Line Coding
• What is Line coding?
• Why it is required ?
• Different forms of representing binary data

Why line Coding
• Digital data transmitted through a bandlimited channel
• Dispersion in the channel causes overlap in time between successive symbols
• This form of distortion –Inter Symbol Interference (ISI)
• Adverse affect on the quality of reception
• Hence shaping the binary data required

What is Line coding ?
• Method of converting binary sequence into digital signal
• Selection of line coding technique depends basically
-to maximize the bit rate in a given channel
-to recover synchronous information (bit timings) from the received signal (LAN's)
-reduced power of transmission
- to reduce dc component

Line Coding Techniques

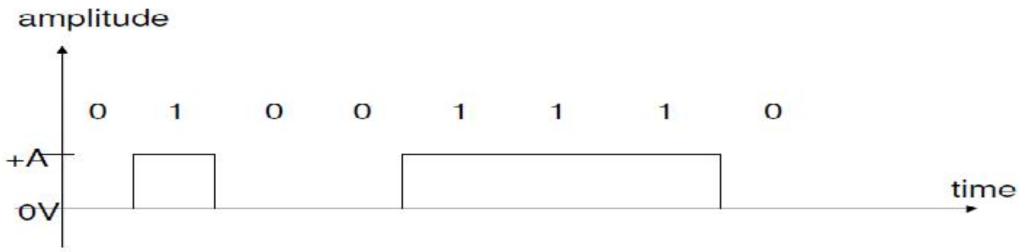
•Unipolar Non-Return-to-Zero (NRZ)
•Polar NRZ
•NRZ inverted
•Bipolar encoding
•Manchester encoding
•Differential Manchester encoding
Line Coding
• Unipolar
• Polar Ex : NRZ, RZ, Manchester, Differential Manchester
• Bipolar

Unipolar encoding

0 ⟶ One voltage level
1 ⟶ another voltage levels
Polarity is either +ve or –ve
⇊
Uses only one polarity
1 ⟶ + A v
0 ⟶ 0 v

- Simplest
- Obsolete

Unipolar Encoding



Disadvantage : dc component is not zero (average amplitude of encoded signal is not zero)
If $p(0)=p(1)=1/2$, the average power transmitted for unipolar line code
$= p(0)\ 0V + p(1)\ (A)^2 = A^2/2$

Polar encoding
• Two Voltage levels
– One +ve voltage
– One –ve voltage
– Average or dc component is reduced
Ex : NRZ, RZ, Manchester, Differential Manchester

Non Return to Zero (NRZ)

•Value of the signal is *always* either +ve or –ve

•Two popular forms (a) NRZ-L (Level)

(b) NRZ-I (Invert)

• (a) NRZ-L (Level) encoding

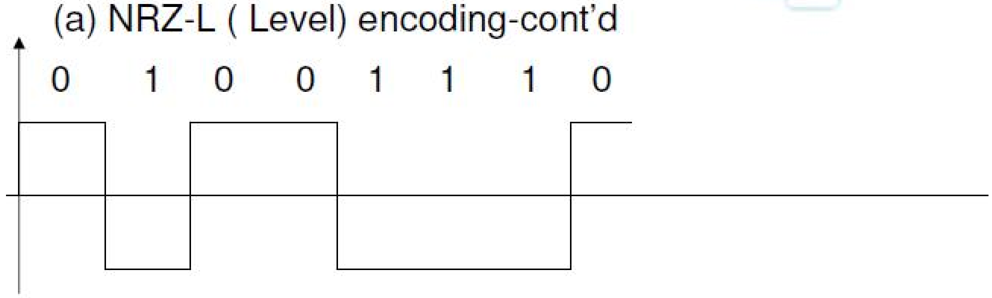
- level of the signal depends on the type of bit that it represent

-0 bit -- +ve voltage

-1 bit -- -ve voltage

Level of the signal depends on state of the bit

(a) NRZ-L (Level) encoding-cont'd



•If p(0)=p(1)=1/2, the average power transmitted for unipolar line code

$$= p(0)\,(+A)^2 + p(1)\,(-A)^2 = A^2$$

•Synchronization of clock problem arises when there is long sequence of bits

(b) NRZ-I (Invert)

•Inversion of voltage level represents a 1 bit

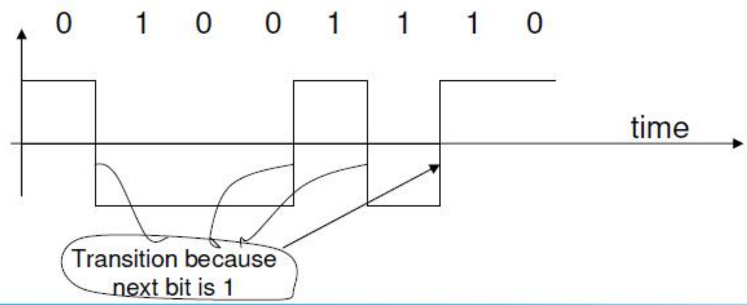
•Transition between a +ve & -ve voltage level that represent a 1 bit

•0 bit -- no change in voltage level

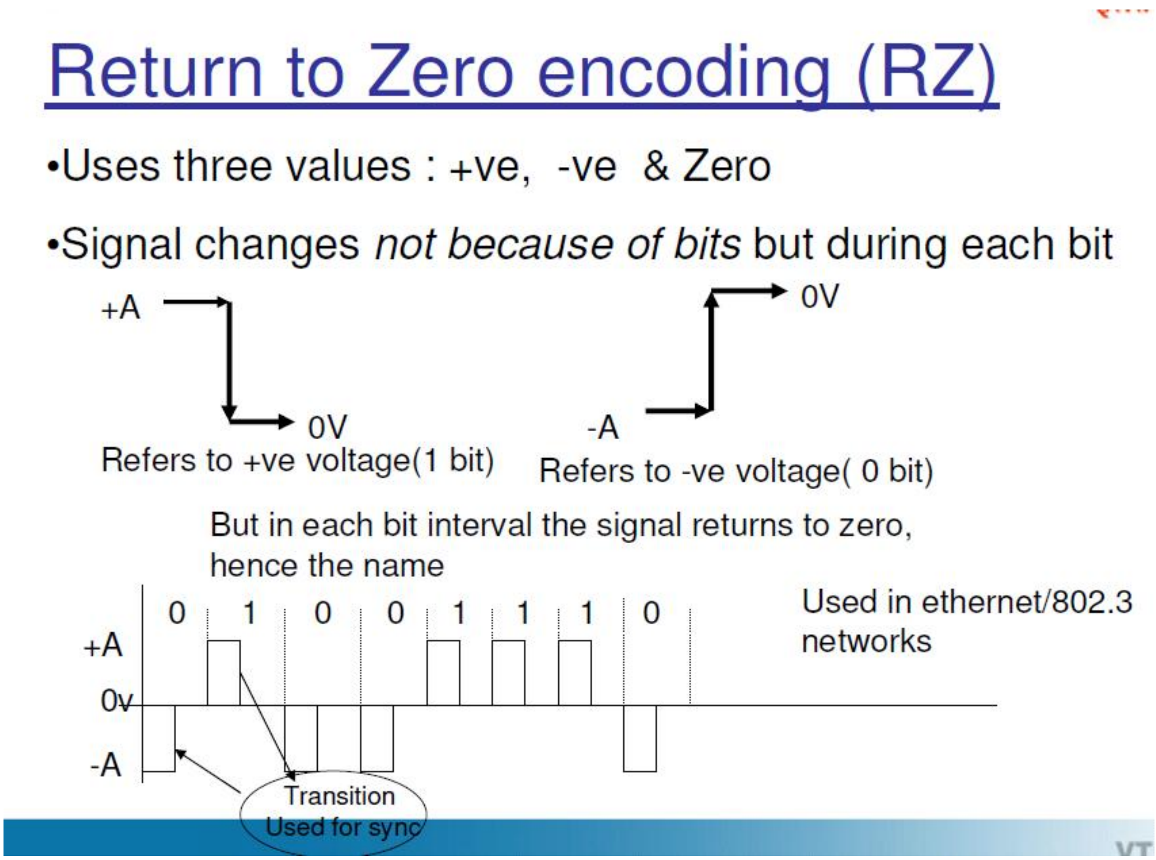
•It is superior to NRZ –L

-synchronization is provided by the signal change each time a 1bit is encoded

-existence of 1's in data stream makes the receiver to synchronization



Used in several LAN system



RZ – Cont'd

Advantage:-

•most effective encoding

Disadvantage:-

•Requires *two signal* changes to encode one bit

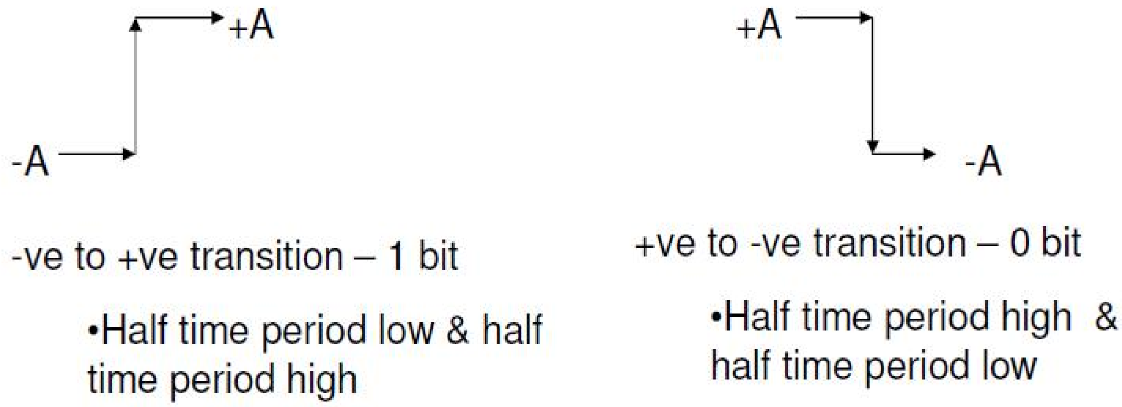
•Hence occupies more bandwidth

Manchester encoding

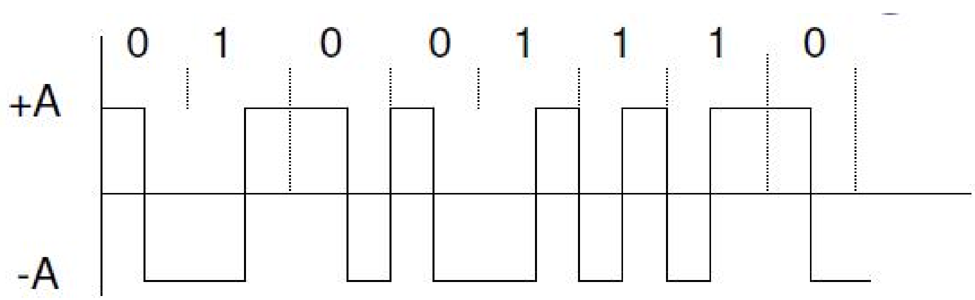
•Instead of 'high ' equaling 1 and 'low' equaling 0 a timing interval is used to measure high or low transition

•Uses inversion at the middle of each bit interval

- provides synchronization
- bit representation

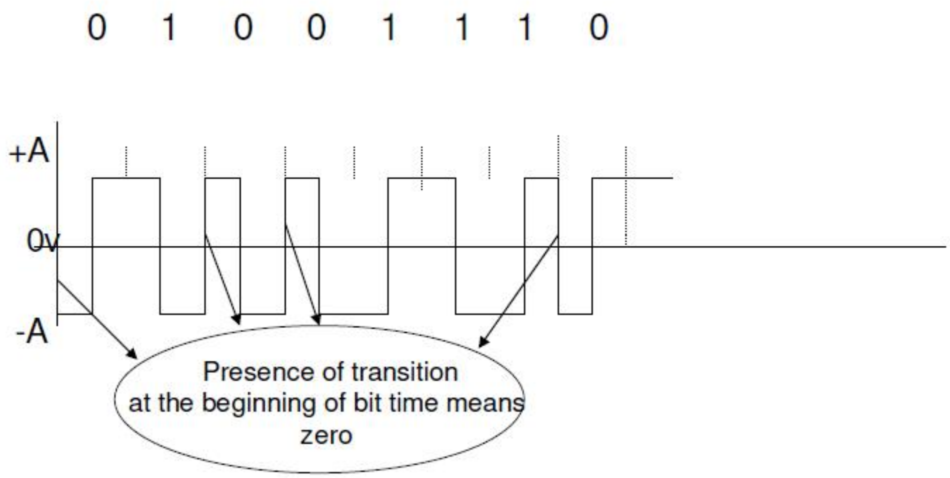


Manchester encoding-cont'd



•Achieves same level of synchronization as RZ
•Requires only two level of amplitudes
Advantages :-
•Error recovery – if part of the signal clipped or distorted still "intelligence" is available for timing recovery
•Signal is falling or raising
Differential Manchester encoding
• Similar to Manchester encoding
• - each bit period is partitioned into two intervals
• -Transitions are functions of previous bit period
• - transitions means binary 0
• - no transitions means binary 1
• Requires two signal changes to represent '0' but only one to represent '1'
• A low-to-high transition could be '0' or '1' depending on the value of previous bit period

Differential Manchester cont'd

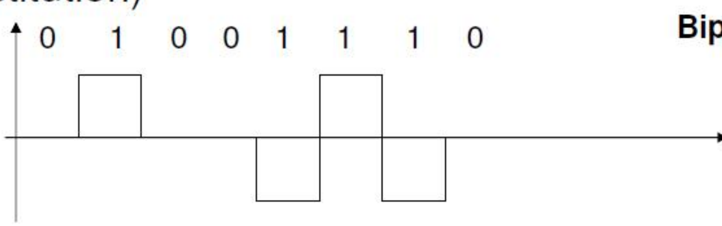


- Used in ethernet & token ring LAN standard
- Manchester code is an example of mBnB code (n>m) typical 4B5B
- Used in OFC standard called FDDI(Fiber Distributed Data Interface)

Bipolar encoding

- Use three voltage levels +ve, -ve & 0V
- Here 0→ 0v

  1 → alternating +ve & -ve voltage levels
- If the first 1bit is +ve amplitude next 1bit is –ve and so on
- AMI (Alternate Mark Inversion) or BnZs (Bipolar n-Zero substitution)



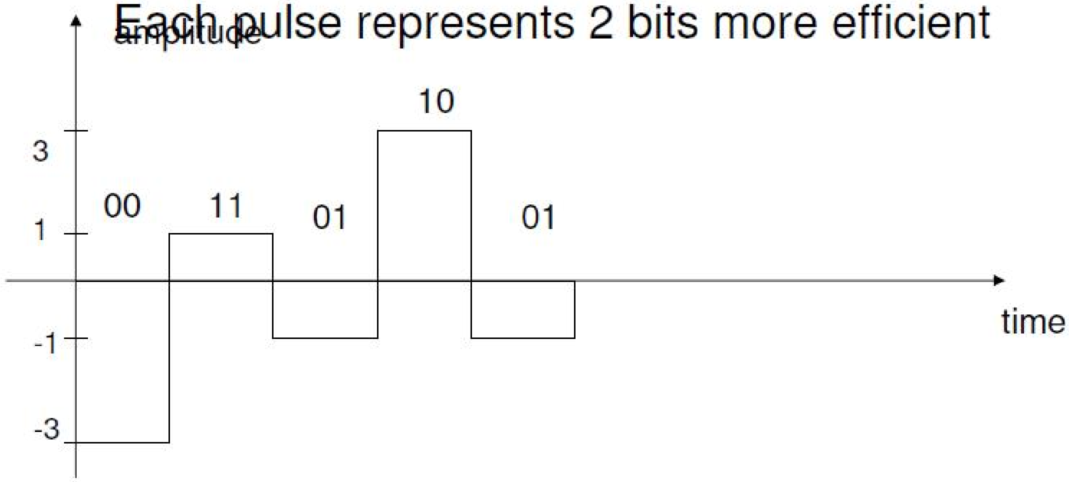
Bipolar AMI encoding

Other line coding scheme

Other line coding scheme

2B1Q- (2 Binary, one quaternary)

- Uses four voltage levels
- Each pulse represents 2 bits more efficient

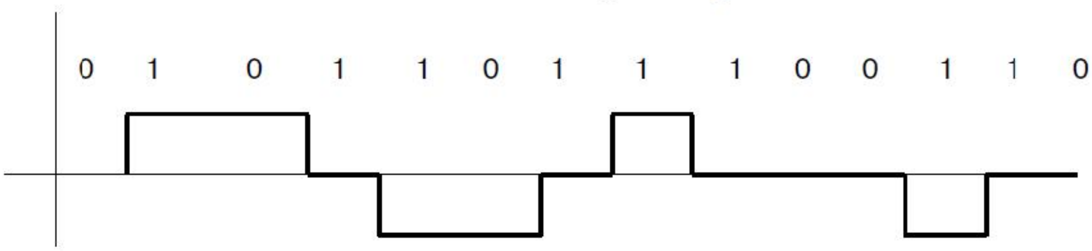


MLT3 (Multi Line Transmission Three level)

- Similar to NRZ-I (Non return to zero, invert)

But uses 3 levels of signals (+1, 0, & -1)

- Signal transition from one level to the next at the beginning of a 1 bit
- There is no transition at the beginning of a '0' bit

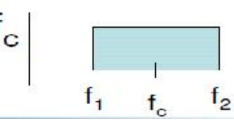


Digital Modulations
- What is Digital Modulation ?
- What is the difference between line coding & Digital modulations ?
- Analog modulation versus Digital modulation
- Different types of digital modulation schemes

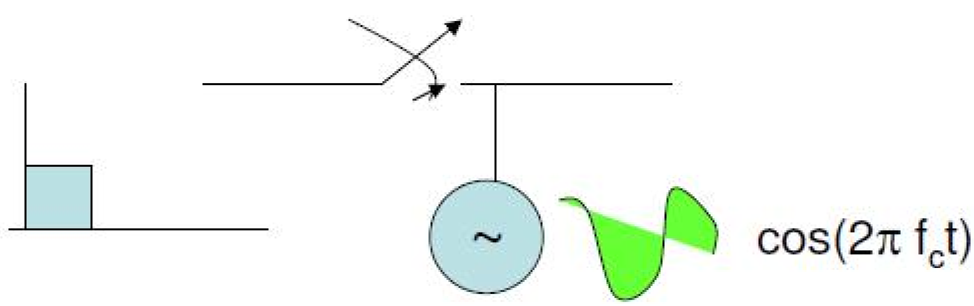
What is Digital Modulation ?

- converting binary data to analog signal is digital modulation
- Has a carrier- data signals modulates in some form- amplitude, frequency, phase
- Better spectral efficiency

  η = bit rate (bps)/ BW(Hz)
- BW restriction is much more severe
- Consider band-pass channel
- $W = f_1 - f_2$, $f_c = (f_1 + f_2)/2$
- $\cos(2\pi f_c t)$ power is concentrated at f_c



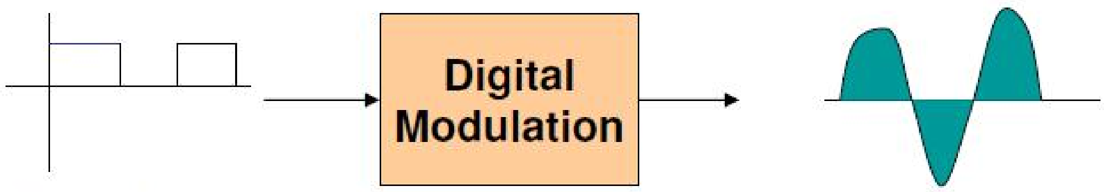
What is digital modulation-cont'd
- *Modulation is the process by which some characteristic of a carrier is varied in accordance with a modulating wave* Basically is a keying operation here



•Modulation process involves switching or keying

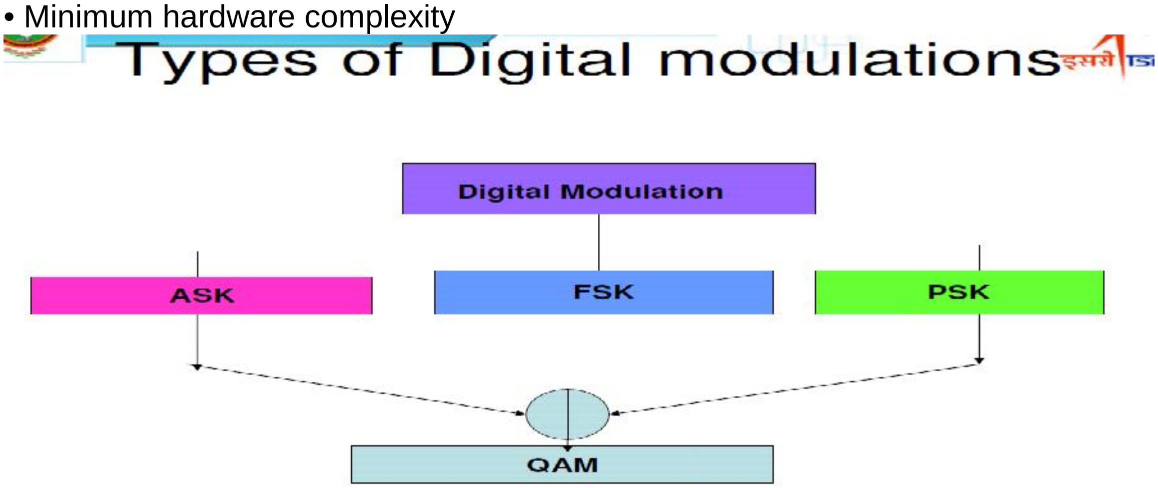
the amplitude, frequency, or phase of the carrier
in accordance with the in coming data

Digital Data, Analog Signal

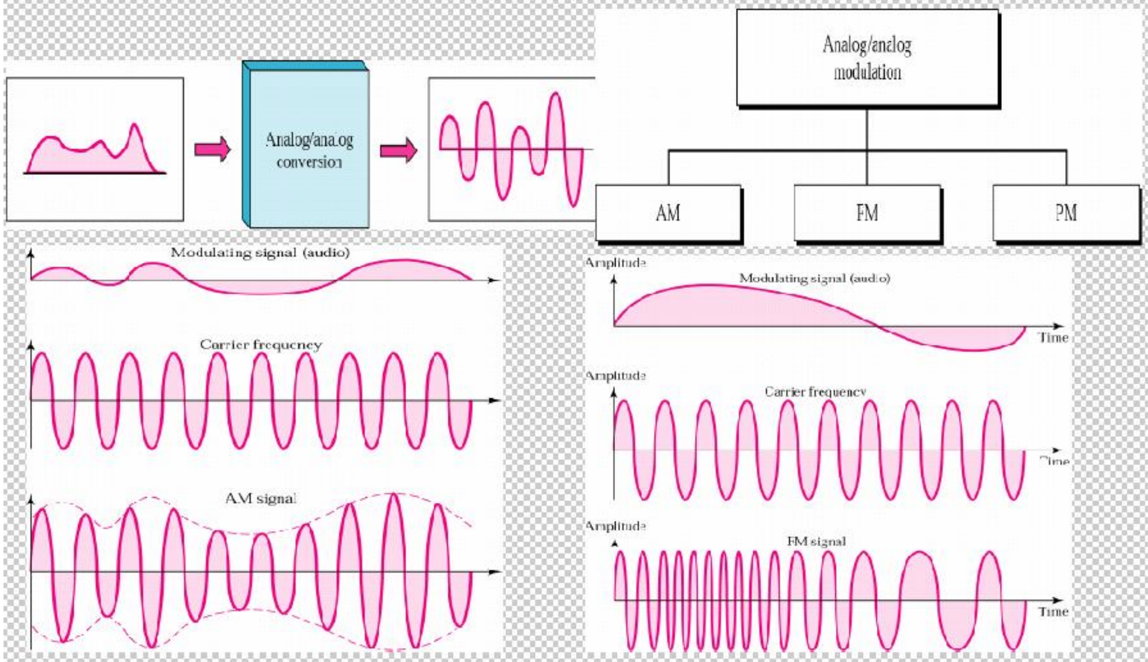


• Public telephone system
– 300Hz to 3400Hz
– Used in modem (modulator-demodulator)
-device that carries out operation in these frequency range
• Amplitude shift keying (ASK)
• Frequency shift keying (FSK)
• Phase shift keying (PSK)

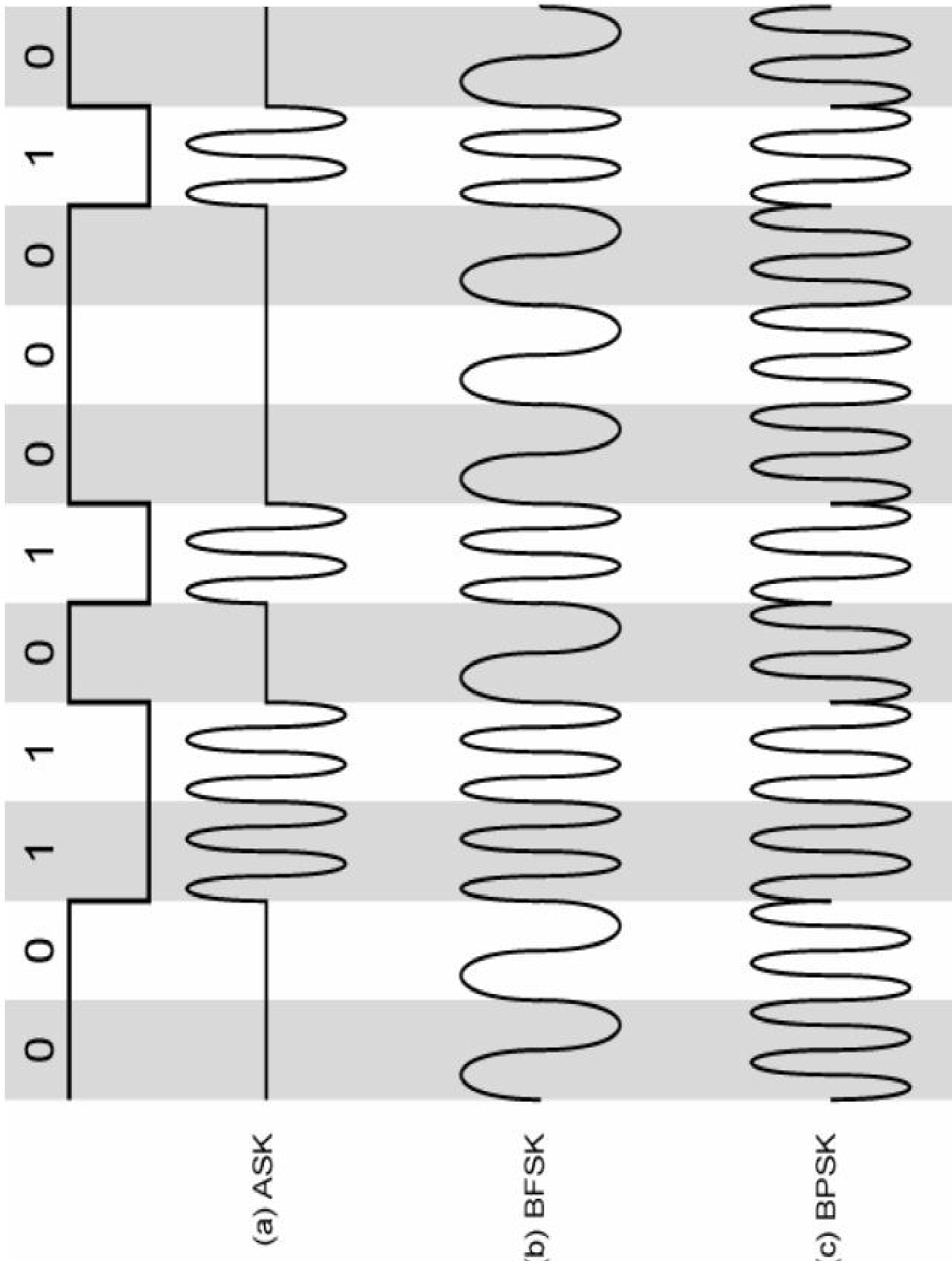
Goals of Digital modulation
• Maximum data rate
• Minimum probability of error
• Minimum transmitted power
• Minimum channel bandwidth
• Maximum resistance to interfering signals
• Minimum hardware complexity



Analog Modulation

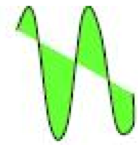


Slide courtesy data communication & Networking Forouzan, TMH

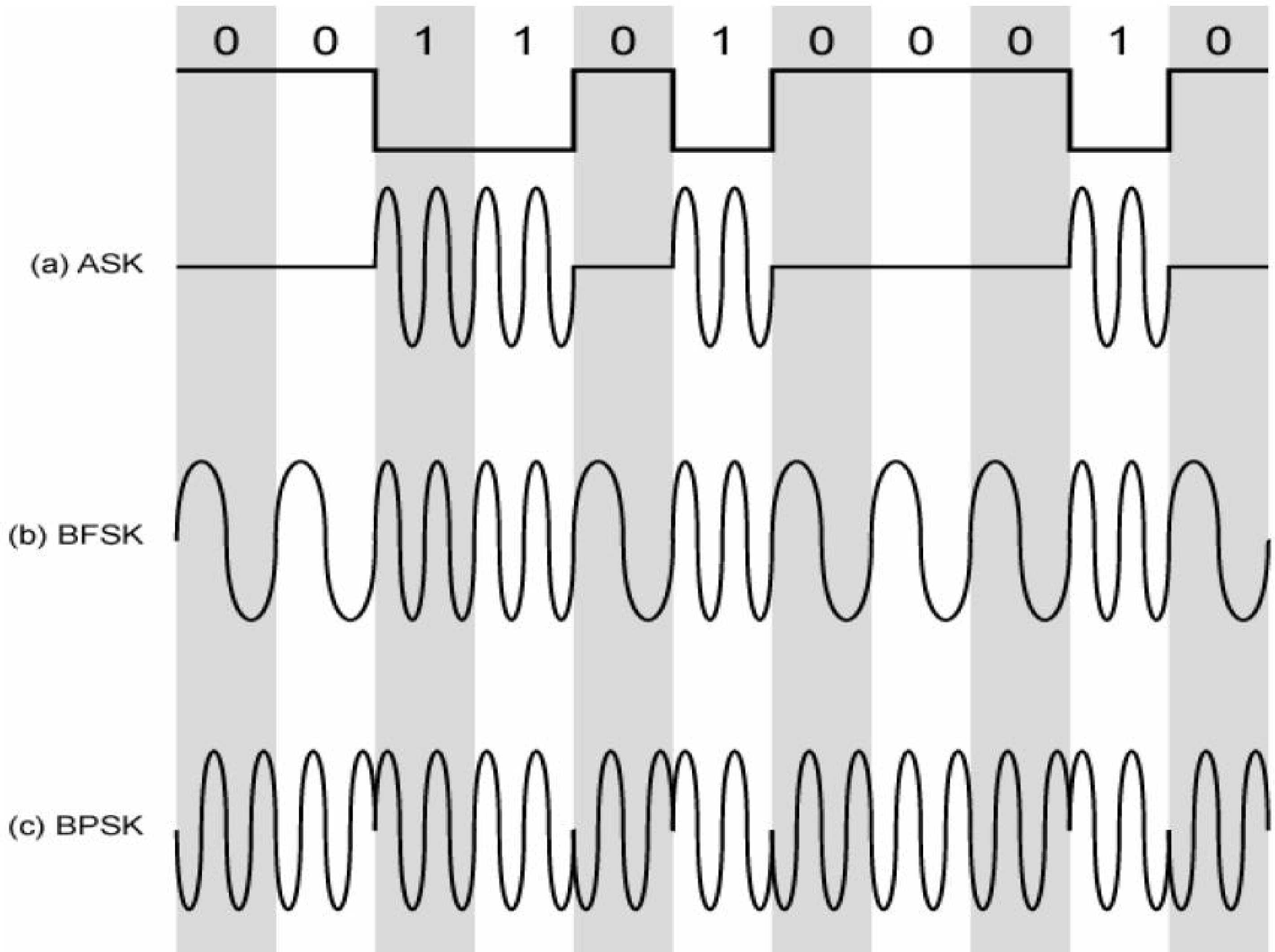


Amplitude Shift Keying (ASK)
• Values represented by different amplitudes of carrier

• presence of a carrier – binary 1

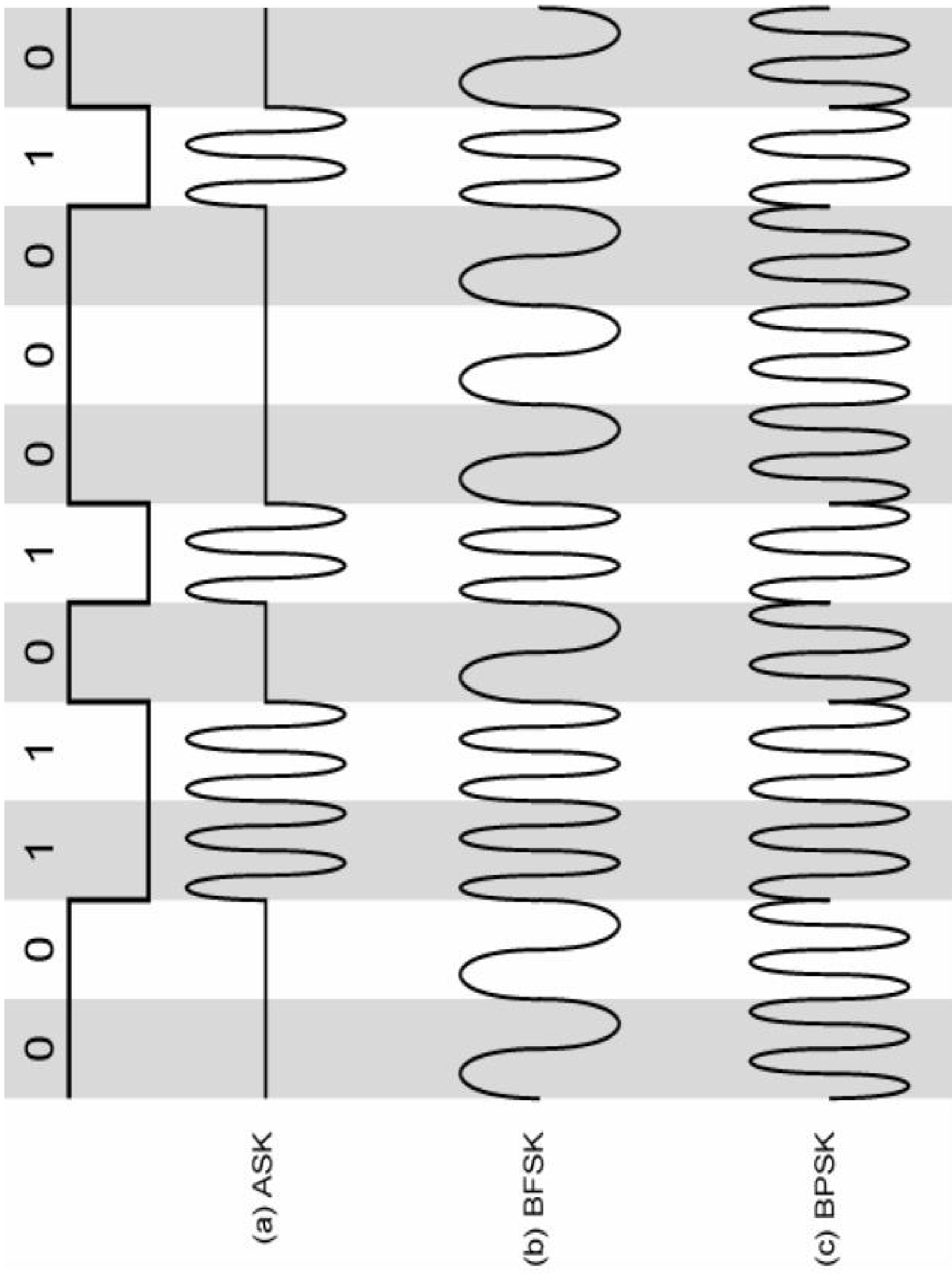


• absence of carrier is – binary 0
• Sinusoidal signal is turned ON & OFF according input data- Modulator
• Demodulator – only to determine presence or absence of carrier


0 0 1 1 0 1 0 0 0 1 0
(a) ASK
(b) BFSK
(c) BPSK

ASK-cont’d
• Amplitude is susceptible to sudden changes
• Bit rate = baud rate (bit rate=number of bits/ sec
: Baud rate = number of signal units /sec)
• BW= bit rate
• Inefficient
• Up to 1200bps on voice grade lines
• Used over optical fiber
• Example:
• Bandwidth of 5000 Hz for an ASK signal, what are the Baud rate & bit rate?
for ASK Baud rate=bit rate
Bit rate =5000bps
Baud rate = 5000

Binary Frequency
Shift Keying (BFSK or FSK)
• Most common form is binary FSK (BFSK)
• Two binary values represented by two different
frequencies (near carrier)
• Both amplitude & phase remains constant
• cos(2 f1 t) refers to binary 1 where f1= fc - a
• cos(2 f2 t) refers to binary 0 where f2 = fc+ a



FSK-cont'd

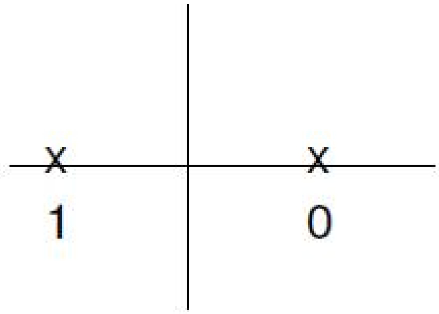
• BW= bit rate + (f1 - f2)
• Less susceptible to error than ASK
• Up to 1200bps on voice grade lines
• High frequency radio
• Even on LANs using co-axial cable
• Example:
• FSK signal transmitting at 2000bps transmission half duplex , carrier separation is 3000Hz Find Minimum BW ?
• BW= bit rate + (f1- f2)=2000+3000 = 5000Hz

Multiple FSK
• More than two frequencies used
• More bandwidth efficient
• More prone to error
• Each signalling element represents more than one bit
Binary Phase Shift Keying (BPSK)
• Phase of carrier signal is shifted to represent data
• Binary PSK modulates the carrier phase depending on the information bit

• cos(2 fc t + b(t)) b(t) =` $\begin{cases} 0 \\ 1 \end{cases}$

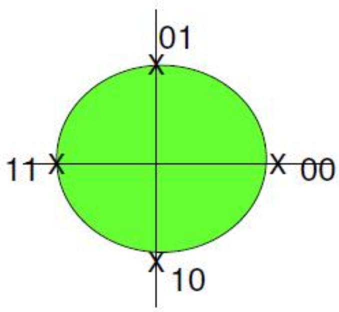
• Binary PSK
– Two phases represent two binary digits
• cos(2 fc t) refers to binary 1
• cos(2 fc t +)=-cos(2 fc t) refers to binary 0

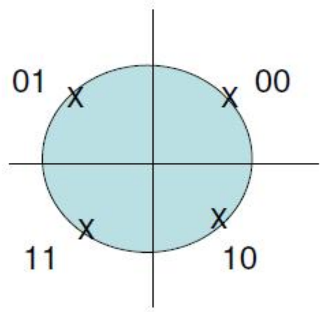
PSK - cont’d
• Equivalent to sinusoids by multiplying with +1 for binary 1
• Equivalent to sinusoids by multiplying with -1 for binary 0
• Demodulator to detect the phase with respect some reference phase



M-PSK

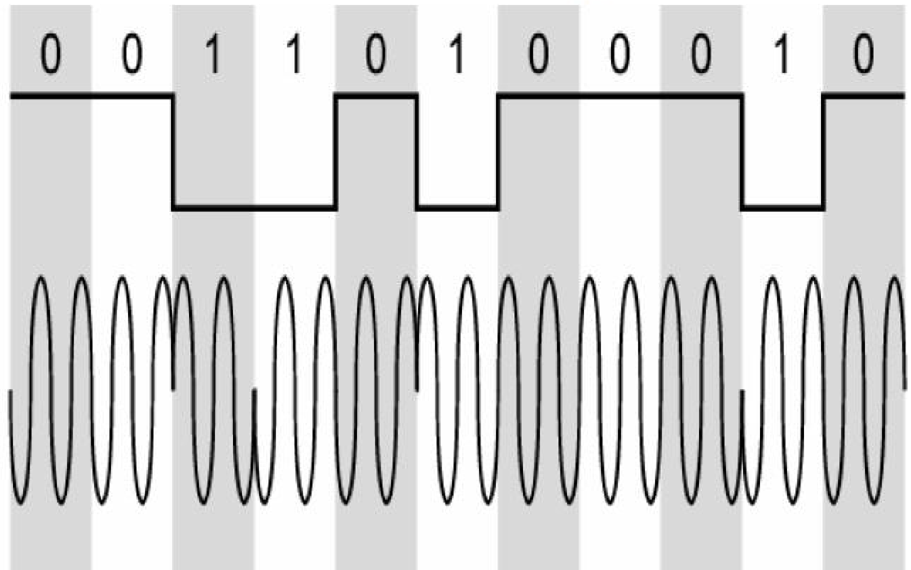
- $\cos(2\pi f_c t + b(t)\,\pi)$ $\qquad b(t) = \begin{cases} 0 \\ 1 \end{cases}$
- This chooses one of two phases.
- Collects two bits & picks one of 4-phase values
- $(\ 0,\ \pi/2,\ \pi\ ,\ 3\pi/2)$ or $(\ \pi/4,\ 3\pi/4\ ,\ 5\pi/4,\ 7\pi/4)$





Differential PSK

Phase shifted relative to previous transmission rather than some reference signal



Quadrature PSK
• More efficient use by each signal element representing more than one bit
– e.g. shifts of /2 (90o)
– Each element represents two bits
– Can use 8 phase angles and have more than one amplitude
– 9600bps modem use 12 angles , four of which have two amplitudes
• Offset QPSK (orthogonal QPSK)
– Delay in Q stream

Performance of Digital to Analog Modulation Schemes
• Bandwidth
– ASK and PSK bandwidth directly related to bit rate
– FSK bandwidth related to data rate for lower frequencies, but to offset of modulated frequency from carrier at high frequencies
– (See Stallings for math)

• In the presence of noise, bit error rate of PSK and QPSK are about 3dB superior to ASK and FSK

Quadrature Amplitude Modulation (QAM)

• QAM used on asymmetric digital subscriber line (ADSL) and some wireless
• Combination of ASK and PSK
• Logical extension of QPSK
• Send two different signals simultaneously on same carrier frequency
– Use two copies of carrier, one shifted 90°
– Each carrier is ASK modulated
– Two independent signals over same medium
– Demodulate and combine for original binary output

QAM Levels

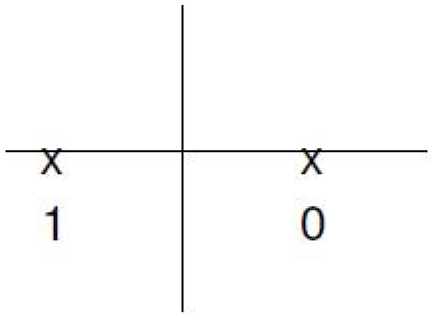
• Two level ASK
– Each of two streams in one of two states
– Four state system
– Essentially QPSK
• Four level ASK
– Combined stream in one of 16 states
• 64 and 256 state systems have been implemented
• Improved data rate for given bandwidth
– Increased potential error rate

Binary Phase Shift Keying (BPSK)

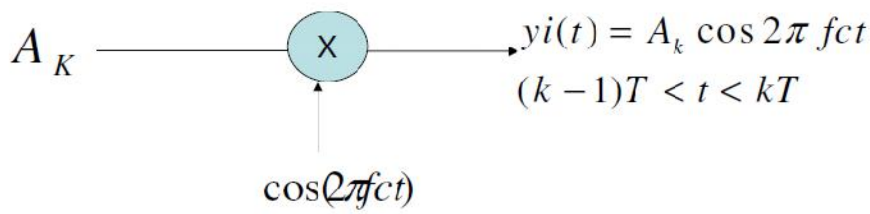
- Phase of carrier signal is shifted to represent data
- Binary PSK modulates the carrier phase depending on the information bit
- $\cos(2\pi f_c t + b(t)\,\pi)$ $b(t) = \begin{cases} 0 \\ 1 \end{cases}$
- Binary PSK
  - Two phases represent two binary digits
- $\cos(2\pi f_c t)$ refers to binary 1
- $\cos(2\pi f_c t + \pi) = -\cos(2\pi f_c t)$ refers to binary 0

PSK - cont'd

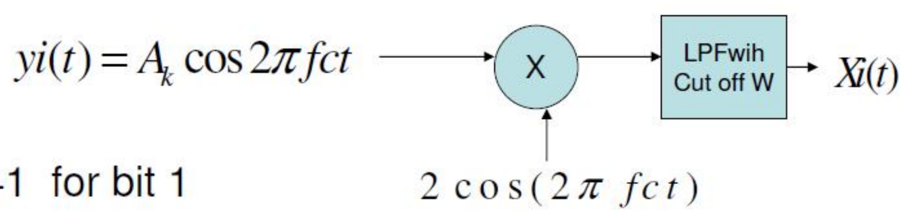
- Equivalent to sinusoids by multiplying with +1 for binary 1
- Equivalent to sinusoids by multiplying with -1 for binary 0
- Demodulator to detect the phase with respect some reference phase



a) Modulator



b) Demodulator(To recover A_k)



A_k = +1 for bit 1

= -1 for bit 0

$$y_i(t)\cos(2\pi fct) = 2A_k \cos^2(2\pi fct) = A_k(1+\cos 4\pi fct/2)$$

QPSK (quadrature PSK)

• More efficient use by each signal element representing more than one bit

– e.g. shifts of /2 (90o)

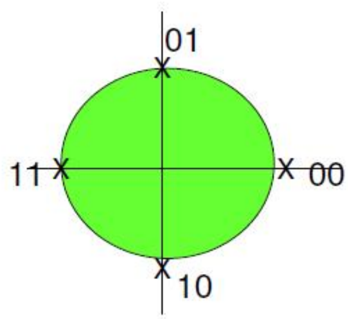
– Each element represents two bits

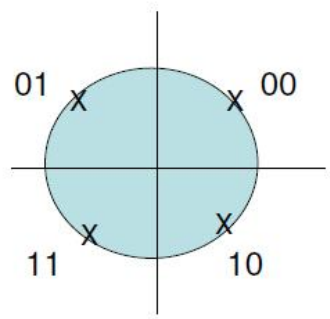
--Collect two bits & pick on of four phase values

– Can use 8 phase angles and have more than one amplitude
– 9600bps modem use 12 angles , four of which have two amplitudes

M-PSK

- For BPSK $\cos(2\pi f_c t + b(t)\pi)$ $\quad b(t) = \begin{cases} 0 \\ 1 \end{cases}$
- This chooses one of two phases.
- Collects two bits & picks one of 4-phase values
- ($0, \pi/2, \pi, 3\pi/2$) or ($\pi/4, 3\pi/4, 5\pi/4, 7\pi/4$)

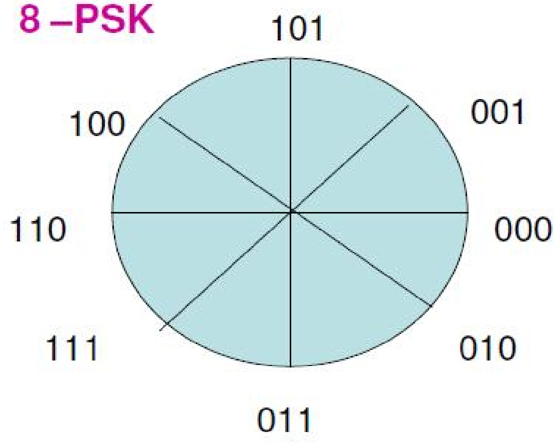




$$(0,\pi,\pi/2,\pi,3\pi/2)$$
$$\cos 2\pi fct \rightarrow 00$$
$$\cos(2\pi fct+\pi/2) \rightarrow 01 = -\sin 2\pi fct$$
$$\cos(2\pi fct+\pi) \rightarrow 11 = -\cos 2\pi fct$$
$$\cos(2\pi fct+3\pi/2) \rightarrow 10 = +\sin 2\pi fct$$
$$= \pm\frac{1}{2}\cos 2\pi fct \mp \frac{1}{2}\sin 2\pi fct$$

$$(\pi/4, 3\pi/4, 5\pi/4, 7\pi/4)$$
$$00 \rightarrow \cos(2\pi fct+\pi/4)$$
$$01 \rightarrow \cos(2\pi fct+3\pi/4)$$
$$11 \rightarrow \cos(2\pi fct+5\pi/4)$$
$$10 \rightarrow \cos(2\pi fct+7\pi/4)$$

8 –PSK



$$Q_i = (i-1)\pi/4$$
$$i = 1,2\ldots8$$

Fig. Constellation Diagram

-Signal Constellation refers to a set of possible message points

Tribit	Phase in Degree
000	0
001	45
101	90
100	135
110	180
111	225
011	270
010	315

- Minimum bandwidth is same as ASK
- Maximum rate may be much higher

Example :

Given a bandwidth of 5KHz for an 8 PSK signal, What are baud rate & bit rate ?

For PSK baud rate = bandwidth

= 5000

For 8 PSK bit rate = 3 x band rate

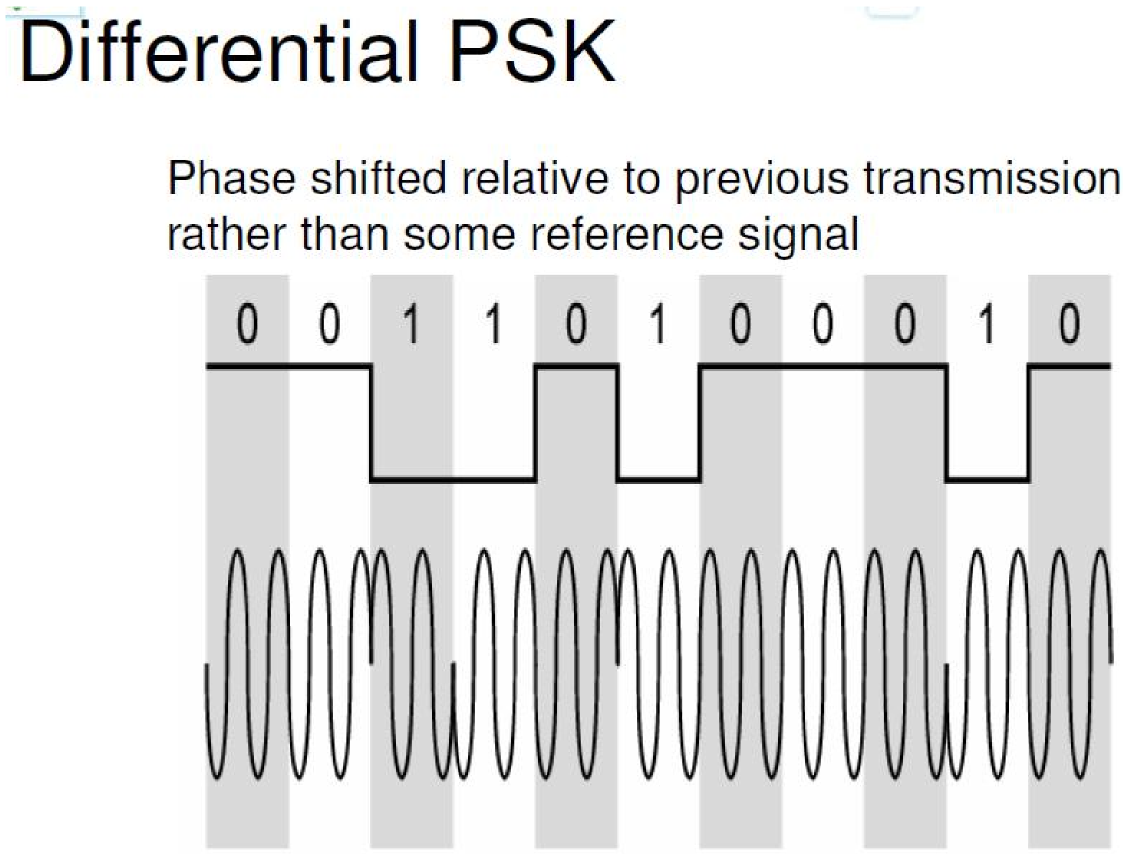
= 3 X 5000

15000 bps

Note :

Nyquist signaling rate – for a LP Channel of Bandwidth ' W' Hz, the maximum signaling rate is 2W pulse/sec

. For PSK we can transmit only W pulse / Sec over Band pass
channel that has a Band width of W Time /bit is T=1/W
PSK attains half the signaling rate of LP Case QAM is used to recover the factor 2’



Quadrature Amplitude Modulation(QAM)

• Combination of ASK and PSK
• Maximum Contrast between each signal unit(bit,dibit,tribit and son on) is achieved
• Simultaneous modulation of the amplitude and phase of a carrier signal
• Symbols are generated at a rate = W Symbols/Sec

QAM Levels

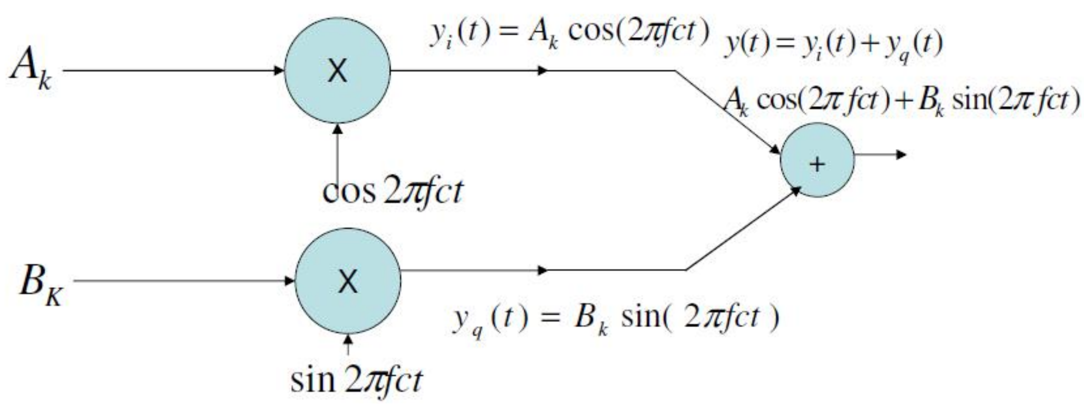
• Two level ASK
– Each of two streams in one of two states
– Four state system
– Essentially QPSK
• Four level ASK
– Combined stream in one of 16 states
• 64 and 256 state systems have been implemented
• Improved data rate for given bandwidth

– Increased potential error rate

QAM- cont'd
– Send two different signals simultaneously on
same carrier frequency
• Use two copies of carrier, one shifted 90°
• Each carrier is ASK modulated
• Two independent signals over same medium
• Demodulate and combine for original binary output

QAM Scheme-cont'd

• Split the original information stream into two sequences consisting of odd & even symbols A_k, B_k



QAM - cont'd

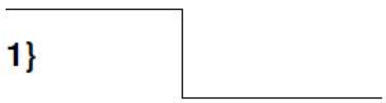
- 2D Modulation Scheme
- A_k is called *in-phase* component
- B_k is called *Quadrature* phase component
-

Consider

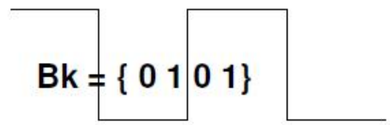
00 01 10 11

Ak = { 0 0 1 1}

NRZ { Ak}

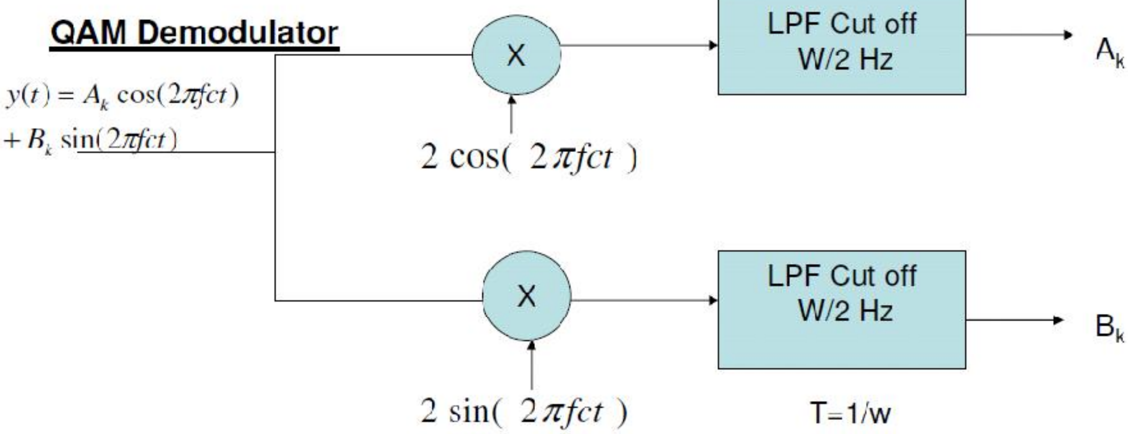


Bk = { 0 1 0 1}



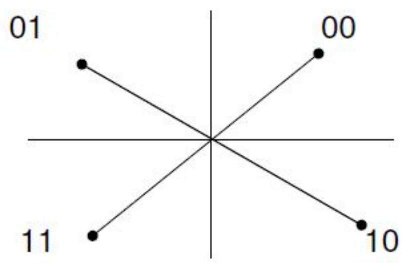
- Sum of in phase & Quadrature modulated wave is transmitted
- Transmitted over a bandpass channel

<u>QAM Demodulator</u>



- QAM is a 2 D system that achieves an effective signaling rate 2 W

pulse/sec over the Band pass channel of W Hz



4-QAM

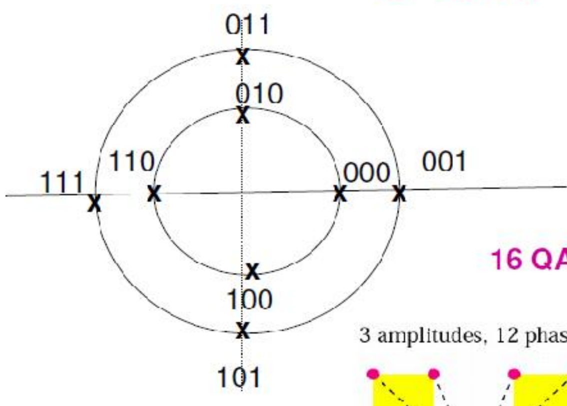
1 Amplitude, 4 phase

4 levels /pulse

2 bits/pulse

2W bits/sec

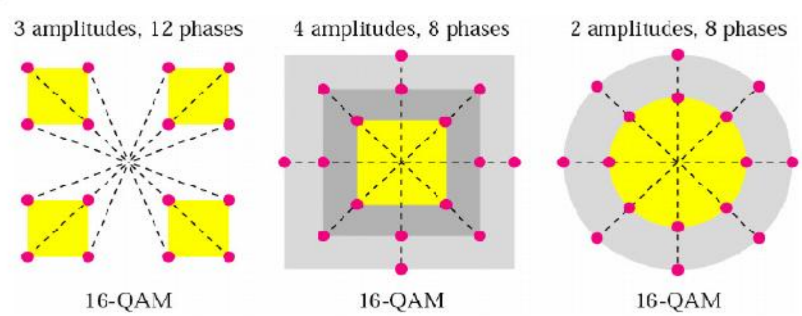
8- QAM



2 Amplitude, 4 phase

QAM used on asymmetric digital subscriber line (ADSL) and some wireless

16 QAM Constellations



Performance of Digital to Analog Modulation Schemes

- Bandwidth

– ASK and PSK bandwidth directly related to bit rate
– FSK bandwidth related to data rate for lower frequencies, but to offset of modulated frequency from carrier at high frequencies
• In the presence of noise, bit error rate of PSK and QPSK are about 3dB superior to ASK and FSK

Bit and baud rate comparison

Modulation	Units	Bits/Baud	Baud rate	Bit Rate
ASK, FSK, 2-PSK	Bit	1	N	N
4-PSK, 4-QAM	Dibit	2	N	2N
8-PSK, 8-QAM	Tribit	3	N	3N
16-QAM	Quadbit	4	N	4N
32-QAM	Pentabit	5	N	5N
64-QAM	Hexabit	6	N	6N
128-QAM	Septabit	7	N	7N
256-QAM	Octabit	8	N	8N

Signalling constellations & Telephone Modem standards
• Signal Constellation diagrams used in signaling standards
•used over telephone lines
• data communication over telephone channels
BW = 2900 – 500 = 2400Hz
W = 2400 Hz
Signalling rate 1/T = W = 2400 Pulse/Sec

Trellis coded modulation (TCM)
• Modified version of QAM
• Incorporates extra bits for for error correction
• combine error correction coding with modulation
• number of constellation points is 2m+1

• after every T – Seconds, it accepts m bits and generates m+1 bits for constellation points

•**Example :**
Trellis - 32 system:
25 Constellation points of which 16 are valid at any given time
Bit rate = 4 X 2400 = 9600bps
Similarly
Trellis 128 system : bit rate 6 X 2400 = 14,400 bps
TCM – Cont'd
• only 2m out of 2m+1 possible constellation points are valid at a given interval
• Redundancy improves robustness of modulation scheme with respect to error

Modems
• Stands for modulator/ demodulators
• Modulators Digital signal to analog signal ASK,FSK,PSK ..
• Demodulators Analog signal into digital signal
•- > Sending End
• Modem transforms a computer Signal into analog form
• Analog signal carried across a standard telephone line
•> Receiving Side
• it converts the transmitted analog signal from telephone line to digital form before passing into computer

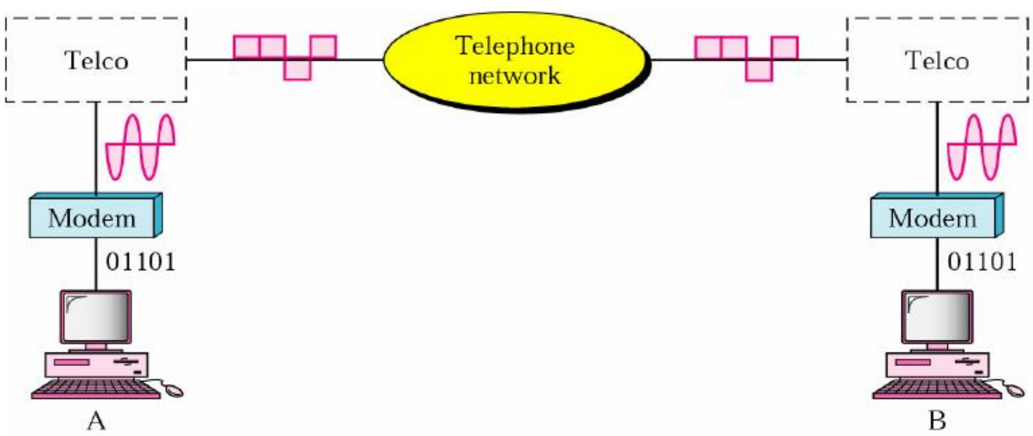


Fig courtesy – data communication & Networking Fourzon, TMH

Modems-cont'd

- ITU-T and modem manufacturers come out with standard specification

type of modulation, error control & Compression.

- **Popular Standard**

Standard	Description
V.32	{ 9600bps, QAM and Trellis Coding, 14,800 bps { 33,600 bps(Software Enhancement)
V.34	1024 QAM and Trellis coding (960)
V.90	56k bps

Highest speed possible a modem can achieve over an analog line is 33,600bps & 38,400 bps depending on line conditions

Properties of media and Digital Transmission Systems

Medium

Coverage-

- Communication system
- Types of Media
- Characteristics & standard

Communication system

- Transmits information by modulating a sinusoidal signal of frequency f_o
- Signal propagates in a guided medium or free space
- Sinusoidal variation of modulated signal propagates in a medium
- Velocity

$$v = 1 / \sqrt{\mu \in}$$

$$= 1 / \sqrt{\mu_o \in_0} \sqrt{\mu_r \in_r}$$

$$v = c / \sqrt{\mu_r \in_r}$$ c= 3X 10^8 m / Sec

Types of Media

Wired Media

- Copper pair wires
- Coaxial Cable
- Optical Fiber

Wireless media

Ex : Radio Wave,
Infrared Light

Properties

Wired Media

- Provides point to point Communication
- Well defined discrete network topologies
- Energy is confined with in the medium
- Requires ' right of way through the land cable travels
- Complicated, costly, time consuming
- Attenuation exponentially varies with distance

Alfa = kddb

K= constant

D= distantce

Wireless Media

- Eliminates Directionality
  Ex: Broadcasting radio
- Continuous in nature
- User to share the available frequency band
- Radio spectrum in finole has limited capacity
- Wireless system can be displayed quickly, reduced cost

Alfa= d power of n

n= path loss exponents

Ex: free space n=2

Wireless media
For medium with obstruction n>2
Alfa = nlog10 d dB Signal level can be maintained over distance

Twisted pair

Copper cable

- UTP (Unshielded Twisted pair)
- STP (Shielded Twisted pair)

2 wire

Signal is transmitted through one wire

A ground reference is transmitted through other

Susceptible to cross talk (picking signals from other adjacent wires)

Noise (from other electromagnetic sources such as broad band cast radio)

Twisted Pair
Two wires twisted together ?
Reduces interference
Reduce cross talk
Passes wide range of frequencies
Alfa 1 to 4db/mile at 1 khz
10 to 20 db/mile at 500khz
UTP is used in telephone network

Application
Digital Subscriber loops (DSL)
LAN
Description of twisted pair Cable categories
Category 1 Voice transmission, not suitable for data transmission
Category 2 Voice & low speed data transmission capacity up to 4 mbps
Category 3 Data & voice transmission rated at1 0 mhz, used in ethernet , Fast Ethernet , Trunking <16 MBPS

Ethernet LAN Standard wires

10 Base T - > 10 Mbps operated using baseband transmission over twisted pair

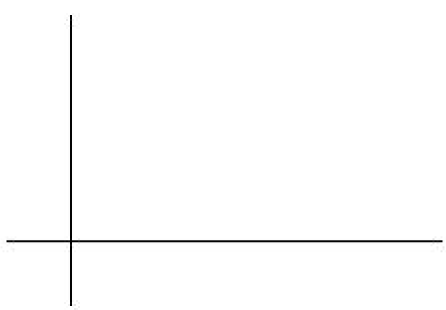
100 Base T - > 100 mbps using Twisted pair wire

Base band network Transmits digital signals directly without modulating their transmission

Capable of transmitting only a single stream of data

Use entire bandwidth to carry a signal

2. Co-axial Cable
A solid center conductor is coaxially located with a cylindrical outer conductor
Two conductors are separated by insulator
Provides better immunity over interference & crosstalk Provides higher BW(>MHZ) Ex Cable TV System uses a BW of 500 MHZ



Applications
1) Cable TV Distribution
54 - 500 MHZ
Analog TV signal occupies 6 MHZ band
50 to 70 Channels
Unidirectional
2) Ethernet LAN
10 Base 5 - > 10 Mbps Maximum lengths of 500 meters

10 Base 2 - > Thin Co-axial Cable (5mm)
10 mbps, maximum length 200 meters
3. Optical Fiber
Greater advantages over copper based digital transmission system
Greater reduction in cost
Reduces space requirement
High transmission rate
Structure
Very fine cylinder of glass (core)
Surounded by a concentric layer of glass

Information in the form of beam of light travels through the core
Refractive index of core is higher than Cladding
Refractive index of core/refractive index of cladding=> critical angle Qc
Attenuation is 0.2db/km
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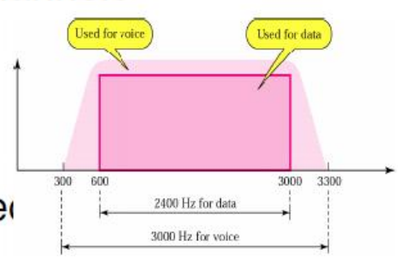

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MODEMS –Cont'd

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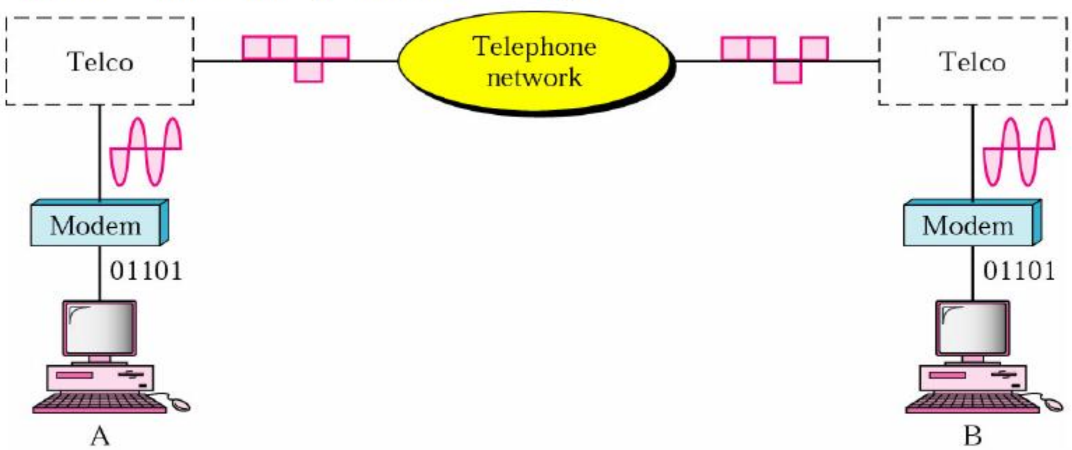

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Ex : Radio Wave,

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•Energy is confined with in the medium-losses are less

•Requires ‘ right of way’ through the land cable travels

Wireless Media

•Eliminates Directionality
Ex: Broadcasting radio

•Network topologies Continuous in nature

•User to share the available frequency band

•Radio spectrum in finite, has limited capacity

Properties-cont’d

Wired media

•Complicated, costly, time consuming

•Attenuation exponentially varies with distance

$\alpha = k\ d$ dB

k= constant

d= distance

Wireless media

•Wireless system can be deployed quickly, reduced cost

$\alpha = d^n$

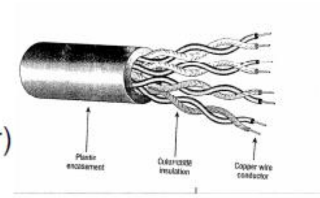
n= path loss exponents

Ex: free space n=2

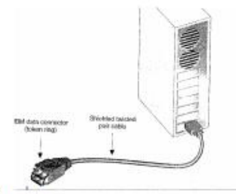
•For medium with obstruction $n>2$, $\alpha = n\log_{10} d$ dB

•Signal level can be maintained over distance

1. Twisted pair



Copper cable
- UTP (Unshielded Twisted pair)
- STP (Shielded Twisted pair)



2 wire

•Signal is transmitted through one wire

•A ground reference is transmitted through other

•Susceptible to cross talk (picking signals from other adjacent wires)

•Noise (from other electromagnetic sources such as broad band cast radio)

VTU

Twisted pair-cont'd

•Two wires twisted together ?

STP: Same as UTP but with a aluminum/polyester shield

•Reduces interference

•Reduce cross talk

•Passes wide range of frequencies

• α = 1 to 4dB/mile at 1 kHz

= 10 to 20 dB/mile at 500kHz

} Depends on gauge

• used in telephone network

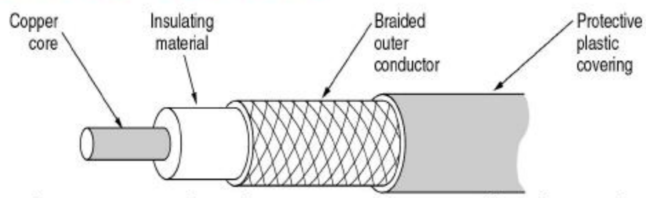
Description of twisted pair Cable categories

Category 1 Voice transmission, not suitable for data

transmission
Category 2 Voice & low speed data transmission capacity up to 4 Mbps
Category 3 Data & voice transmission, rated at 10 MHz, uses-ethernet , Fast Ethernet , Token ring
<16Mbps
Category 5 100 Mbps
Application:
• Digital Subscriber loops (DSL)
• LAN

Ethernet LAN Standard wires
10 Base T 10 Mbps operated using base band transmission over twisted pair, Max length 100m
100 Base T 100 Mbps using Twisted pair wire
•**Base band network** transmits digital signals directly without modulation
-Capable of transmitting only a single stream of data
-Use entire bandwidth to carry a single signal

2. Co-axial Cable



•A solid center conductor is coaxially located with a cylindrical outer conductor

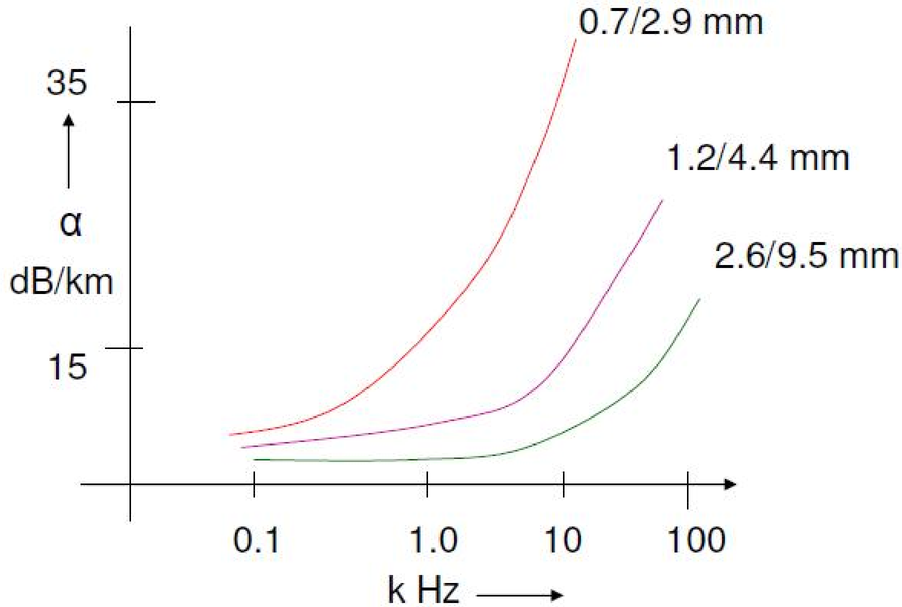
•Two conductors are separated by insulator

•Provides better immunity over interference & crosstalk

•Provides higher BW(>MHz)

•Ex Cable TV System uses a BW of 500 MHZ

Co-axial Cable-cont'd



Co-axial Cable-cont'd

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Unidirectional
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10 Base 2 - > Thin Co-axial Cable (5mm),10 Mbps, maximum length 200 meters

3. Optical Fiber

•Greater advantages over copper based digital transmission system
•Greater reduction in cost (usage of repeater is reduced)
•Reduces space requirement
•High transmission rate-single optical fiber carry higher rate than copper system
•Do not radiate significant energy, interference from external sources, crosstalk

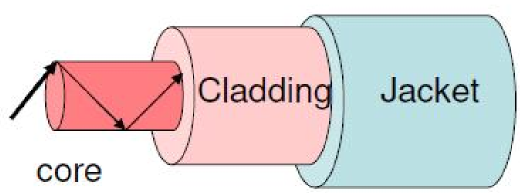


Fig. Geometry of OF cable

•Consist of very fine cylinder of glass-core

•Surrounded by a concentric layer of glass-cladding

•Information in the form of beam of light travels through the core

•Refractive index of core is higher than Cladding

•Refractive index of core/refractive index of cladding= critical angle θ_c

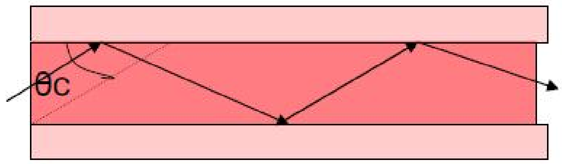
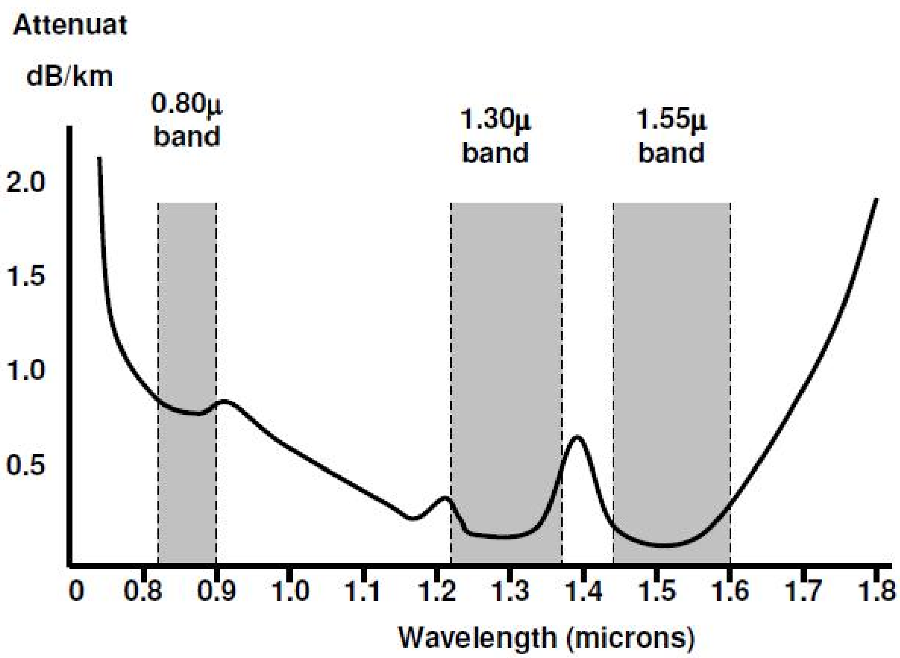


Fig. Reflection in optical fiber

- rays are guided within the fiber, as light from the core approaches cladding at an angle < θc
- Attenuation is low if impurities in glass is less
- Attenuation is 0.2dB/km
  - -Wave length 850nm,1300nm,1550nm
  - - earlier using *LEDs* operating at 850nm bit rate of several G bits achieved
  - -higher bit rates using laser source at 1300nm & 1550nm (BW of 10^{12} Hz is possible !!!!)



Types of optical fiber

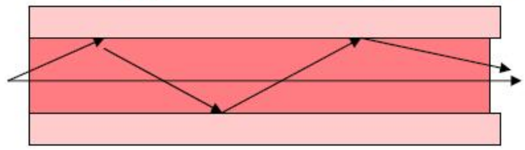


Fig. Multimode fiber

- Input ray of light reach the receiver over multiple paths
- Direct path & reflected paths
- Different in delay causes the rays to interfere each other
- Multiple paths limits the maximum bit rate

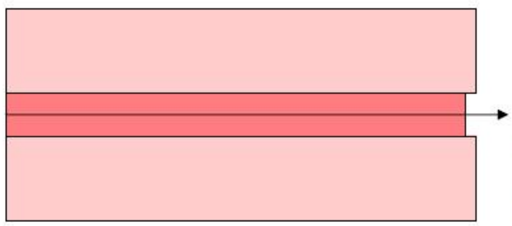
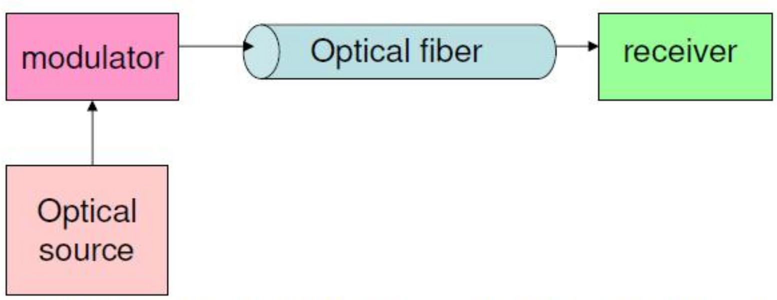


Fig. Single mode

- Core of the fiber is made narrower
- Restrict propagation as a single direct path
- Achieves higher G bps speed

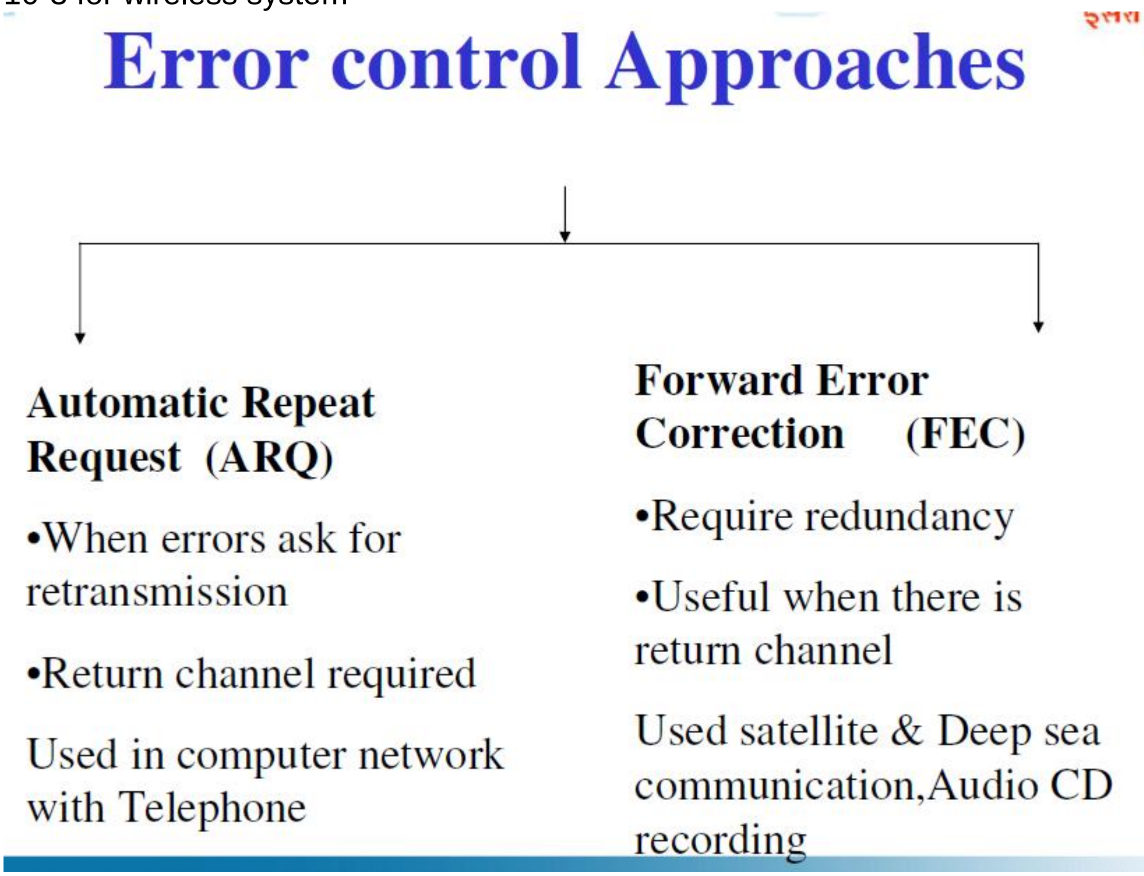
Optical Fiber transmission system



- Transmitter is light source modulated according to an electrical input
- Beam of light made to propagate through fiber
- Binary sequence is mapped into sequence of ON/OFF light pulses of some wavelength
- Optical detector converts received optical signal to electrical signal
- Original information is retrieved form electrical signal

Error Correcting Codes
• Parity check bit Scheme
• Forward Error Correcting Codes
• Block codes
• Convolutional codes
• Detail study of Block codes

Error Detection & correction
• Data corruption due to noise in the channel
• For reliable transmission error to be detected and corrected
• Uses encoding & Decoding
• Tolerable BER 10-6 for copper wire line
10-9 for optical fiber system
10-3 for wireless system



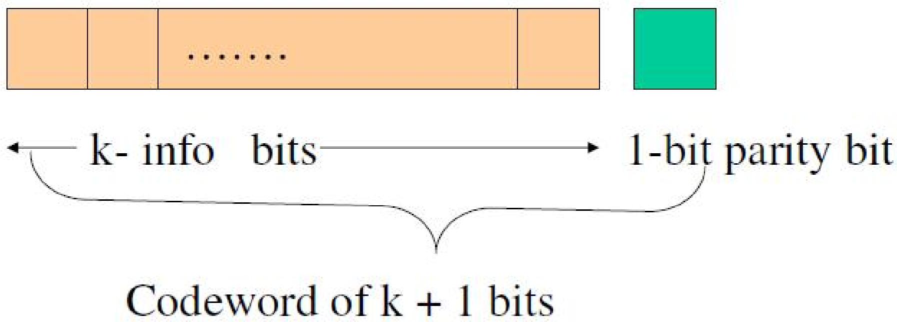
Error Detection method

- Parity Check codes
- Internet Checksum
- Polynomial codes
- Linear codes

Fig. General error-detection system

Parity Check codes

- normally used is even parity



0 0 0	0
0 0 1	1
0 1 0	1
0 1 1	0
1 0 1	0
1 1 0	0
1 1 1	0

ASCII uses 7 bit info & 1 bit parity

Parity Check code-cont'd

- It is a linear code
- Calculated as modulo-2 sum of info bits
- What is Modulo-2 = EX-OR

$0 + 0 = 0$

$0 + 1 = 1$

$1 + 0 = 1$

$1 + 1 = 0$

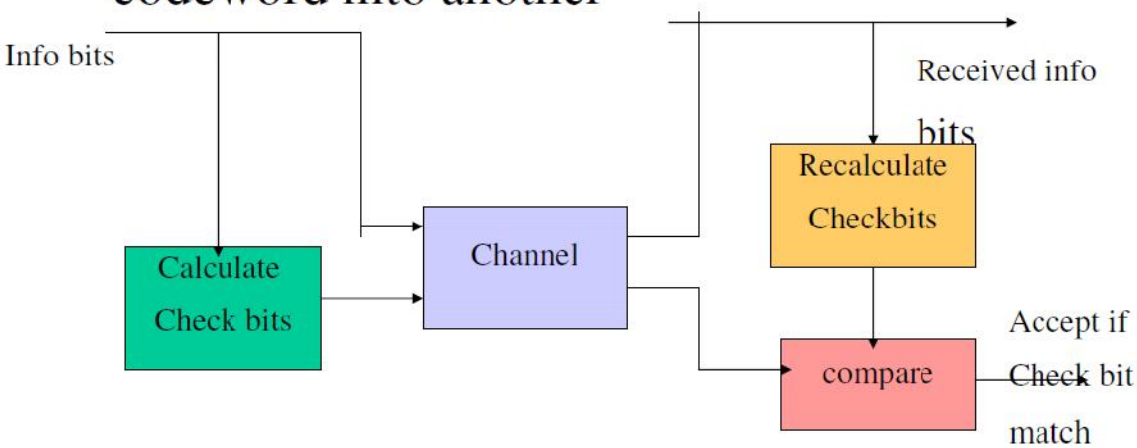
$$b_{k+1} = b_1 + b_2 + \cdots b_k \mod 2$$

- requires <u>redundancy- adding extra bit/bits</u>

•Detect half of all possible errors, burst errors(only if total number of errors in each data units is odd

Objective of error detection code

- Likelihood of channel converting one valid codeword into another



Parity Check code-cont'd

•Failure to detect errors- valid code word detected may be in errors

Random bit error model

- For random bit occurrence

p = probability of an error in a single bit

- if j error occurs with probability p , each of (n – j) correct transmission occurs with prob (1- p)
- Prob of an error vector that has j errors

$$= p^{j}\ (1-p)^{n-j} \quad = (1-p)^{n}\ (p/(1-p))^{j}$$

$$= \binom{n}{j} (1-p)^{n}\ (p/(1-p))^{j}$$

2D Parity checks

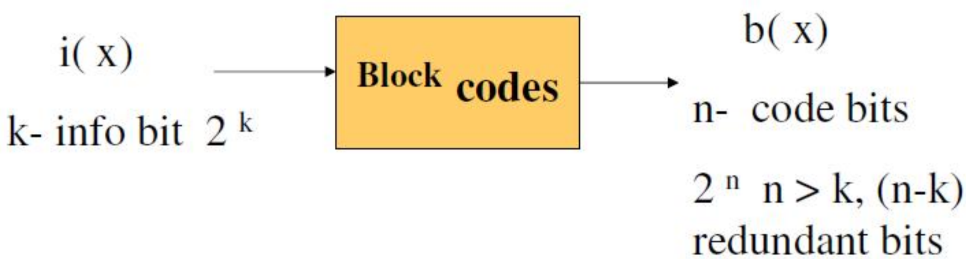
- Better approach
- Block of bits is arranged as a matrix
- Calculate parity bit for each rows & each column
- Create a new row & new column

1100111 1011101 0111001 0101001

1100111	**1**
1011101	**1**
0111001	**0**
0101001	**1**
0101010	**1**

Polynomial Codes

- Used in error detection & correction
- Easily implemented in hardware- shift registers
- block codes
- Under this- Cyclic Redundancy code
  - Linear codes



Cyclic Redundancy Codes(CRC)

- Cyclic shift of codeword produces another codeword
- Called (n, k) codes
- Info bits sequence is expressed as polynomials ex., [1 0 1 1] then

$i(x) = x^3 + x + 1$

In general $i(x) = i_{k-1} x^{k-1} + i_{k-2} x^{k-2} + \dots i_1 x + i_0$

- uses mod-2 operation

CRC – Cont'd

- CRC Method

‘ Shifting the info bits left & dividing by predetermined binary number using mod-2 arithmetic’

- Division results in a binary remainder

$\Rightarrow$ CRC code

- CRC code is appended to info bits $\Rightarrow$ encoded info bits
- Predetermined binary number $\Rightarrow$ Generator polynomial

$g(x) = x^{n-k} + g_{n-k-1} x^{n-k-1} + \dots g_1 x + 1$

Computing the CRC code

- Multiply info polynomial by x^{n-k}
  this is equivalent to shifting the message bits by x^{n-k} bits
- Divide x^{n-k} i(x) by g(x) to obtain the remainder r(x)
- x^{n-k} i(x) / g(x) = q(x) + r(x)
- r(x) gives the CRC
- Encoded word b(x) = x^{n-k} i(x) + r(x) (use mod-2 operation)

- Single error in i^{th} bit in R would lead to a syndrome vector that is identical to i^{th} row of H^T and correcting i^{th} receiving bit yield correct received codeword
- How many error possible to detect & correct in linear code ?
- Define distance between codewords

$C_1 = 0\ 0\ 1\ 1\ 1\ 0$

$C_2 = 0\ \underline{1}\ 1\ \underline{0}\ 1\ \underline{1}$ d= 3

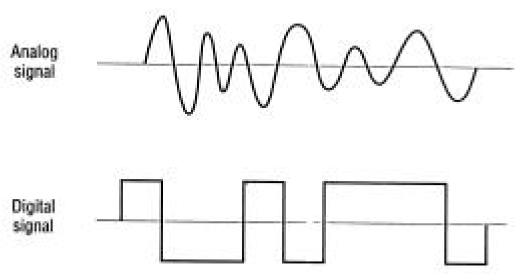
- minimum distance of the (n, k) code= d_{min}
- Linear code can correct upto t= [(d_{min} -1)/2]
- Can detect up to (d_{min} -1) errors

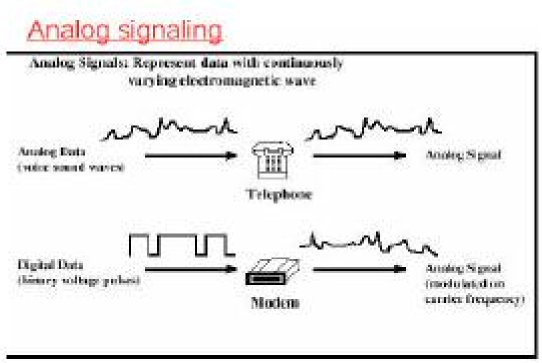
Digital Transmission Fundamentals
Contents
• Digital representation of information
Properties of Media
• Need for digital communication
• Characterization of communication channels
• Line coding

Digital Transmission Fundamentals
Contents cont'd
Modems and digital modulation
• Error Detection & Correction

Digital Representation of Information
• Transport of Information over Network
• Types of Information-
-text
-speech
-audio
-data
-images,
-video

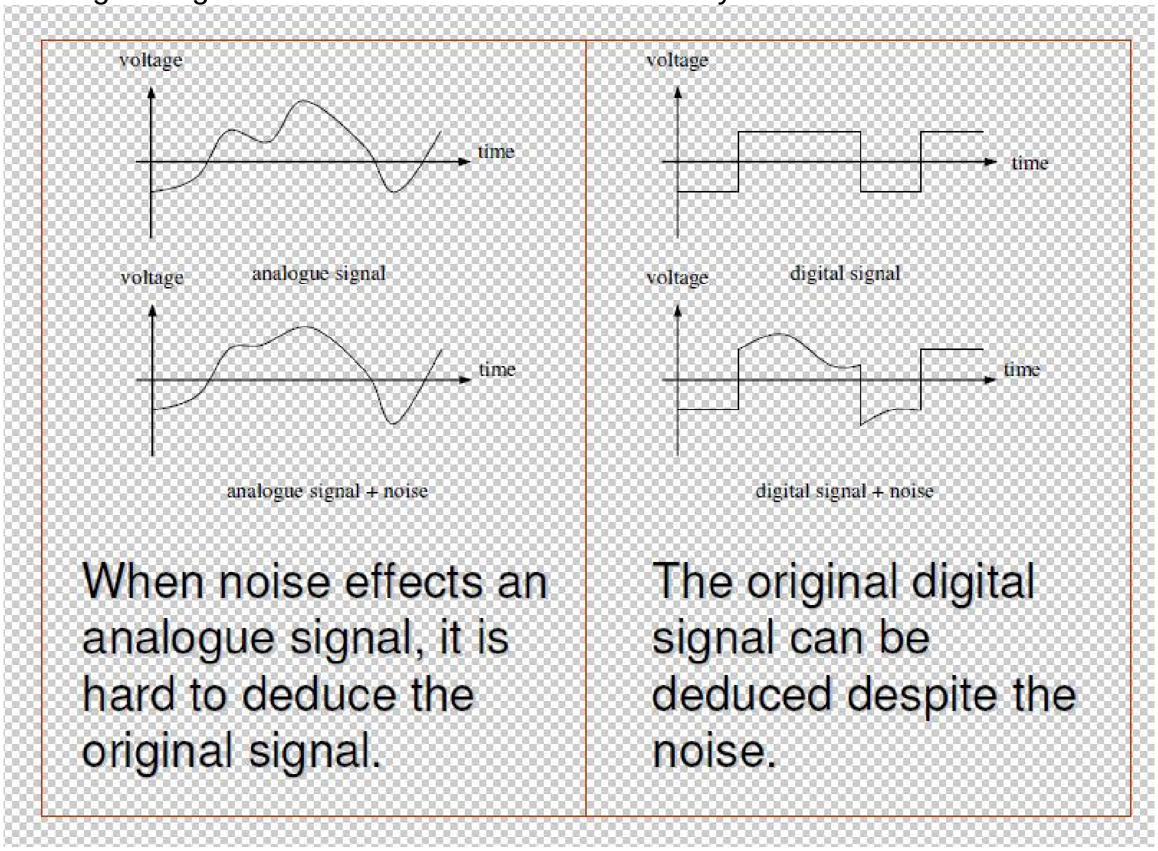
Basic Terminology
• Signal-
-Analog signal-continuous in
time & Value
e.g. audio (human speech)
or video.
-Digital Signal-discrete in
time & value





Analog versus Digital

In digital communication, it is often possible to reconstruct the original signal even after it has been effected by noise

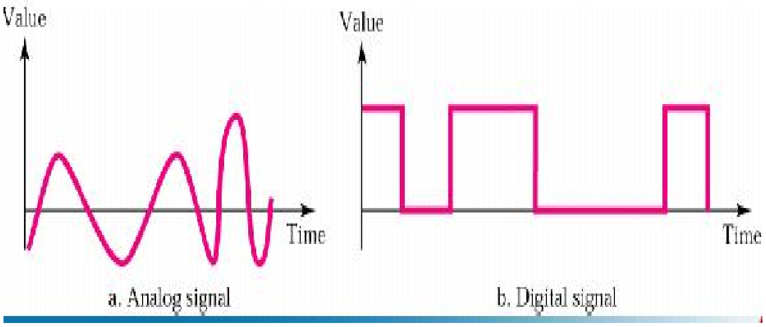


Analog transmission

- analog waveform transmission
- Time & amplitude to be exactly reproduced
- Cost of transmission line is high as distance increases
-eg-pair of copper wire
- Attenuation/distortion is more
- Requires repearters

Digital transmission

- Symbols are transmitted
- Receiver to find symbols with probability
- Cost of transmission line is less-
-eg pair of copper wires
- Attenuation/distortion tolerable
- Requires digital repeaters



Digital Representation of Information cont'd

•Digital transmission system

•Physical layer

_Lowest Layer of OSI Model

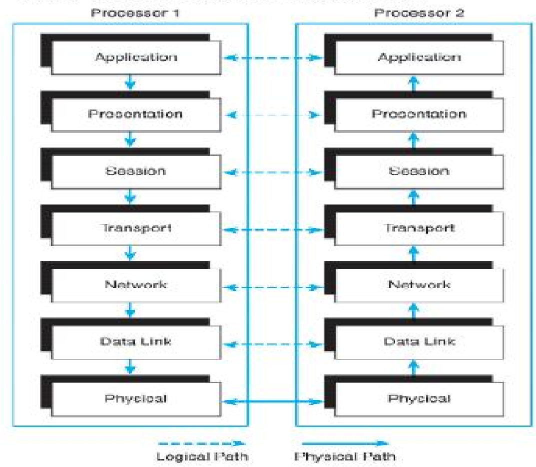
_Physical Layer on the Local Node Process Raw Data Stream

_Translate Frames received from Data Link Layer into Electrical, Optical or EM Waves representing 0 or 1

_Local Physical Layer Transmits Bits sequence through network medium

_provides pipes to carry information flow across network

Figure 1-8 OSI Peer Layer Communication

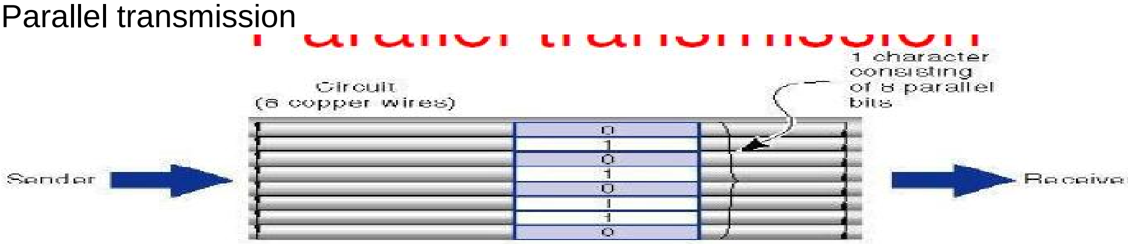


Terminologies
•Serial Transmission
•Parallel transmission
•Simplex modes of transmission
•Duplex modes of operations
•Half duplex modes of operations
Terminology cont'd
•Synchronous Transmission
•Asynchronous Transmission
•Spectrum of signal

Serial Transmission

•Data Transmission Method
•Bit Representing a *Character* of Data Transmitted in sequence
•One Bit at a time over a single communication channel
•Speed is limited to speed of the line
•One channel transmits one bit at a time
•Its simple
•Difficult to identify beginning and end of character
•Examples
•Terminal to System communication
•Phone line to data transfer
•High speed fiber optic lines

Parallel transmission



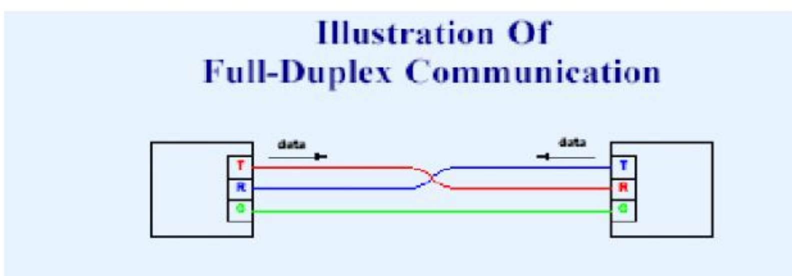
•Simultaneous Transmission
•Each bit on separate channel
•All the bit representing a character
•Transmits group of bits at one time
•No. of bits varies from device to device
•Transmission is quick
•Requires complex communication link (Multi wire copper cable)
•Longer Cable more degradation
•Limited in length (few meters)
•Examples

•Connecting peripheral devices

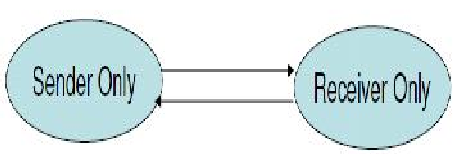
Simplex modes of transmission

• Simple method of communication
•Data flows in only one direction
•One device is sender and other receiver
•Roles may be reversed
•Example
TV Transmission (Broadcast)

Full duplex modes of transmission
• Desirable in practice
• Requires each side to have their own transmitter and Receiver
• Transmitter on side is connected to receiver on other
• Separate wires needed to carry current in each direction
• Common ground wire
• Link allows simultaneous sending and receiving data on both direction
• DB-9,DB-15 or DB-25 connector

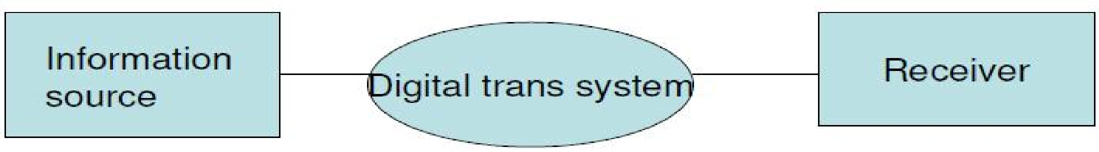


Half duplex modes of transmission
Half duplex modes of transmission



•Data may flow either direction
•But only one device can send at any time
•Example
Walkie Talkie
Information categories
• Block Information-data files-pictures
containing text, numerals, graphics
• Stream Information-voice-music-videosteady
information stream produced
Information categories
• Block Information-
• data files-pictures containing text,
numerals, graphics
• Stream Information-
• voice-music-video-steady information
stream produced

Basic Transmission System



Certain Definitions
• Baud rate
• Bit rate
• Bandwidth
• Delay
• jitter

Baud Rate
•Baud is a unit of signaling speed or transmission
speed
•It is a number discrete changes in a single period of
a signal
Example:
Communication channel transmitted at 300 Baud
-Means signaling rate of the channel is changing 300

Jean Maurice Emile
Baudot (1845-1903)

times per second
•Thus not correspond to number of bits transmitted
per second
•Baud rate is different from data rate – no confusion !

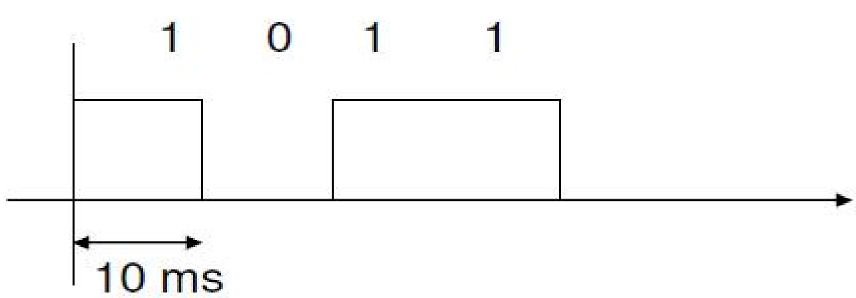
Bit Rate

• Bit Interval-Time required to send one single bit
• Bit rate is the number of bit intervals / second
• It is number of bits sent in one second (bps)

Example 1: Bit rate 2000bps
Duration of each bit = 1/bit rate= 1/2000= 500µs

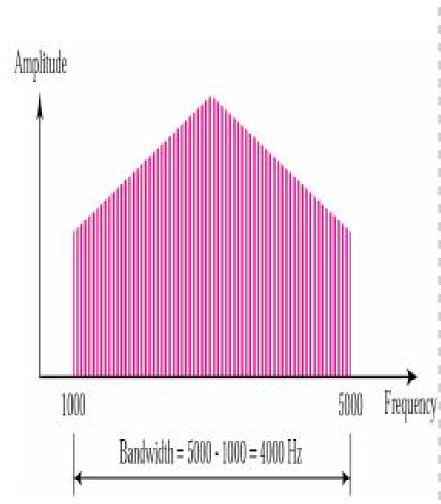
Bit rate is the number of bits per second. Baud rate is the number of signal units per second. Baud rate is less than or equal to the bit rate.

Bit rate = 1/10ms=0.1 kbps



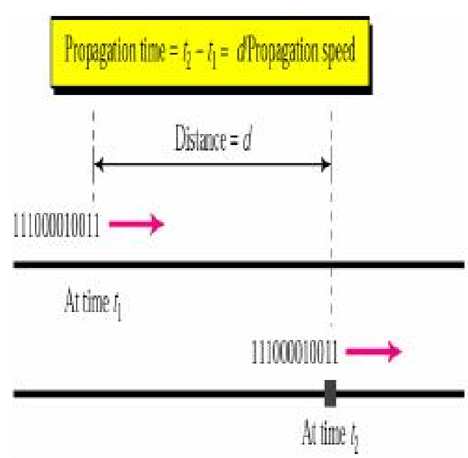
Bit rate and Baud Rate Calculations
An analog signal carries 4 bits in each signal unit. If 1000 signal units are sent per second, find the baud rate and the bit rate
Baud rate = 1000 bauds per second (baud/Baud rate = 1000 bauds per second (baud/s)
Bit rate = 1000 x 4 = 4000 bps

Bandwidth
In Analog Communication
•Total capacity of communication Channel
•Range frequencies medium pass without loosing one half of the power contained in signal
•Difference between highest and lowest frequencies that medium can satisfactorily pass
•Greater bandwidth most signal can carried over given frequency range
Example:
Voice grate lines frequencies 300 Hz to 3300 Hz
BW = 3300-300=3000 Hz
But ITU regulation voice bandwidth 4kHz

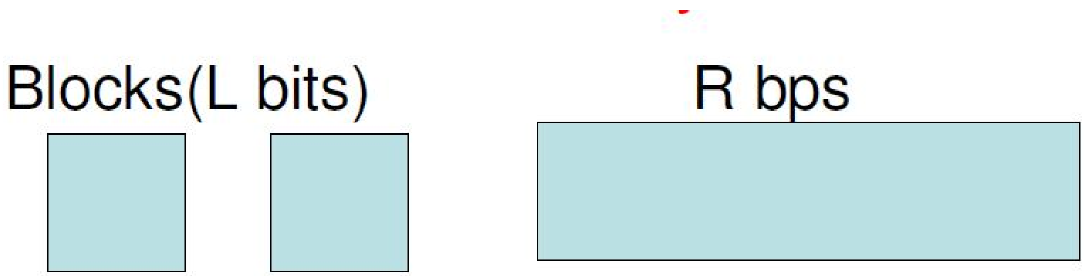


Bandwidth- cont's
In Digital Communication
•Bandwidth refers to data rate
•Amount of data that can be transferred over communication media in a given period
•Measures in bps
Example:
LAN <100 Mbps
Dialup communication Model 300bps to 33.6Kbps or 56Kbps
WAN 1.5 Mbps to 45 Mbps
Music signals vary rapidly
Audio Compact Disk (CD) system BW 22 KHz

Delay
Delay = tprop + L/R
tprop= d/c
d=distance c=velocity of light
•Time to translate a file can be reduced by inreasing transmission bit rate
•Delay and bit rate trade off
Example :



Communication between peoples maximum delay 250msec



Why Digital Communication ?
• What is Transmission system?
• What is Transmission ?
• Transmission media
- Copper wire pairs
- Coaxial cable
- Optical fibers
- Infrared
- radio

Why Digital ?
•Ease with which digital signals are generated compared to analog.
•Digital signals are subject to less distortion and interference than are analog signals.
•Easier to detect and correct errors in digital data
•Digital circuits are :
more reliable
more flexible
cheaper

Digital Transmission Objective
• To transmit a given symbol selected from a finite set of possibilites
- Eg., Binary digital Tx- 0 & 1 transmission

Communication transmission system

Basic Properties of Digital Systems
• How binary information transmitted
• Factors affecting transmission
• Maximum rate of transmission
• Signal-to-Noise Ration (SNR)

Characterization of Communication Channels
• Frequency Domain characterization
• Time Domain characterization
• Limitation of Digital transmission