Physical Layer

Presented by Hung Ba Ngo

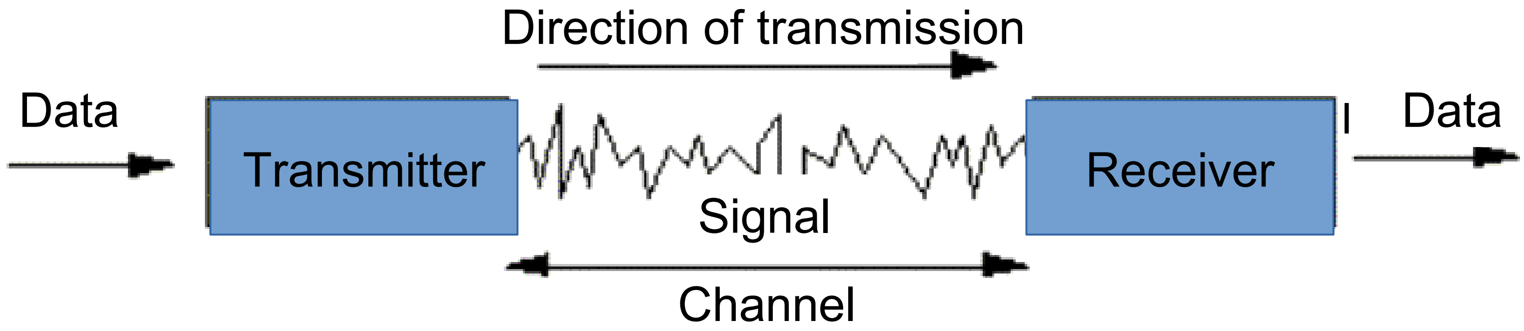
Objectives

- Present core components of a data transmission network
- Identify issues related to a computer based data transmission network
- Introduce methods of digitization
- Present characteristics of communication channels and cable features
- Introduce line coding methods

Requisites

- Learners have to be able to
  - List the issues related to a computer-based data transmission network
  - Describe different digitization methods
  - Differentiate and calculate parameters of a channel such as Bandwidth, Baud rate, Data rate, Bruits, Channel Capacity, Traffic
  - Encoding data using different line coding methods

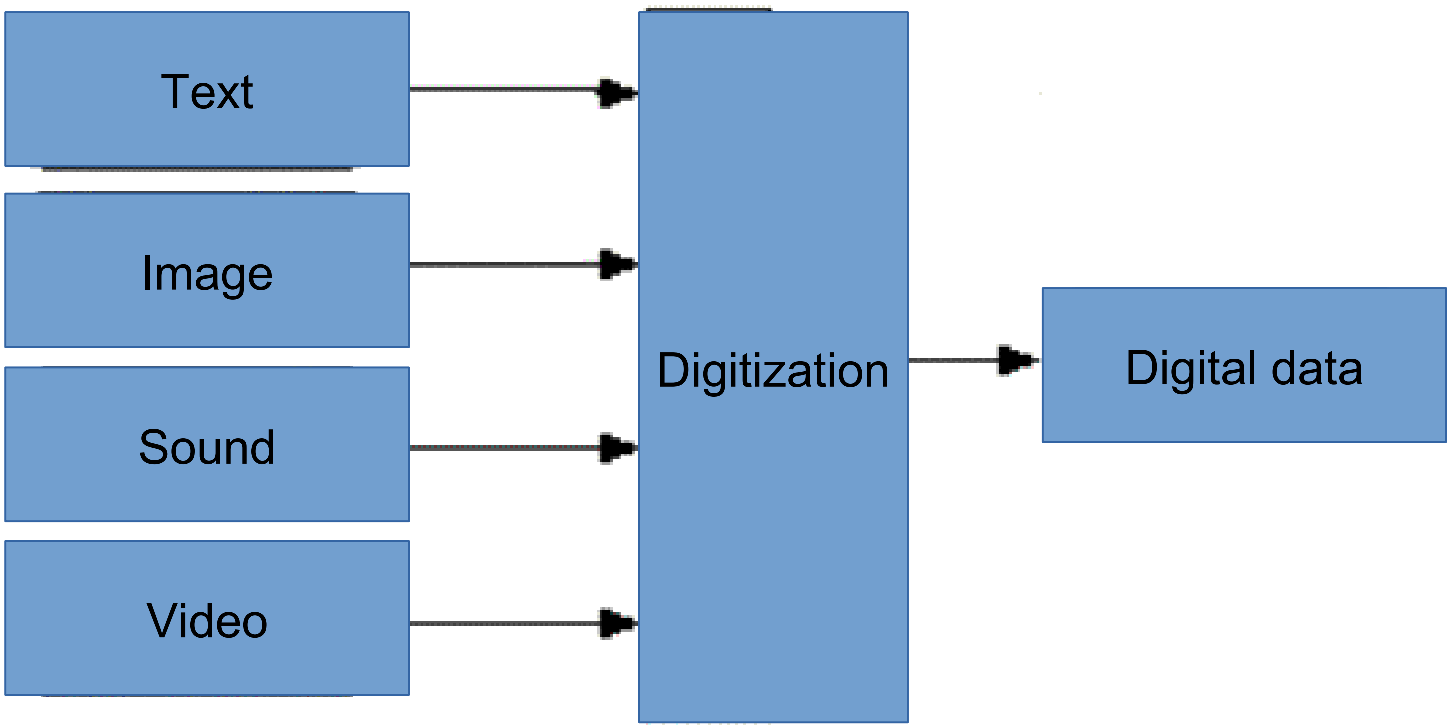
A basic data transmission model



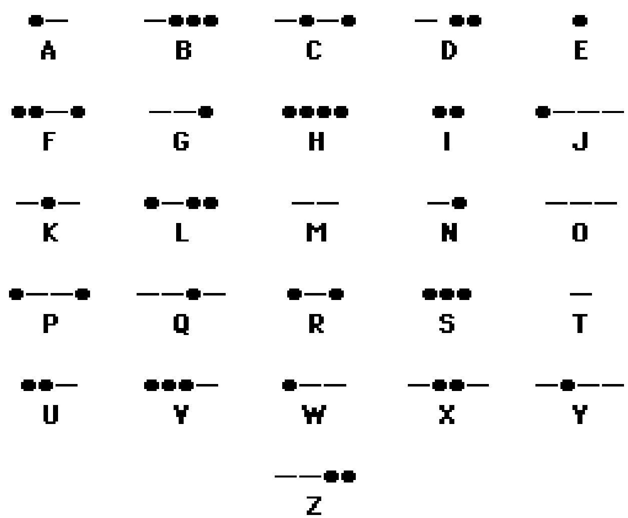
- Issues related to data transmission systems:
  - How to digitize information
  - Types of channel can be used for data transmission
  - Connection schema of communication devices
  - Methods for transmitting raw bit from hosts to hosts

Digitization

Model for digitization



Digitization of text



Mã Morse

poids forts

poids faibles	000	001	010	011	100	101	110	111
0000	NUL	DLE	SP	0	@	P	\	p
0001	SOH	DC1	!	1	A	Q	a	q
0010	STX	DC2	"	2	B	R	b	r
0011	ETX	DC3	#	3	C	S	c	s
0100	EOT	DC4	$	4	D	T	d	t
0101	ENQ	NAK	%	5	E	U	e	u
0110	ACK	SYN	&	6	F	V	f	v
0111	BEL	ETB	,	7	G	W	g	w
1000	BS	CAN	(	8	H	X	h	x
1001	HT	EM	)	9	I	Y	i	y
1010	LF	SUB	*	:	J	Z	j	z
1011	VT	ESC	+	;	K	[	k	{
1100	FF	FS	'	<	L	Ç	l	ù
1101	CR	GS	-	=	M	]	m	}
1110	SO	RS	.	>	N	↑	n	≈
1111	SI	US	/	?	O	<--	o	DEL

code ASCII

- 8 bits code:
  - ASCII - American Standard Code for Informatics Interchange
  - Mã EBCDIC - Extended Binary-Coded Decimal Interchange Code
- 16 bits code: Unicode

Digitization of text

- 8 bits code:
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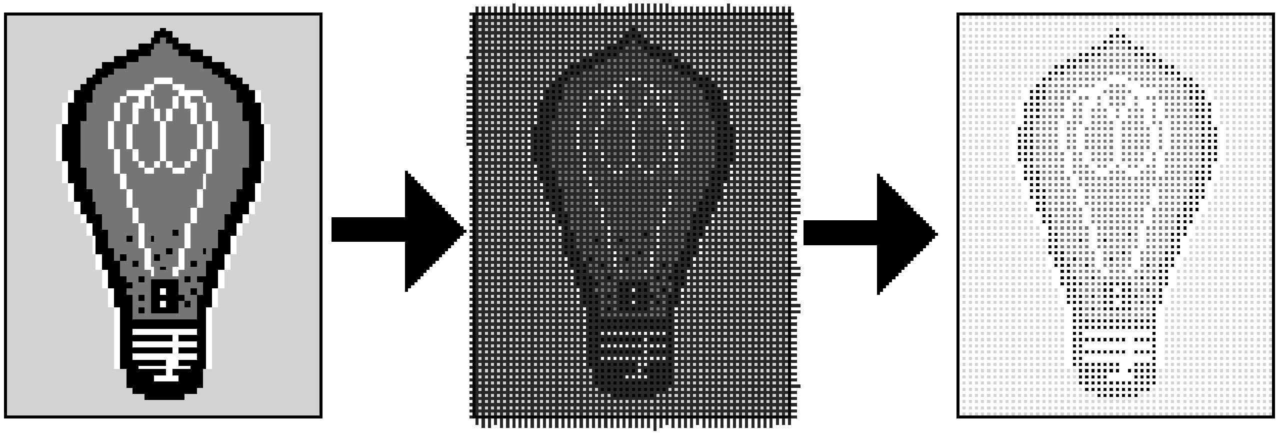
- 16 bits code: Unicode

Digitization of images

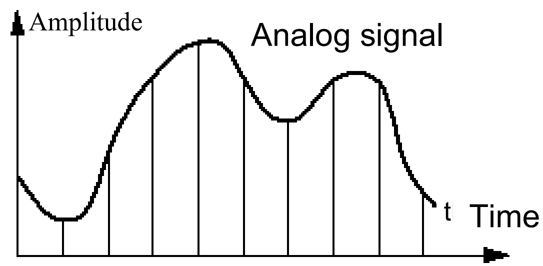


Original image Binary image Reconstructed image

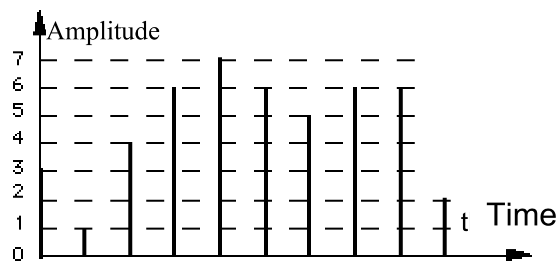
- Black & White images : 0: Black, 1: White
- Images for 256 gray level : 8 bits / pixel
- Color images: 1 pixel = aR + bG +cB

Digitization of sound and movie

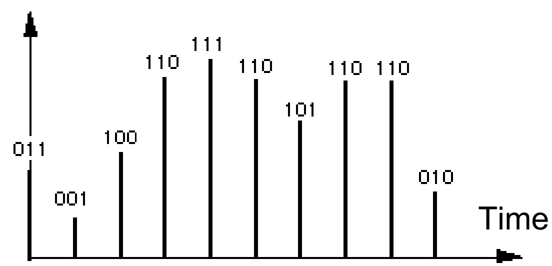
1.Sampling



2.Qualifying



3.Digitizing



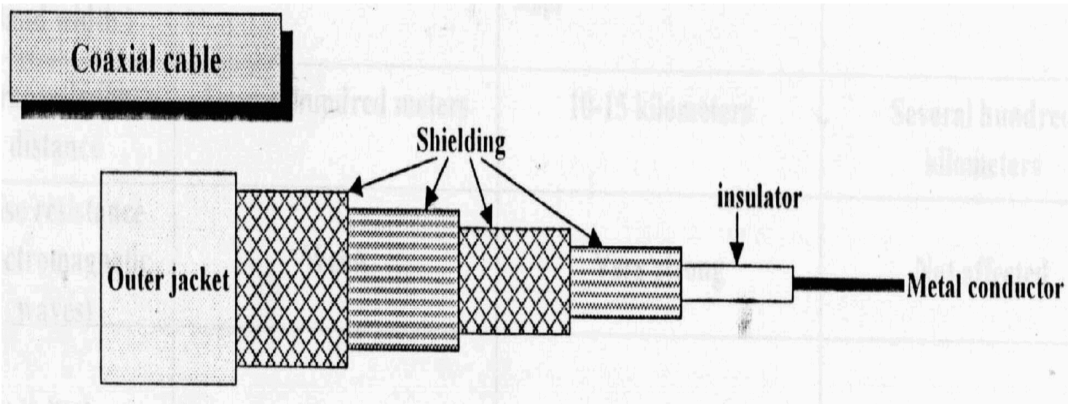
- Volume of result file depends on sampling frequency f and the number of bits p used to represent value of amplitude

Communication Channels

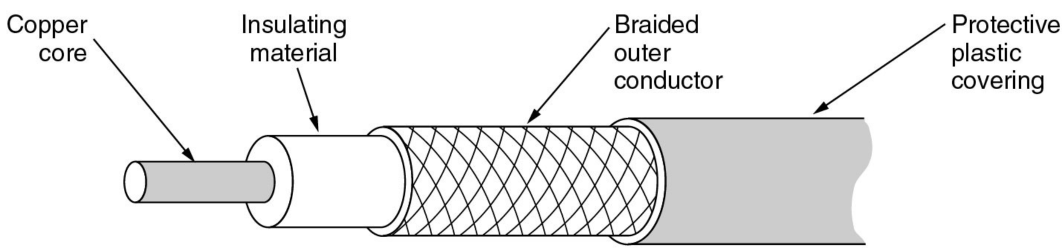
Wired communication media

- 3 popular cables:
  - Twisted pair cable
  - Coax cable
  - Fiber optic cable
- Factors for choosing cable
  - Price
  - Network diameter
  - Number of hosts in network
  - Requirement of bit rate
  - Requirement of bandwidth

Coaxial Cable

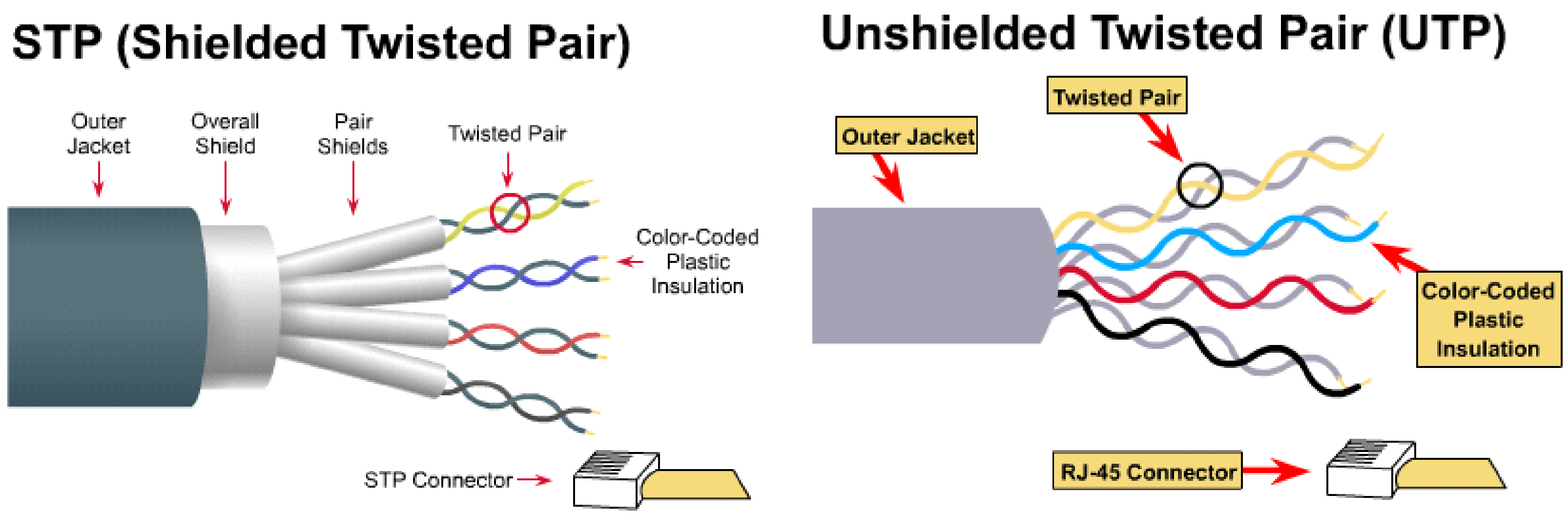


Thick coaxial cable (RG11)



Thin coaxial cable (RG58)

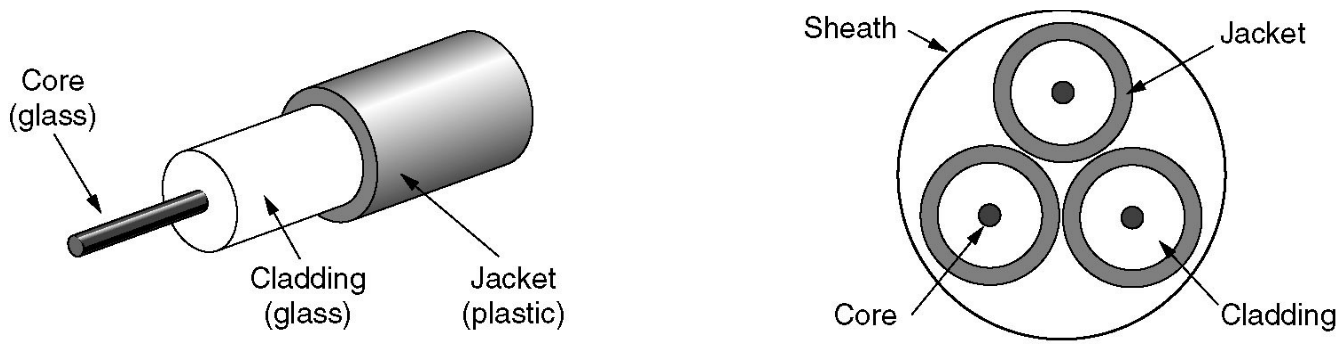
Twisted – pair cable



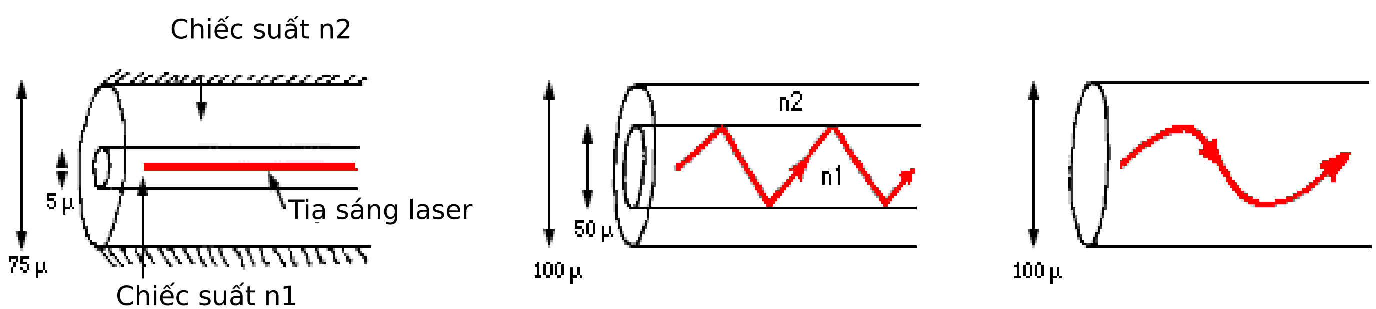
Twisted – pair cable

• CAT 1, 2:	1Mbps	(Telephone)
• CAT 3:	10Mbps	(10BaseT)
• CAT 5:	100MBps	(100BaseT)
• CAT 5E,6:	1000MBps	(1000 BaseT)

Fiber optic cable



(a) (b)

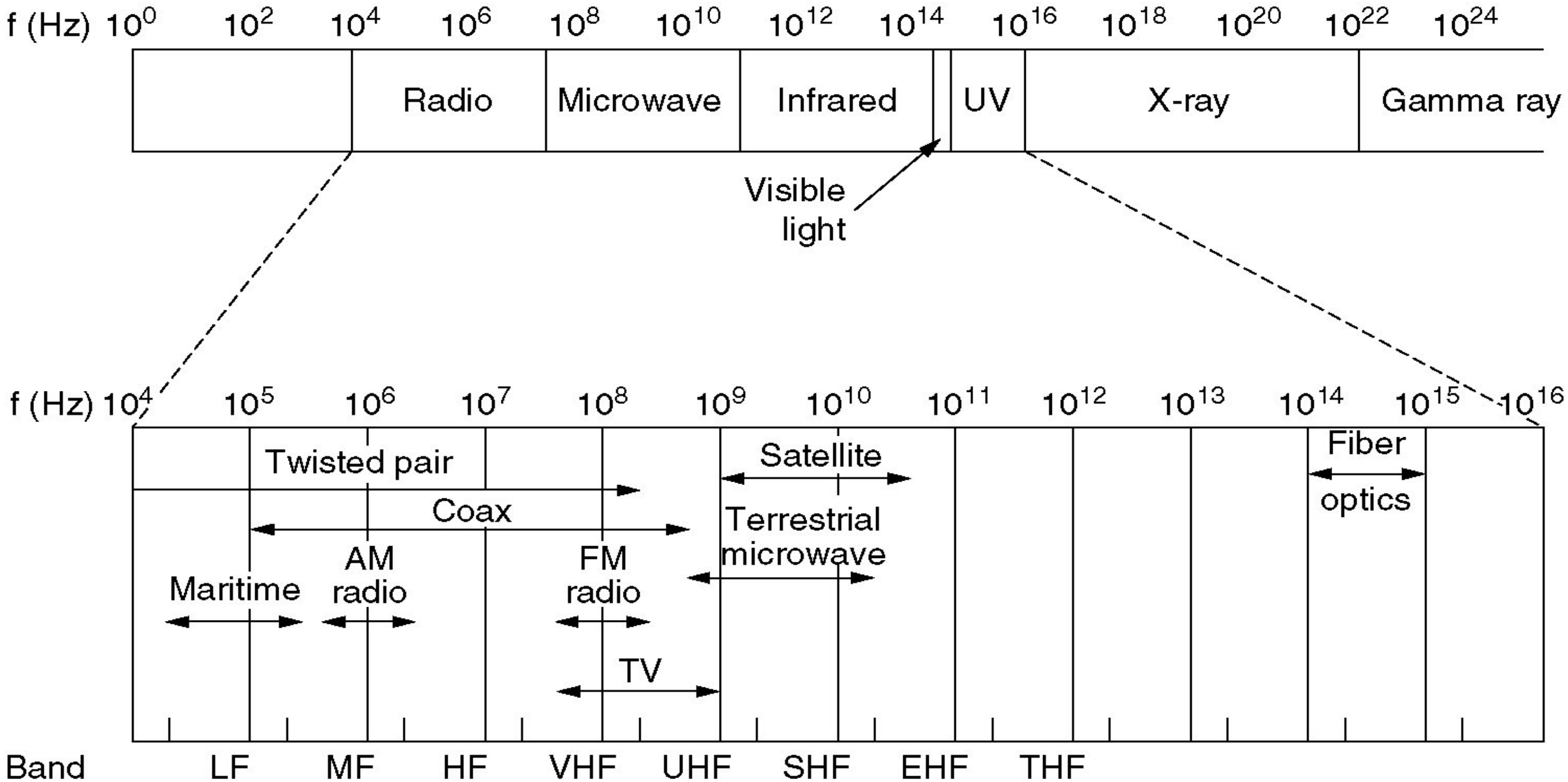


1. Single mode – 2. Multi mode

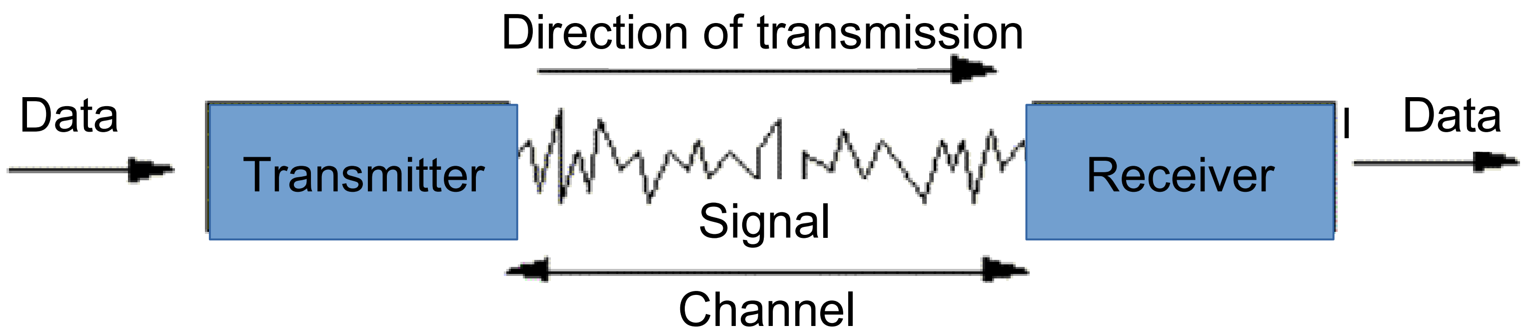
Wireless communication media

- c : Speed of light
- f: Frequency of wave
- λ: Length of wave
- Therefore $c = \lambda f$

Wireless channel

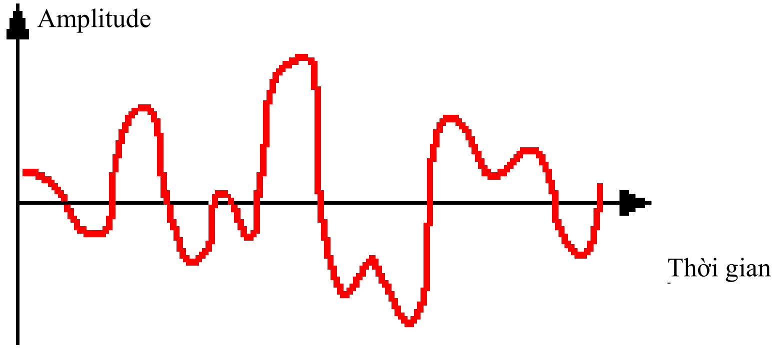


Analog signal & Digital signal

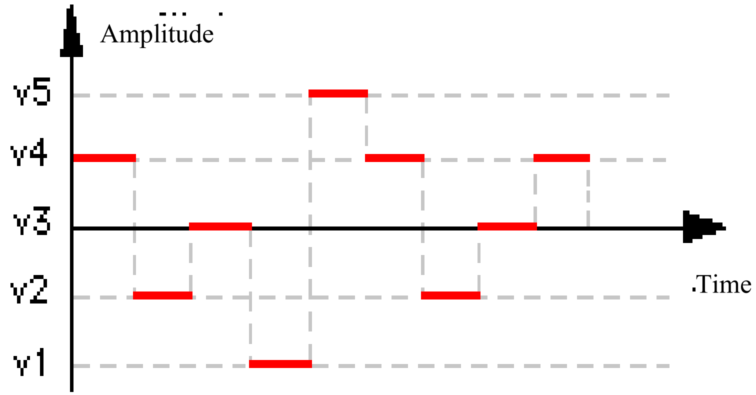


- Data (bits 0, 1) are transmitted from one device to another using analog signals or digital signals.

Analog signal & Digital signal



Analog signal



Digital signal

Sine wave

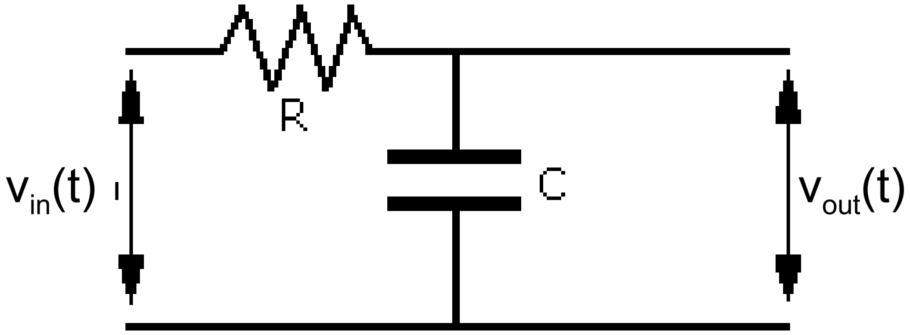
- Sine wave, none terminated or none deduced after a period of time, is an analog signal that can be created simply and easily
- **Any wave can be represented by a set of Sine waves** → This feature is used to defined characteristics of communication channel

Sine wave

- Peak Amplitude (A)
  - maximum strength of signal, typically measured in volts
- Frequency $f = 1/T$
  - T = time for one repetition
  - rate of change of signal, measured in hertz (Hz) or cycles per second
- Phase (ϕ)
  - relative position in time
- Wavelength = λ is a distance occupied by one cycle
  - Assuming signal velocity v, then $\lambda = v \times T$ or $\lambda \times f = v$
  - speed of light in free space $c = 3\times10^8$ m/s

Characteristics of communication channel

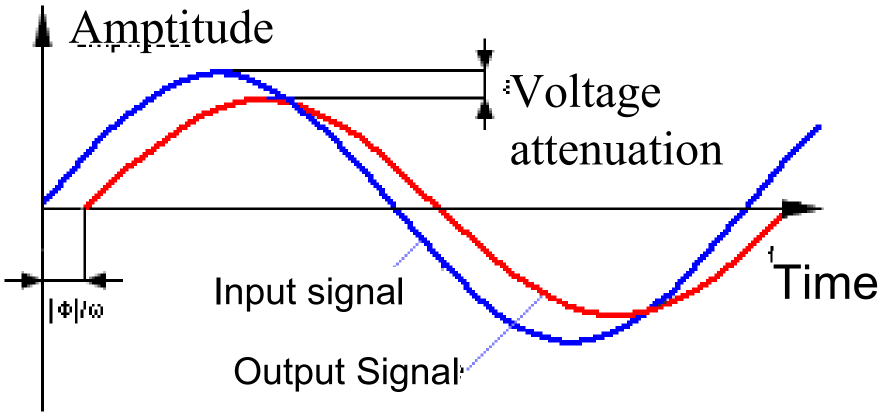
- Modeling a communication channel



- $v_{in}(t)$ = $\mathbf{V}_{in}$ sin wt
  - $\mathbf{V}_{in}$: Amplitude of voltage in input
  - w : nhịp ; f = w/2pi : Frequency;
  - T = 2pi/w = 1/f : Cycle.
- $v_{out}(t) = V_{out}$ sin (wt + F)
  - $\mathbf{V}_{out}$: Amplitude of voltage in output
  - F : Phase deviation

Characteristics of communication channel

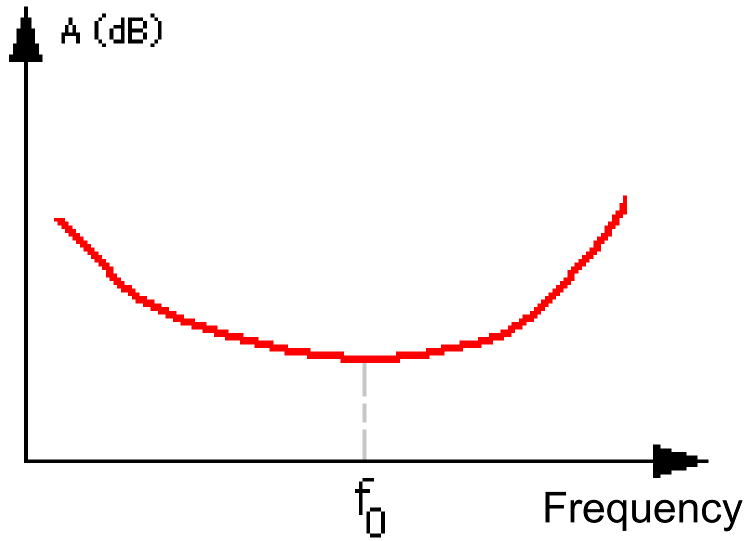
- According to Electromagnetism law:
  - $V_{out}/V_{in} = (1 + R^2C^2w^2)^{-1/2}$
  - $F = atan(-RC\ w)$



Characteristics of communication channel

- Loss of signal = P_{in}/P_{out}
- Calculated in decibel:
  - A(w) = 10 log10(Pin/Pout)

The nearer to f_0 the frequency of the signal is , the less the loss of signal is

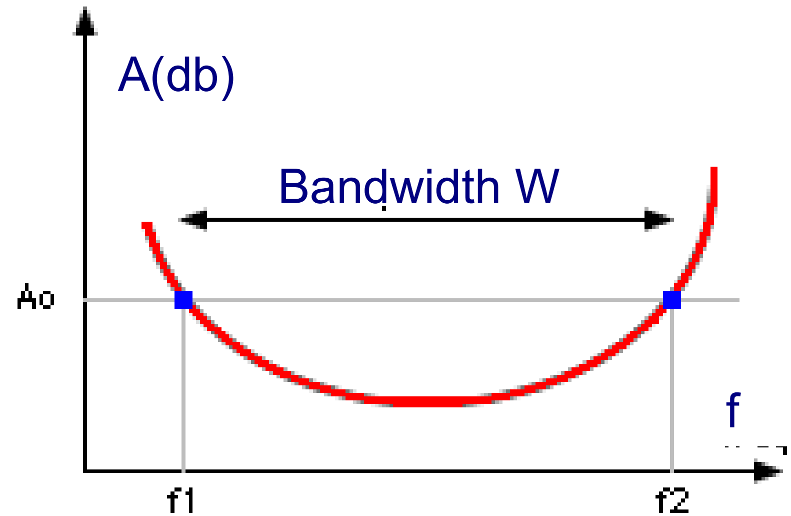


Signal Characteristics

- It can be shown (by Fourier analysis) that any signal is made up (i.e. composed) of a number (possible an infinite number) of components and each signal component is a sine wave.
- Component sine waves are of different frequencies, amplitudes and phases.
- Any periodic signal consists of discrete frequency components, i.e. its components have frequencies that are multiple of one base frequency.
- Any aperiodic signal consists of continuum of frequencies.

Bandwidth

- A_0,: Threshold of hearing
  - Sine waves which frequencies are lower than f1 or grater than f2 are considered as lost
  - Sine waves which frequencies are between f1 and f2 can be received at output
  - Range of frequencies from f1 to f2 is called bandwidth of a physical channel.



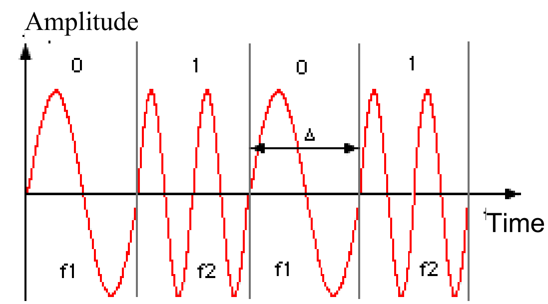
Example: Bandwidth of a telephone channel is about 3100 Hz because frequencies of voice that people can hear are in range from 300 Hz to 3400 Hz

Baud rate and Data rate

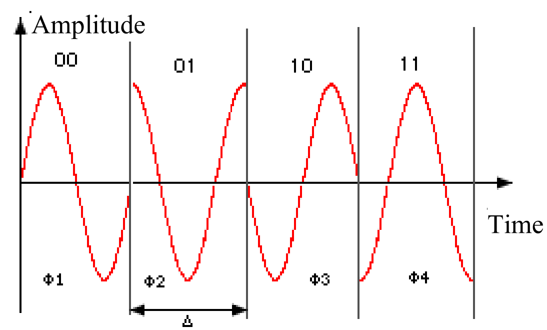
- Baud rate R: the number of distinct symbol changes (signaling events) made to the transmission medium per second
  - $R = 1/t$ (bauds),
  - t: length of signal
- Data rate/bit rate D: the rate at which data can be communicated, in bits per second
  - Each signal carries n bit
  - $D = nR$ (bits/s)
- Example: Given a transmission systems
  - R = 1200 bauds và D = 1200 bits/s.

  → each signal carriers only one bit

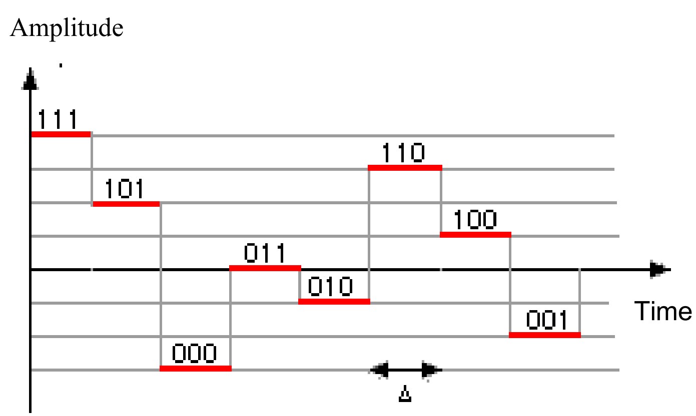
Example of baud rate & data rate



R = 1/Δ D = R



R = 1/ Δ D = 2R



R = 1/ Δ D =3 R

Bài tập

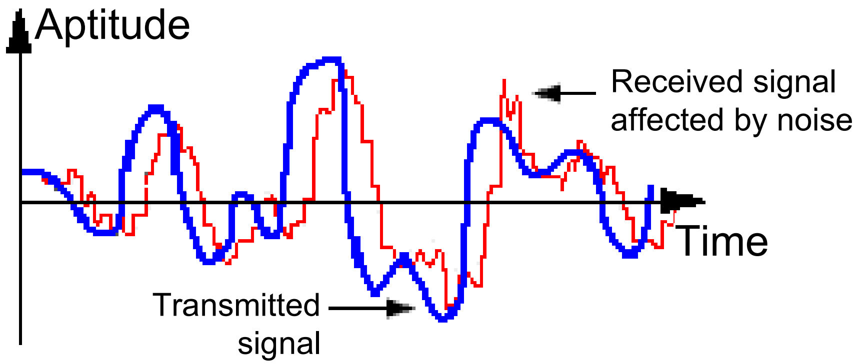
Vẽ hình các sóng truyền đi trên kênh truyền để truyền đi ký tự 'A' sử dụng 3 loại tín hiệu trên.

Increase data rate

- D = n R
- To increase D:
    - Increase n (number of bits carried by one signal), limited by noise.
    - Or increase R(baud rate), limited by Rmax
- Nyquist (1928):
    - In theory: Rmax = 2 W,
    - In practical Rmax = 1,25 W

Noise and channel capacity

- Three kinds of noise
  - Determined noise: depended on channel characteristics
  - Undetermined noise
  - Thermal noise: from the electron motion



Noise and channel capacity

- Rate between power of signal P_S and power of noise P_B is calculated in decibel
  - $S/B = 10\log_{10}(P_S(\text{Watt})/P_B(\text{Watt}))$
- Shannon Theorem (1948) determined the maximum number of bits carried by a signal

$$n_{max} = \log_2 \sqrt{1 + \frac{P_S}{P_B}}$$

Channel capacity

- From Nyquist and Shannon:

$$C = D_{max} = R_{max} n_{max} = 2W \log_2 \sqrt{1 + \frac{P_S}{P_B}} = W \log_2 [1 + \frac{P_S}{P_B}]$$

- C is capacity of a channel, determines the maximum bit rate supported by a channel

Channel capacity

- Example : Telephone channel
  - Bandwidth W = 3100 Hz
  - Rate signal/noise S/B = 20 dB.
  - What is channel capacity C = ?
- We have:

$$C = D_{max} = R_{max} n_{max} = 2W \log_2 \sqrt{1+\frac{P_S}{P_B}} = W \log_2 [\, 1+\frac{P_S}{P_B} \,]$$

  - $S/B = 10\log_{10}(P_S/P_B)$
  - $\Rightarrow P_S/P_B = 10^{((S/B)/10)} = 10^{((20)/10)} = 10^{2}$
  - $\Rightarrow C = W \log_2(1+P_S/P_B) = 3100 * \log_2(1+100) = 20600$ b/s

Traffic

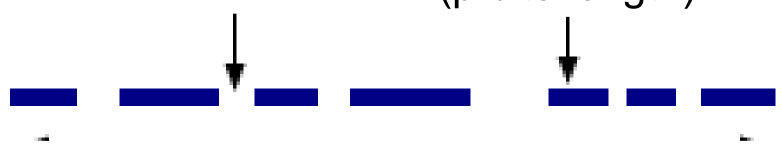
- Traffic is the amount of data moving across a network at a given point of time
- Traffic presents efficiency of channel usage, a base for choosing a appropriate channel (bandwidth)
- A communication is session having average duration T(s)
- Nc is the average number of session per hour
- E is traffic density, used to measure the usage of channel in one second :
  - $E = T\ Nc / 3600$

Traffic

- A session is composed from many **transactions** having the average duration p bits, and separated by silences.
- Supposing that Nt is the average number of transactions per session.
- **D** is data bit of the channel, then the real data bit **d** in this situation is:

$$d = \frac{N_t p}{T}$$

Traffic



One session with duration $T = N_t$ transactions

- **D** is data bit of the channel, then the real data bit **d** in this situation is:

$$d = \frac{N_t p}{T}$$

- Efficiiency of channel usage $\theta = \frac{d}{D}$

Traffic

- Example: In a science computing, a user connects to a remote Host.
- Given that:
  - p = 900 bits, N_t = 200, T = 2700 s, N_c = 0.8, D = 1200 b/s.
  - Then
    - Traffic density of channel $E = 0.6$
    - Efficiency of channel usage $\theta = 0.05$

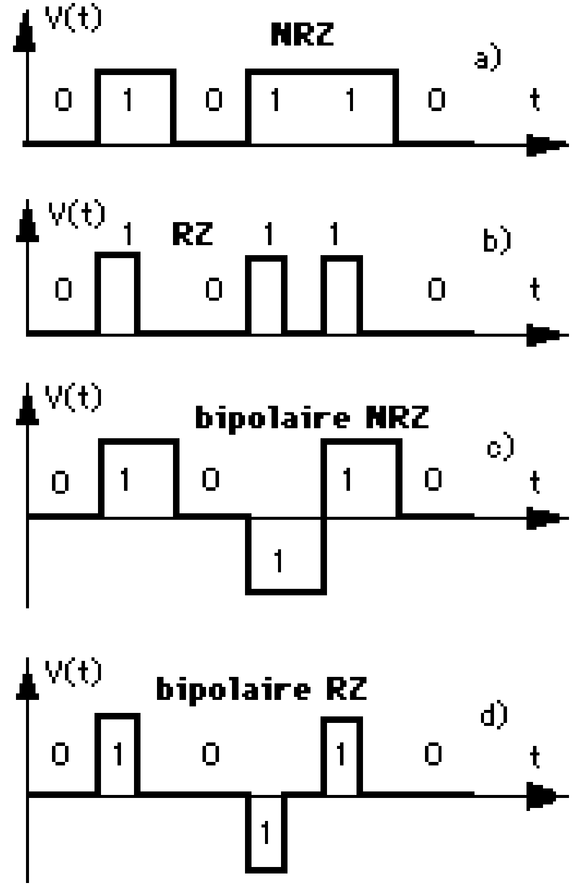
Line Code

What is line code

- Using signal (analog or digital) to transmit bits "0" and "1" over a communication channel

Line code using digital signal

- a) NRZ : A zero voltage represents a bit 0, a positive voltage represents a bit "1“
- b) RZ : A bit "1" is represented by a transmission from voltage V0 to 0.
- c) Bipolar NRZ : A bit "1" is presented by a positive voltage, then a negative voltage and repeatedly
- d) Bipolar RZ : A bit “1” is represented by a transmission from a non zero voltage to zero. First value of none zero voltage is positive, then a negative voltage and repeatedly

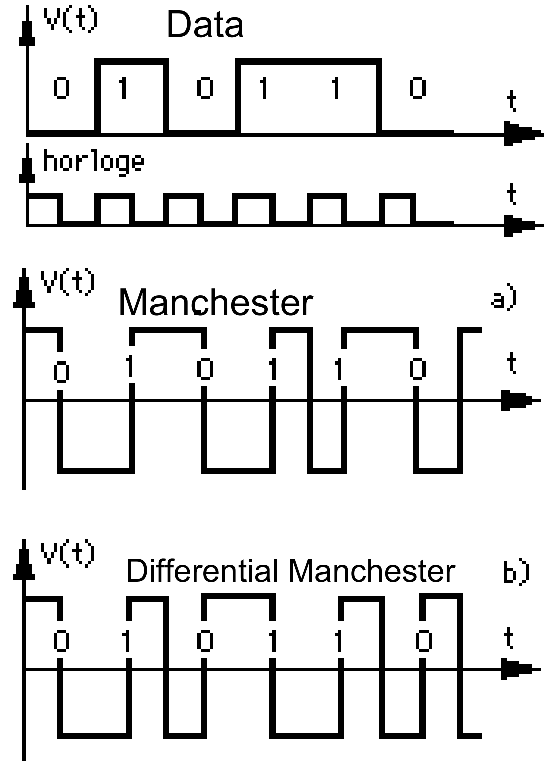


Line code using digital signal

- Biphase

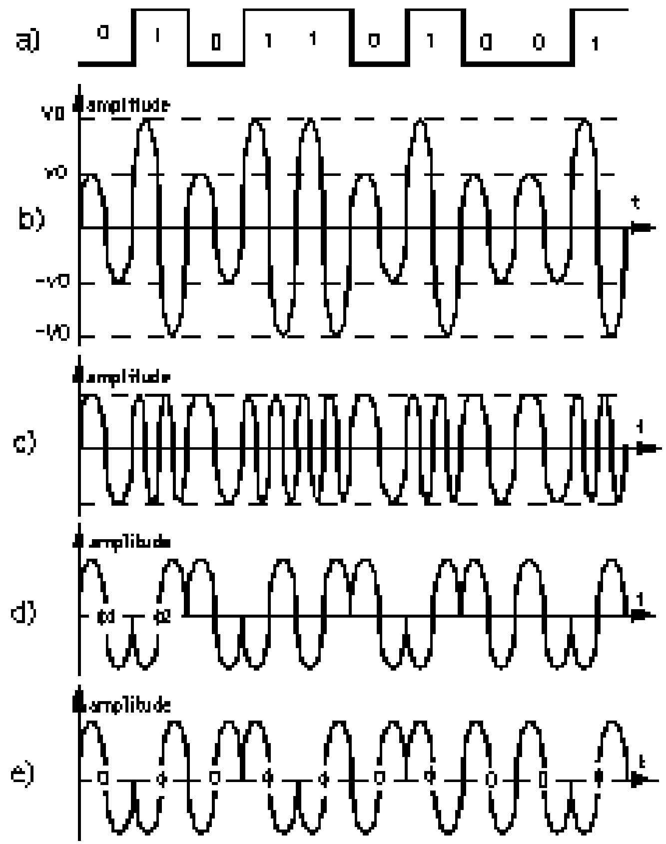
a) Manchester : A bit "0" is represented by a transition from high to low and a bit "1" is represented by a transition from low to high

b) Differential Manchester : Jump a phase 0 to represent a bit 0,Jump a phase 180 to represent a bit 1,



Line code using analog signal

- a) NRZ
- b) Amplitude modulation
- c) Frequency modulation
- d) Phase modulation
- e) Bi-phase modulation



Bài tập

- ADSL sử dụng phương pháp mã hóa đường truyền nào ?
  - http://www.vicomsoft.com/learning-center/dsl-part-2/

Bài tập

Viết chương trình nhận vào một đoạn văn bản và in ra màn hình các tín hiệu mã hóa các văn bản này theo các phương pháp sau:

- Tín hiệu số: NRZ, Manchester
- Tín hiệu tuần tự: Biến điệu cường độ, biến điệu tần số, biến điệu pha