$$\textbf{sampling rate} = f_s = \frac{1}{T_s} \text{ (sample/sec=Hz)}$$

- Quantization and Digitization
  - Quantization – Process that truncate each sampled value as the ones that computer can represent
  - Digitization - Process that represent quantized value as digital binary

Analog to digital conversion (ADC)



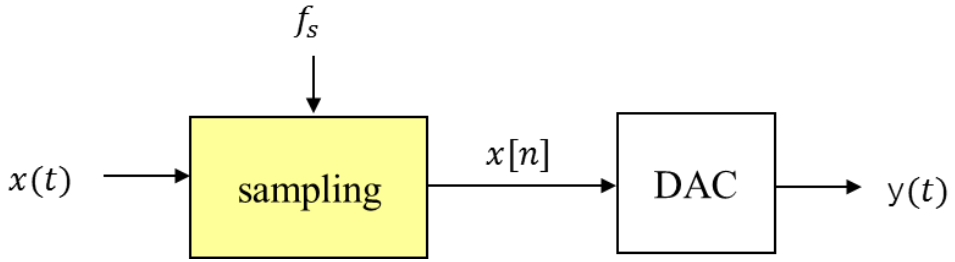
$f_s = \frac{1}{T_s}$=sampling rate
(unit: sample/sec = Hz)

- How fast one must sample analog signal?
  - Must fast enough to take consideration of fast varying portion in analog signal.
  - If sampling speed is too slow, it will lose important high frequency components of the analog signal.
  - Some tradeoff in sampling!

⇒ ***Sampling Theory (1950, Shannon)***

Nyquist-Shannon sampling theory

- Analog signal $x(t)$ can be perfectly reconstructed from its sample values $x[n]$ if we sample analog signal with more than **twice the maximum frequency component f_{max}(or Bandwidth=B)** of the analog signal



If $f_s \geq 2 \cdot f_{max} = 2 \cdot B$, Then $y(t) = x(t)$

- Nyquist sampling rate $f_s = 2B$

- Ex) music signal contains frequency up to 20kHz, what is the Nyquist rate and Nyquist frequency?

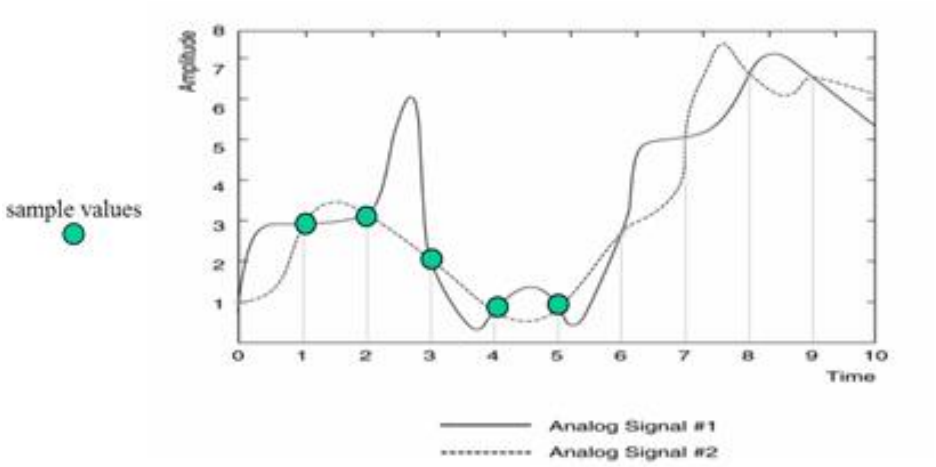
$$f_s \geq 2(20\,kHz) = 40\,kHz$$

  - Nyquist rate - 40kHz
  - Nyquist frequency – 20kHz

- Aliasing effect and anti-aliasing filter
  - What if Nyquist sampling condition is not satisfied ?

$$f_s < 2 \cdot f_{max}$$

  - No unique analog signal can be reconstructed



Quantization

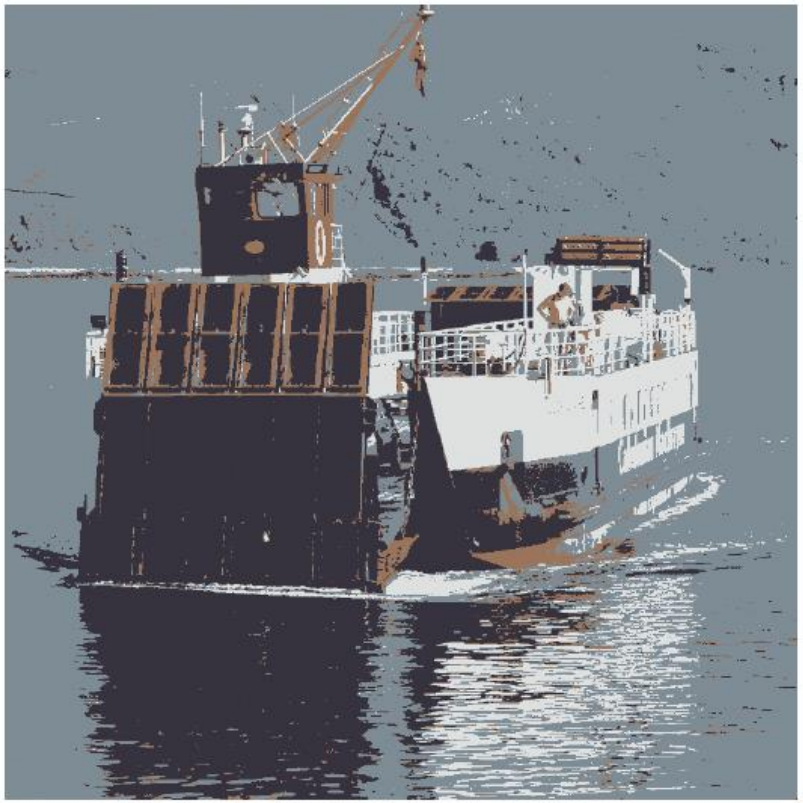
- Tradeoff in quantization
  - If number of quantization bits (N) is increased
    - High resolution, better representation of sample; good reproduction of sound
  - If N is decreased
    - Signal quality is low, but need to process only a small amount of data

- If too few quantization level
- **Sound**: coarse hiss, loss of quiet passages, general fuzziness (quantization noise)
- **Images**: banding and posterization
  - banding – dispersing color
  - Posterization – color discontinuity

Million color and four color

Posterization

Posterization



5bit **4bit** **3bit** **2bit**

as **bit/pixel decrease, more posterization**

Bit rate (Data rate)

- Number of bits to process media signal after ADC to meet signal quality

Bit rate = R =

f_s (sample/sec) X N (bits/sample)

Speech signal Bit rate

- Analog speech BW ≈ 4Khz
- On ADC
  - Sampling rate f_s =4Khz X 2 = 8Khz

    8K = 8000 samples/sec
  - Quantization - 8bit/sample
  - Bit rate R = 8000 X 8 = **64Kbps**

Music signal Bit rate

- Music signal BW ≈ 22.05Khz
- On ADC
  - Sampling rate f_s =22.05Khz X 2 = 44.1Khz

    44.1K=44100 samples/sec
  - Quantization - 16bit/sample
  - Bit rate R = 44100 X 16 = 0.705Mbps MONO
  - Stereo music

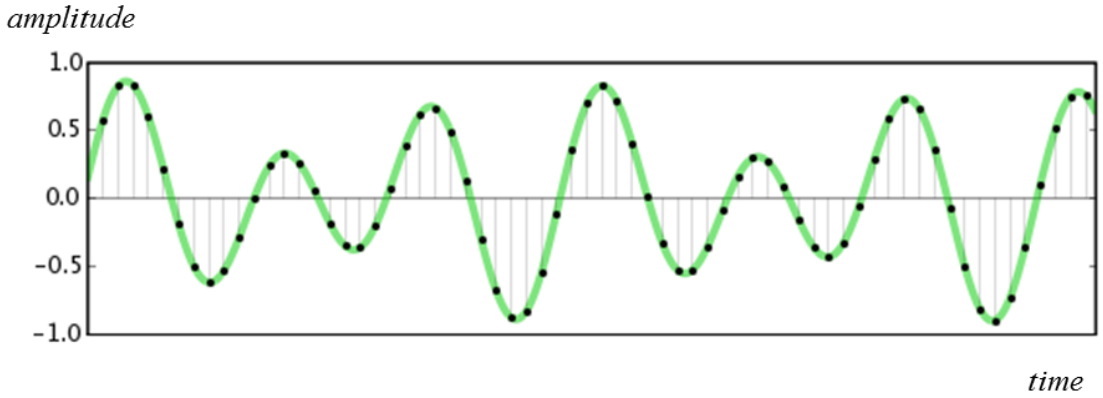
    R = 0.705Mbps X 2 =**1.41Mbps**

Data rate for Audio

	Sampling (KHz)	# of bits	Mono/ST	Bit rate (KByte/S)
Telephone	**8**	**8**	**Mono**	**8**
AM	**11.025**	**8**	**Mono**	**11.025**
FM	**22.050**	**16**	**ST**	**88.2**
CD	**44.1**	**16**	**ST**	**176.4**

Frequency-Domain Spectrum Analysis

- Male/female speech discrimination



  - See frequency spectrum whether it contains high or low frequency component

Ex 1) DTMT Telephone

- Press 5 – signal composed of 770Hz(low) & 1336Hz (High)

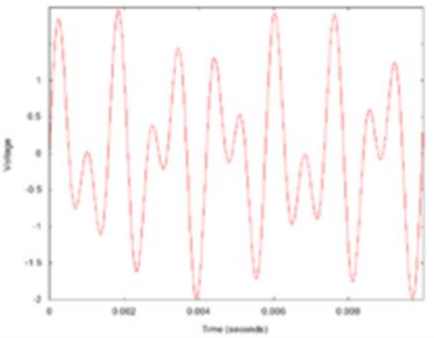
1	2	3	A
4	5	6	B
7	8	9	C
*	0	#	D

(a)

DTMF keypad frequencies (with sound clips)

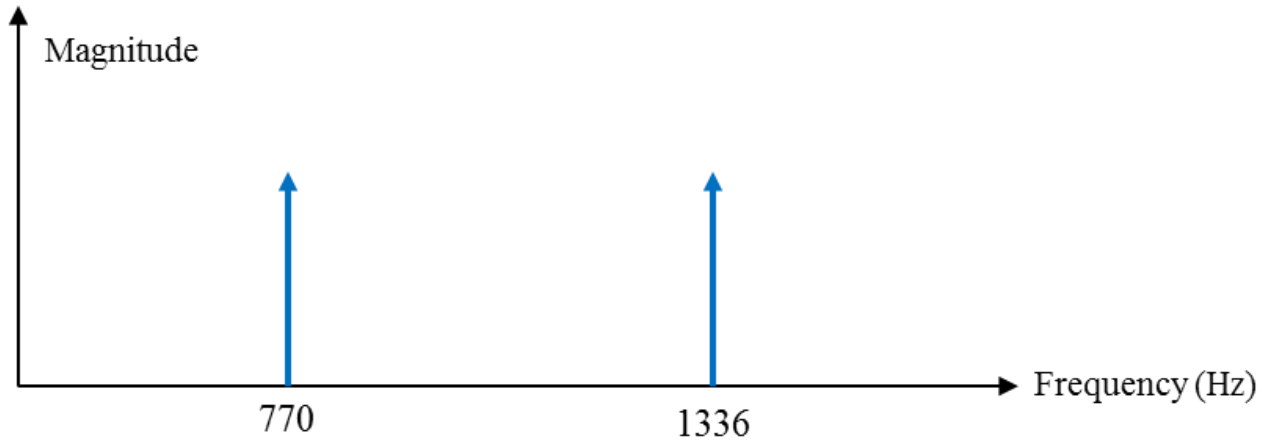
	1209 Hz	1336 Hz	1477 Hz	1633 Hz
697 Hz	1	2	3	A
770 Hz	4	5	6	B
852 Hz	7	8	9	C
941 Hz	*	0	#	D

(b)

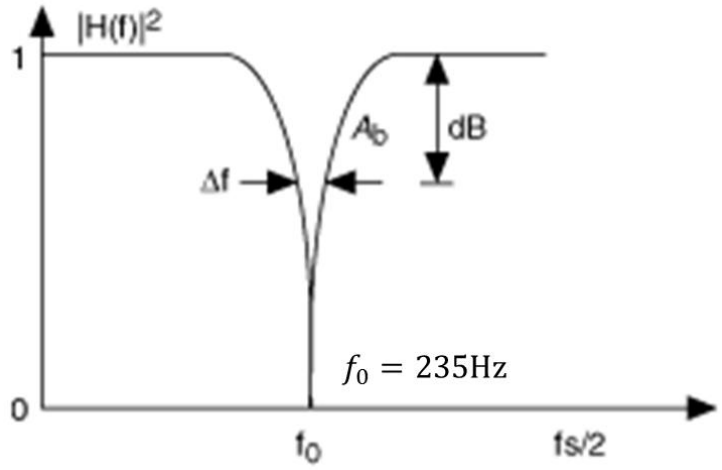


(c)

- Receiver end – Fourier transform of the signal
  - See frequency spectrum to identify the frequency components



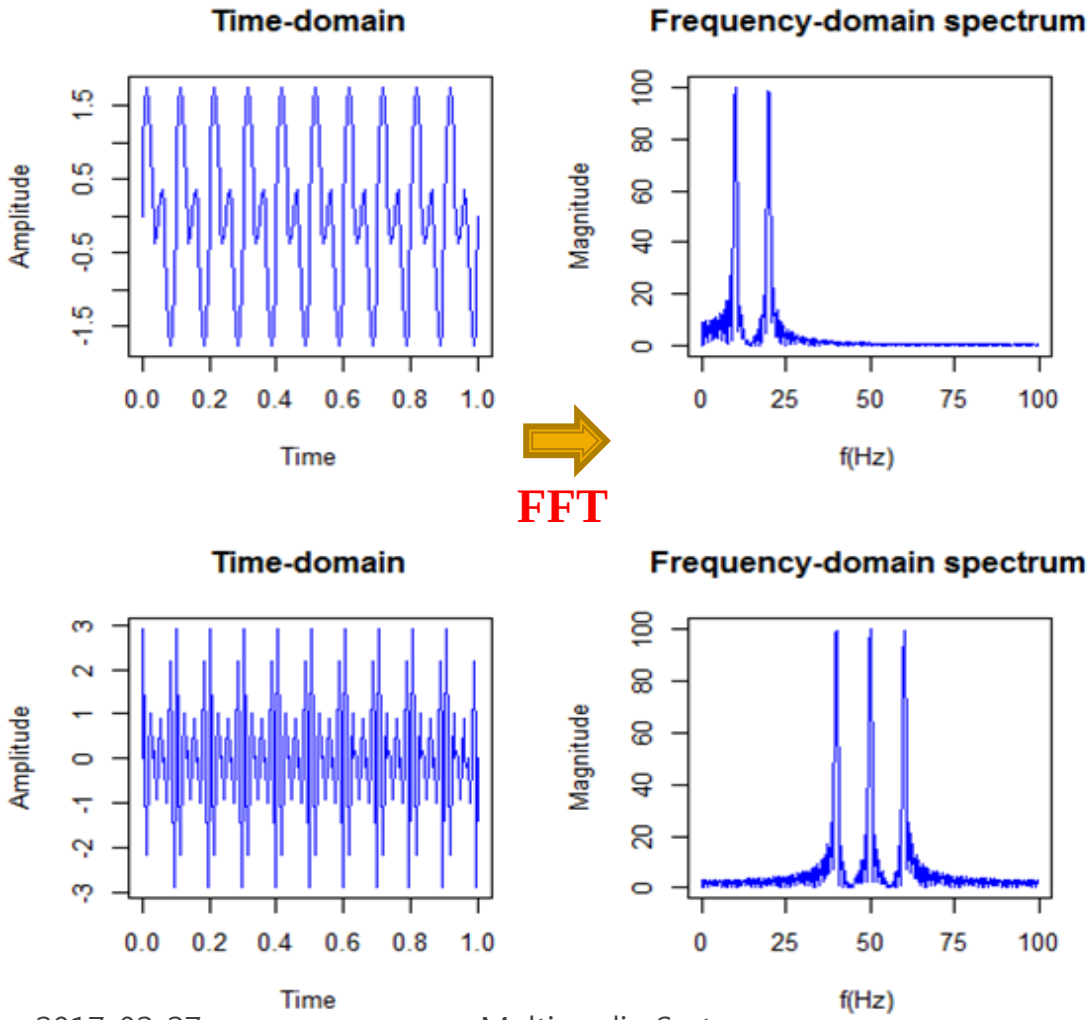
- Ex 2) Vuvuzelas noise
  - World cup soccer game 2014, Brazil
  - Vuvuzelas has a constant pitch or frequency of 235 Hz - Use of **notch filter**



- Two signal representation in DSP

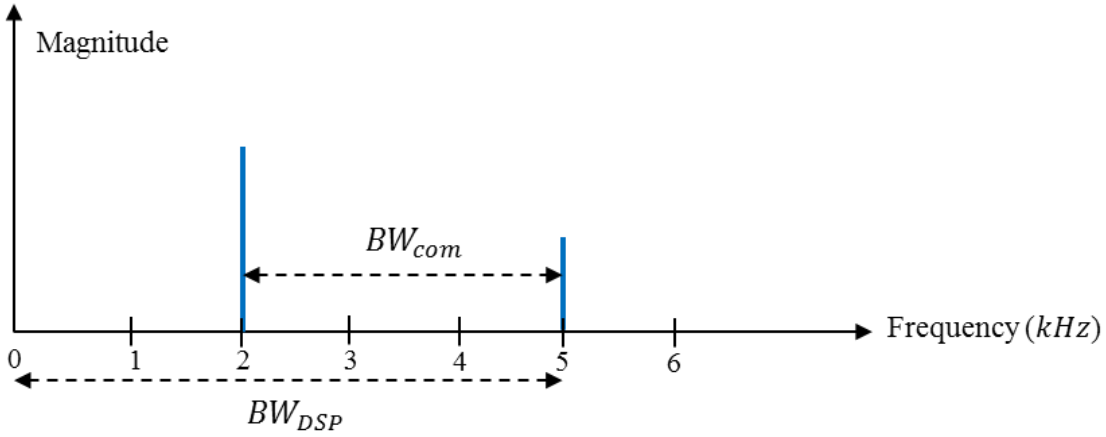
  - **Time-domain waveform** &

    Frequency-domain spectrum



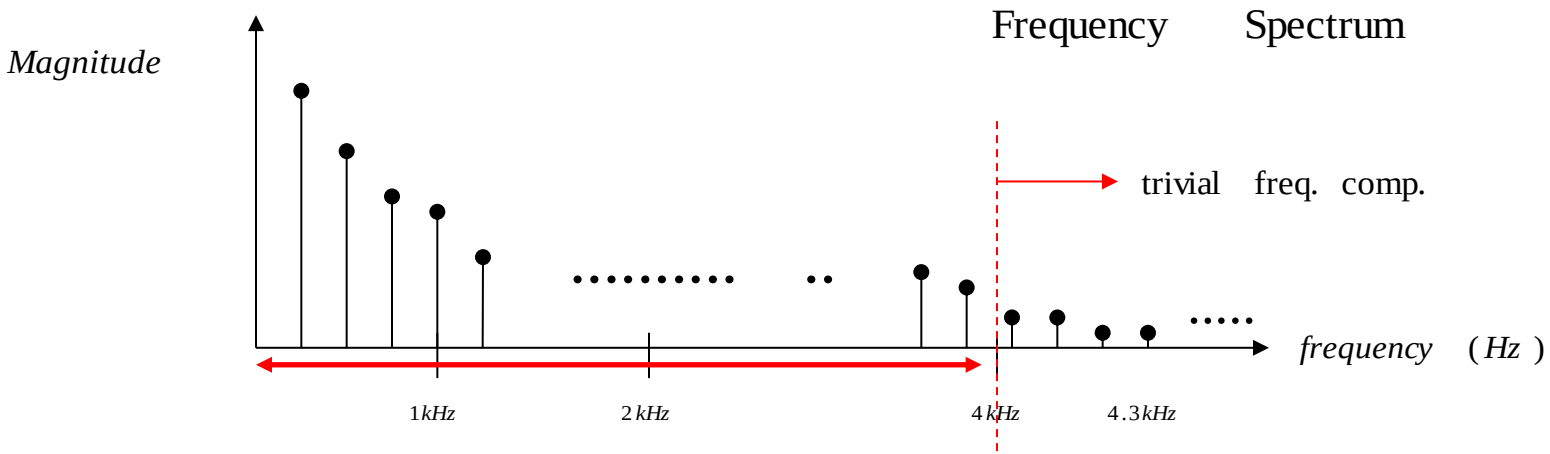
Q) Which one is female's voice?

Bandwidth definition



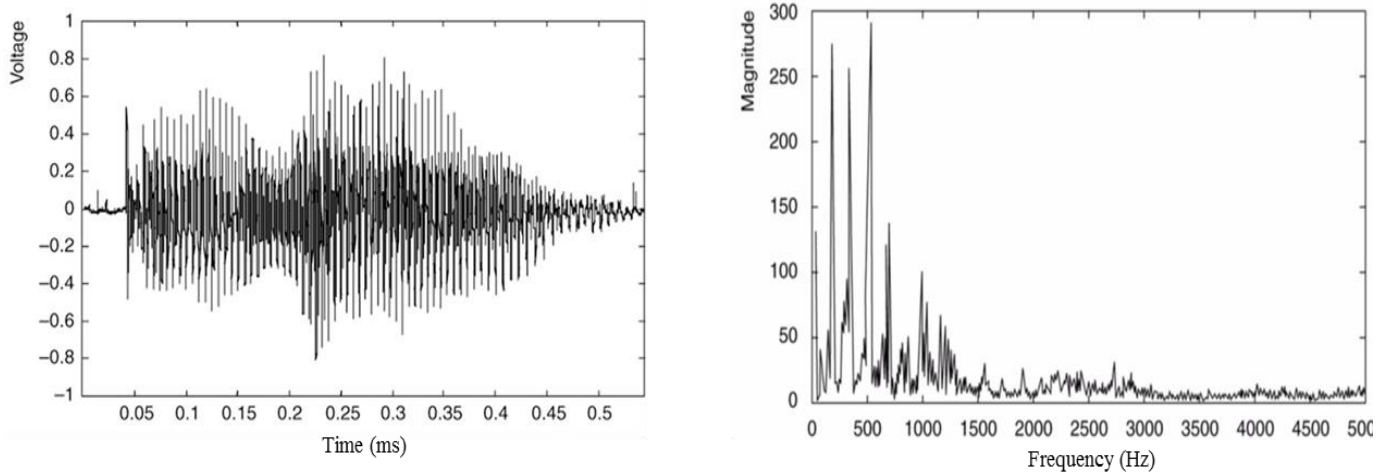
- BW = distance in Hz from 0Hz to max freq. comp.
- BW is very important concept in DSP and communication area

Revisiting def. of bandwidth

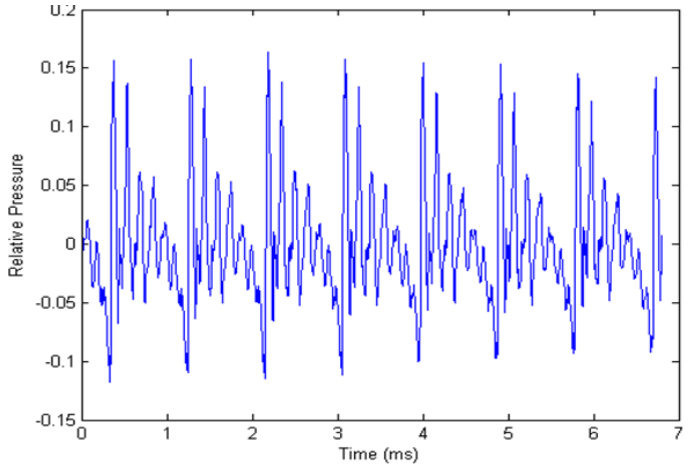


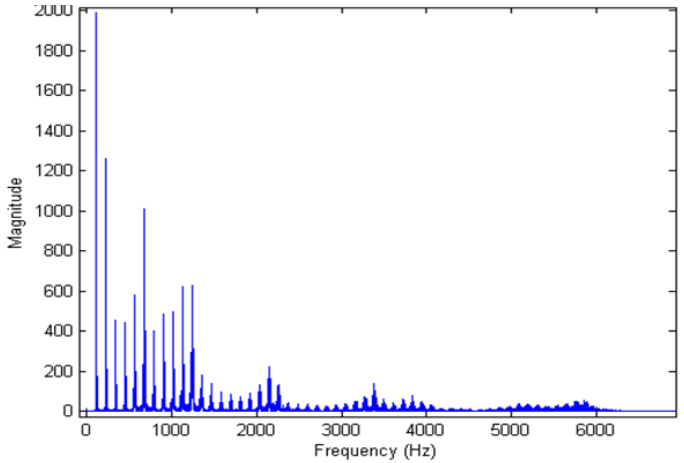
- What is the BW or max. freq. component in this case ? 4.3kHz? 4kHz? or ∞ *Hz*
  - BW is not the actual max. freq. component
  - Instead, it is freq. comp. which has meaningful energy or magnitude values (BW = 4kHz)

Examples of frequency spectrum

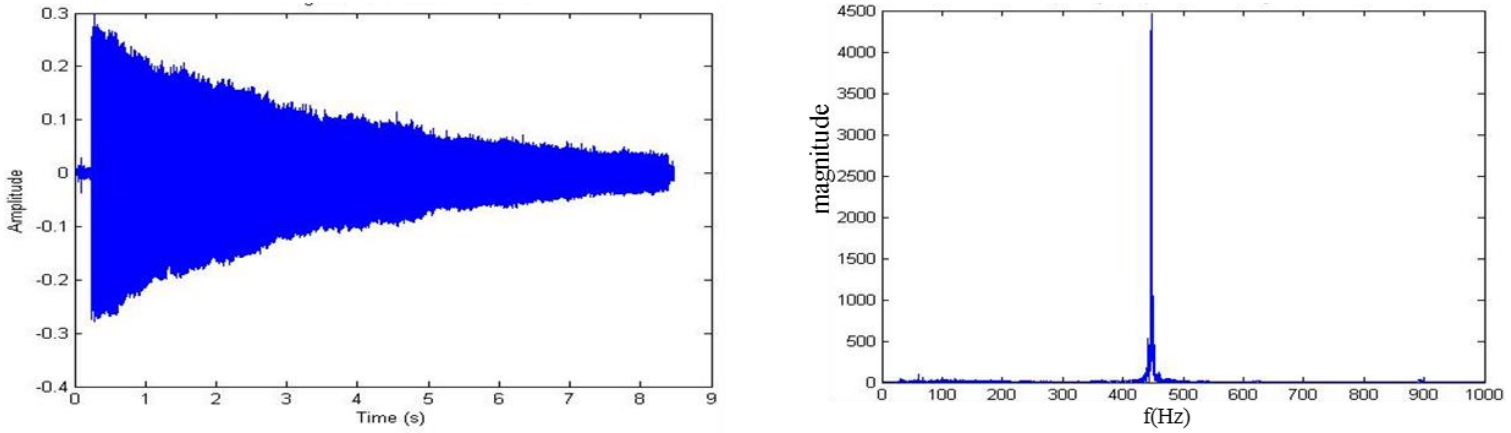


Speech word “away” and frequency spectrum



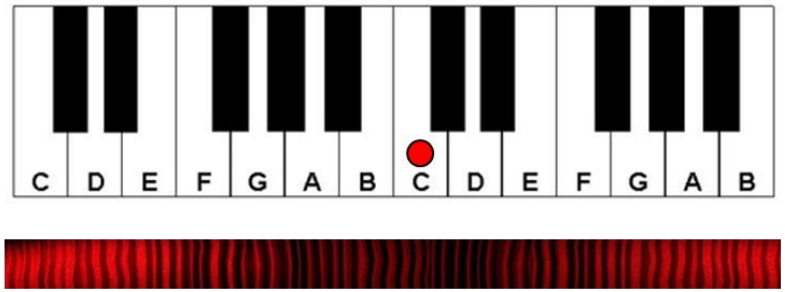


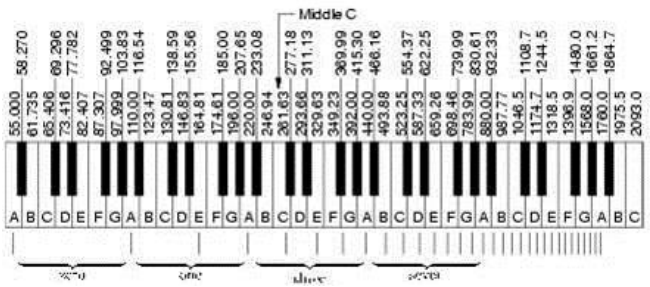
Speech word “ah” and frequency spectrum

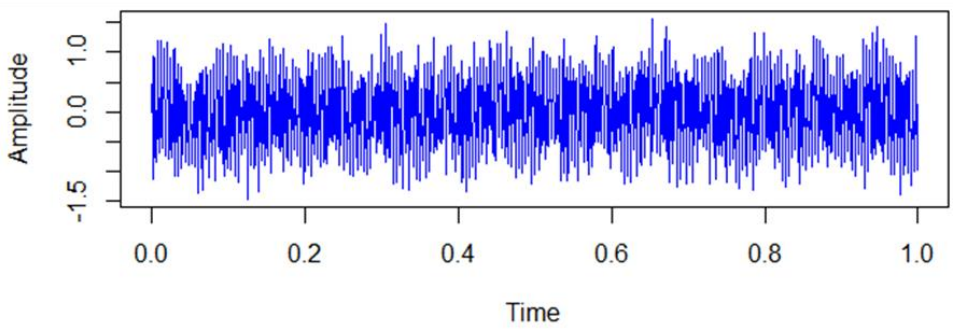


440Hz tuning fork signal

- Single piano tone (middle C)
  - Each piano chord is assigned to single frequency

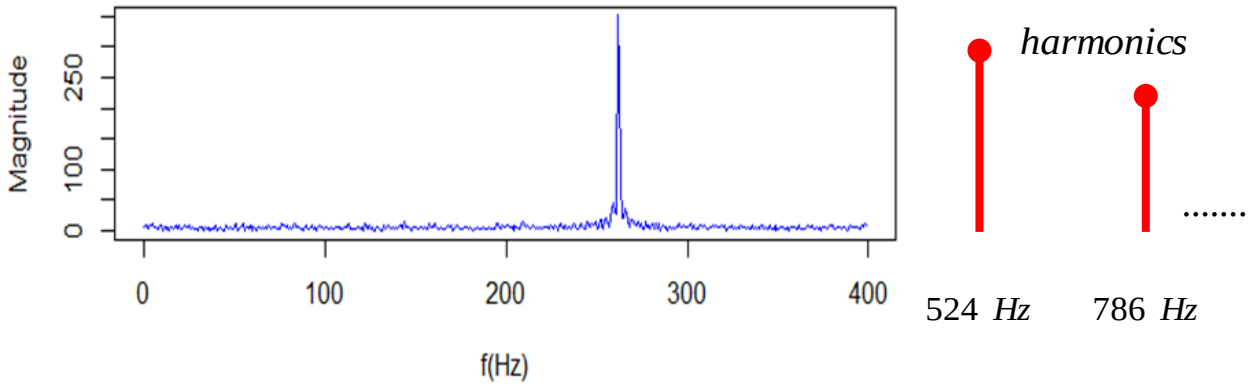






Cord	Freq.
C	262Hz
E	330Hz
G	392Hz

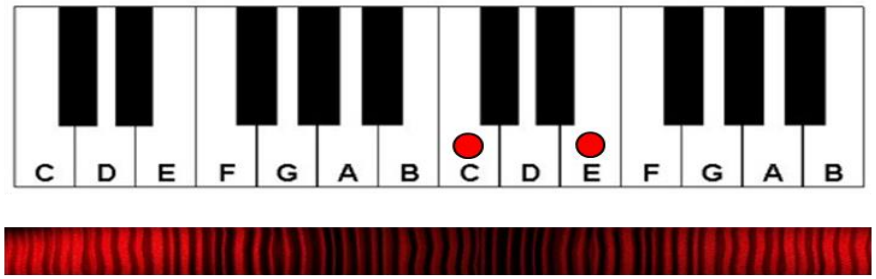
Middle C frequency spectrum

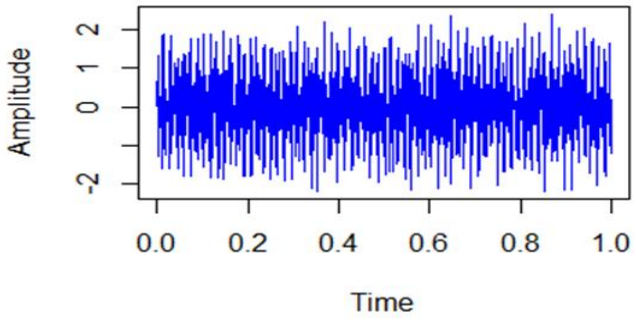


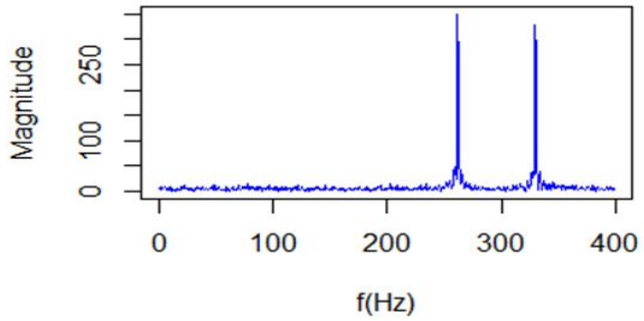
- Fundamental frequency (262Hz) + Harmonics
- Harmonics are integer multiples of fundamental frequency

Multiple piano chord (CE)

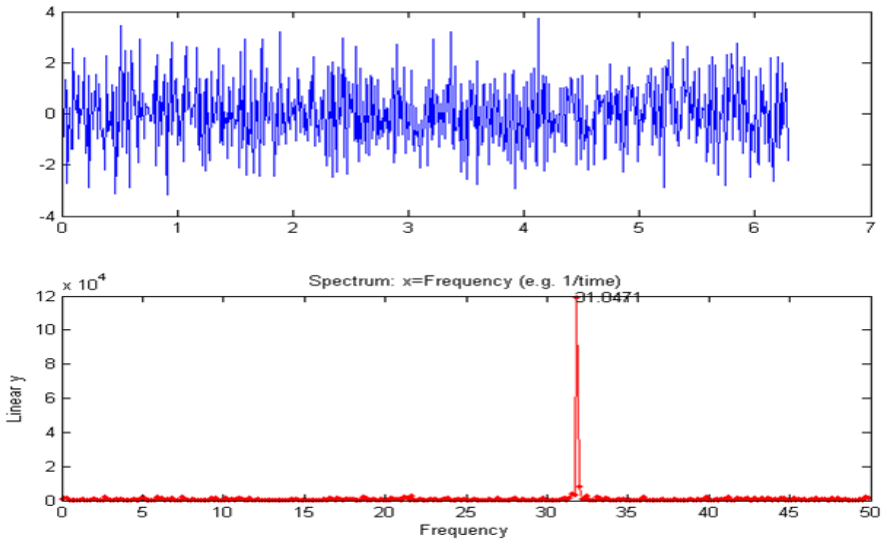
Cord	Freq.
C	262Hz
E	330Hz
G	392Hz







- Periodic signal + random noise



- From frequency spectrum, easily identify the 32Hz sine wave

Networks

- Local area networks (LANs) connect several computers on one site (Ethernet)
- LANs connected together by routers, bridges and switches form an internet
- The Internet is a global network of networks (internet) communicating via TCP/IP protocols
  - Mostly operated by commercial Internet Service Providers (ISPs)

Internet Access

- Old Dial-up connection uses modem and analog telephone line
  - V90 modem - 56kbps maximum
- Broadband always-on digital connection (> 512kbps)
  - ADSL , Cable, Satellite
- Dedicated line (T1, T3)

MIME Types

- Need to identify the type of media data in a data stream in a platform-independent way

- MIME (Multipurpose Internet Mail Extension)
  - Originally designed to allow inclusion of data other than text in email, adopted by HTTP
  - Content-type: type/subtype
  - Types include text, image, audio, video, application, subtypes define specific formats
  - e.g. text/html, image/gif

Homework 2

- Read Chapter 2
- Investigate practical A/D technology
  - PCM, DPCM, ADPCM, DM, ADM …
- Audio quality
  - Depending on sampling freq. & Q. Bit
  - Various kinds of audio format
    - CD, SACD, DVD –audio, XRCD, HDCD

- on Book
  - Add network, DB.. fundamental technology