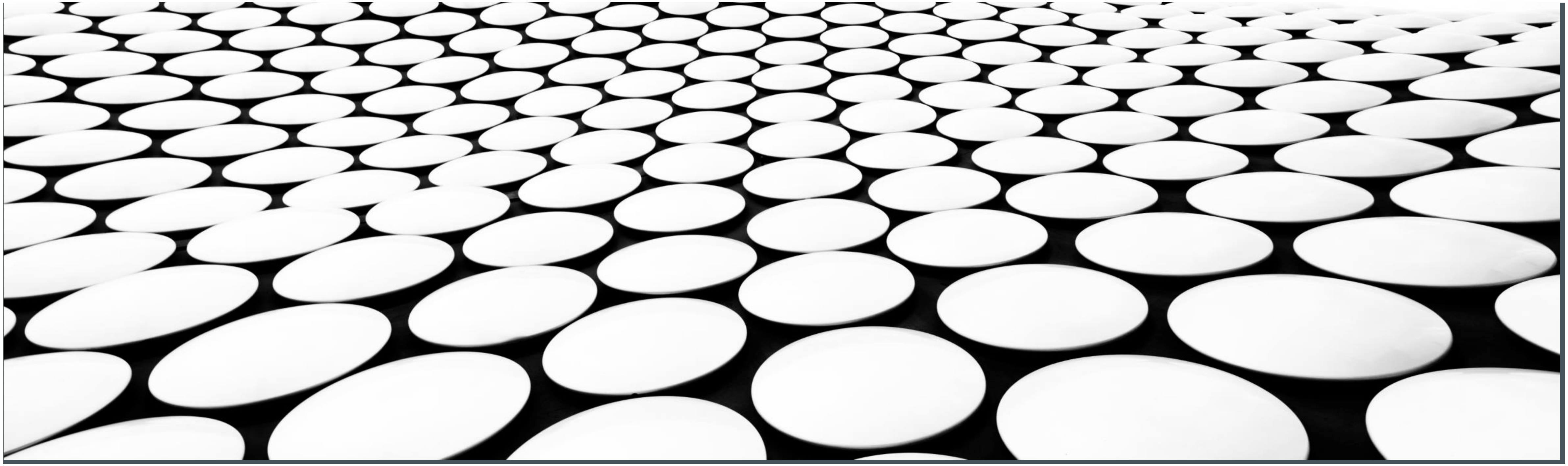
COMPUTER NETWORKS

PHYSICAL LAYER (CH.24-25)

HEMANT GHAYVAT, (hemant.ghayvat@lnu.se)



LAN TOPOLOGIES

Bus

Ring

Star

PHYSICAL LAYER SERVICES

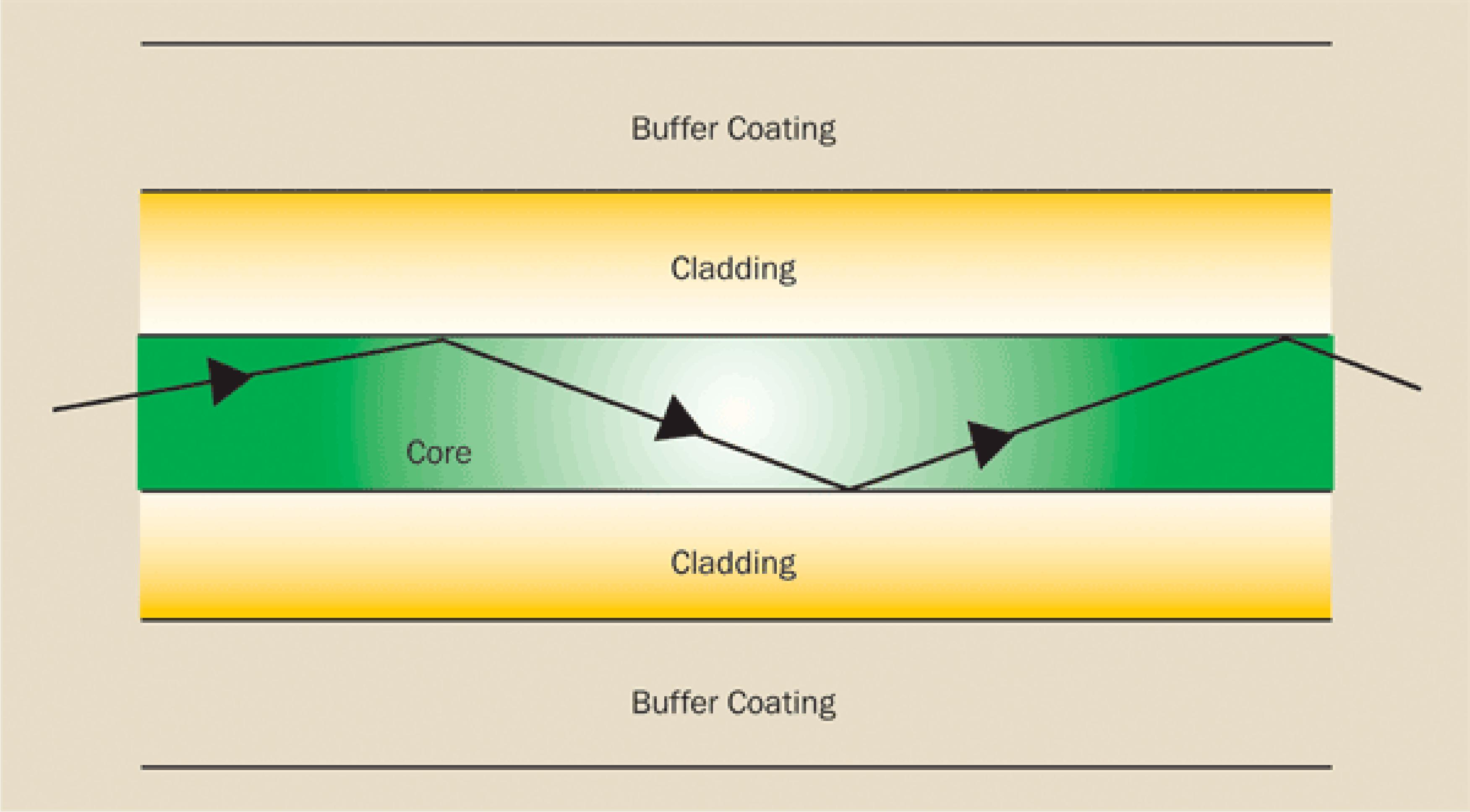
GUIDED TRANSMISSION MEDIA

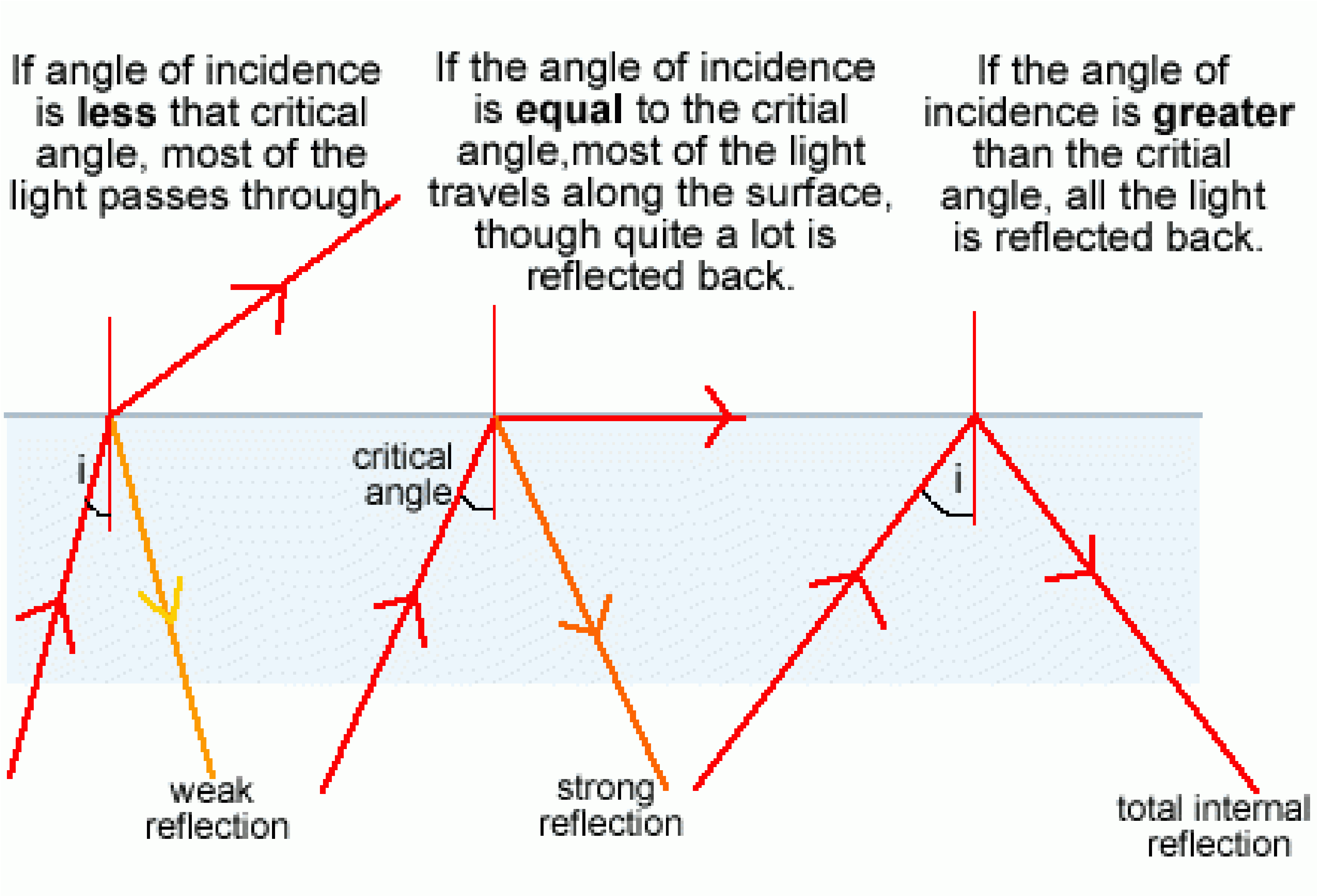
- » Waves are guided along solid medium:

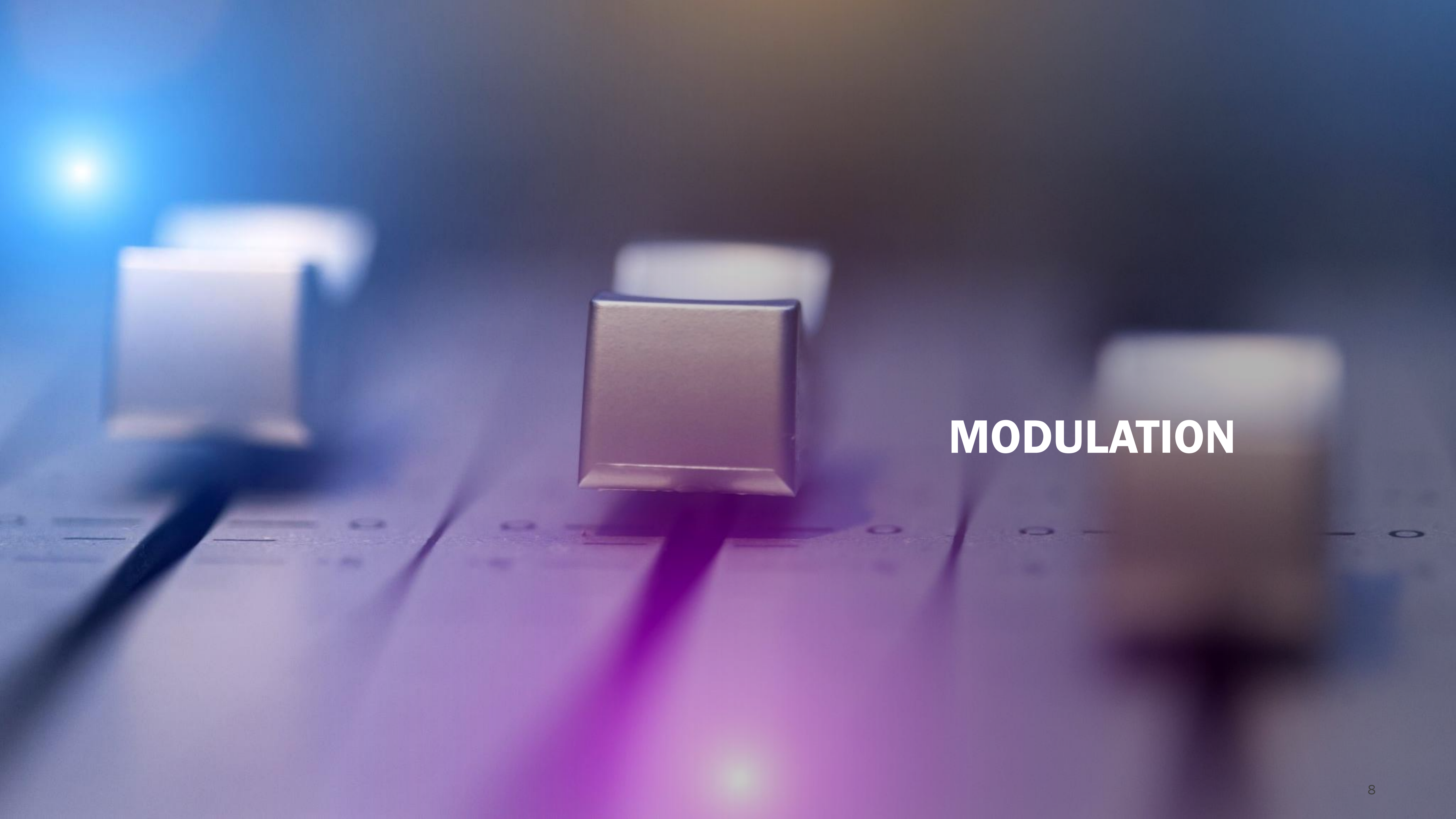
- » Twisted pair
- » Coaxial cable
- » Optical fiber

OPTICAL FIBER

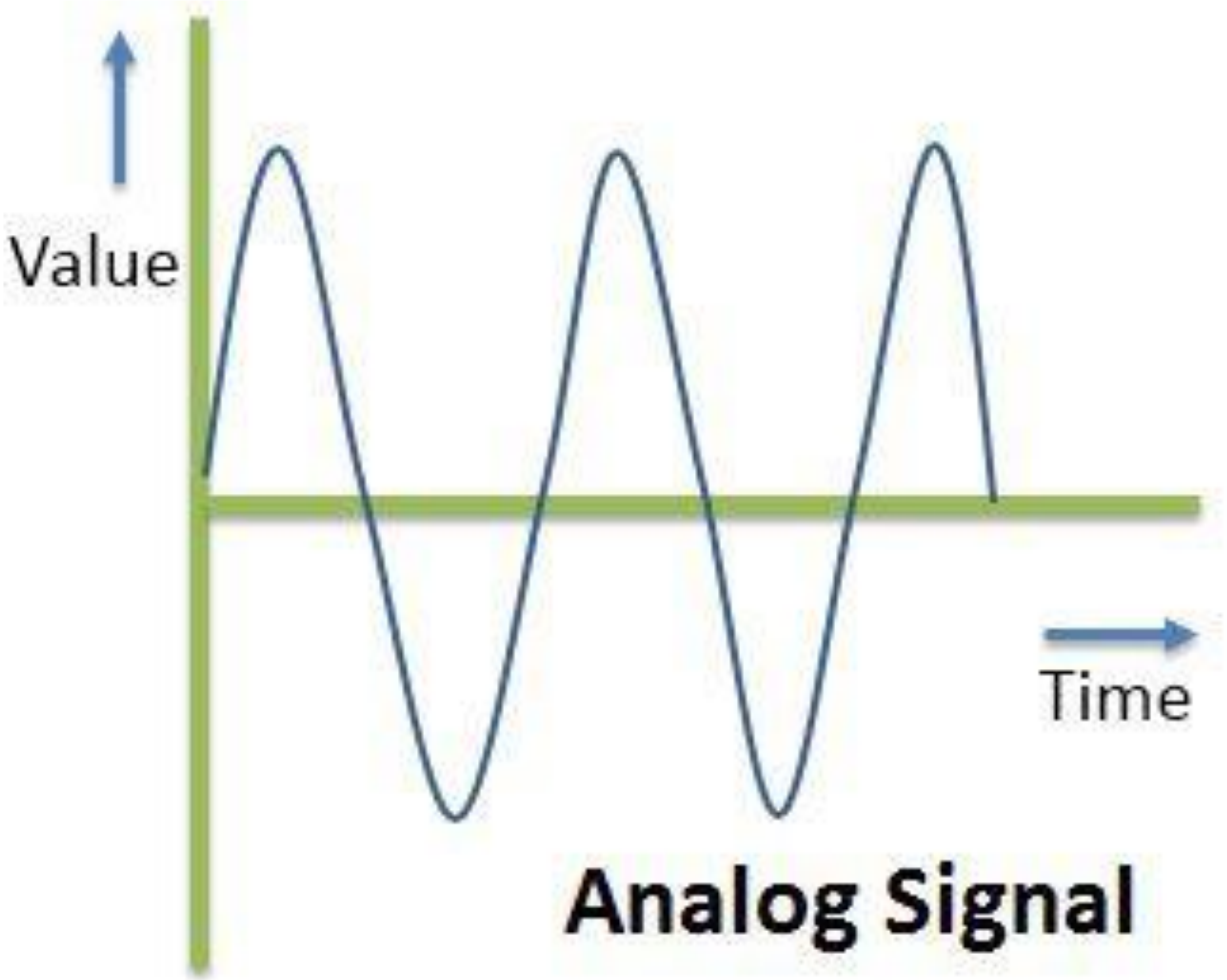
- » Three components: light source, transmission system, and a detector:
  - » Optical rays travel in glass or plastic core.
  - » The detector generates an electric pulse when hit by light.
- » Used in long distance communication.
- » Not affected by external electromagnetic fields, and do not radiate energy.


Buffer Coating
Cladding
Core
Cladding
Buffer Coating

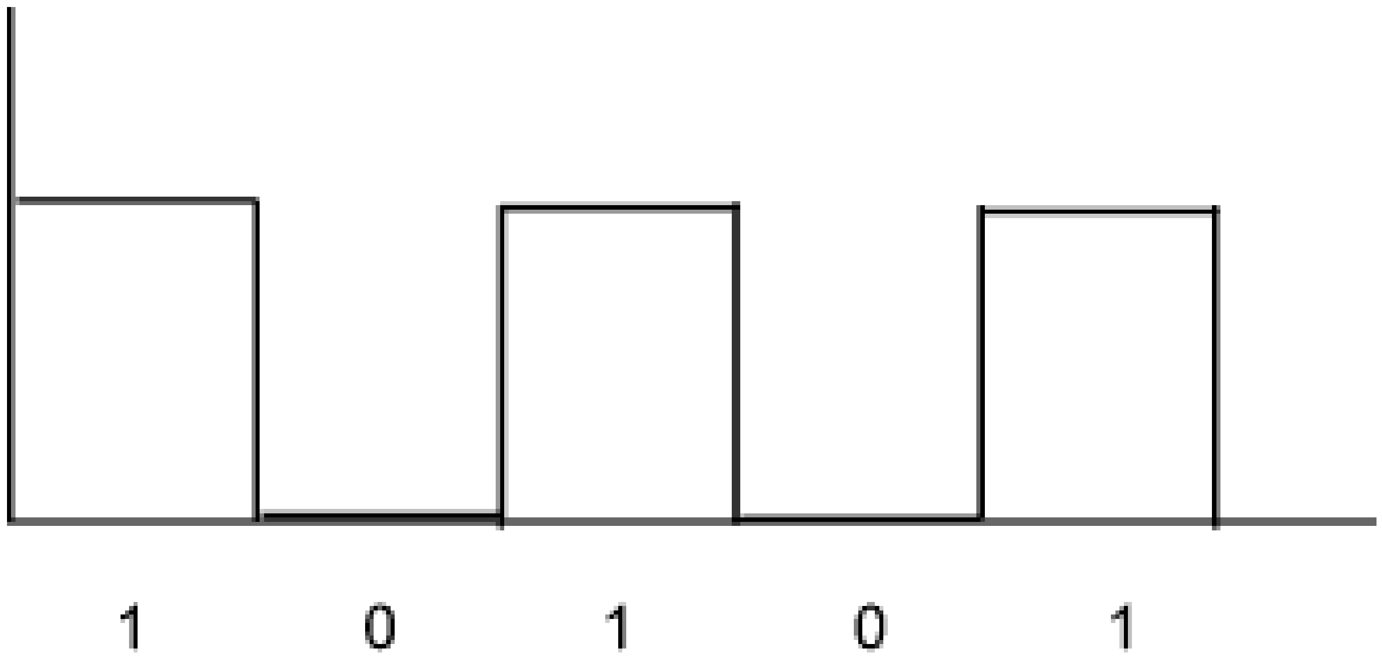

If angle of incidence is **less** that critical angle, most of the light passes through.
If the angle of incidence is **equal** to the critial angle,most of the light travels along the surface, though quite a lot is reflected back.
If the angle of incidence is **greater** than the critial angle, all the light is reflected back.
i
weak reflection
critical angle
strong reflection
i
total internal reflection



MODULATION



MEDIA CARRIES ANALOG SIGNALS

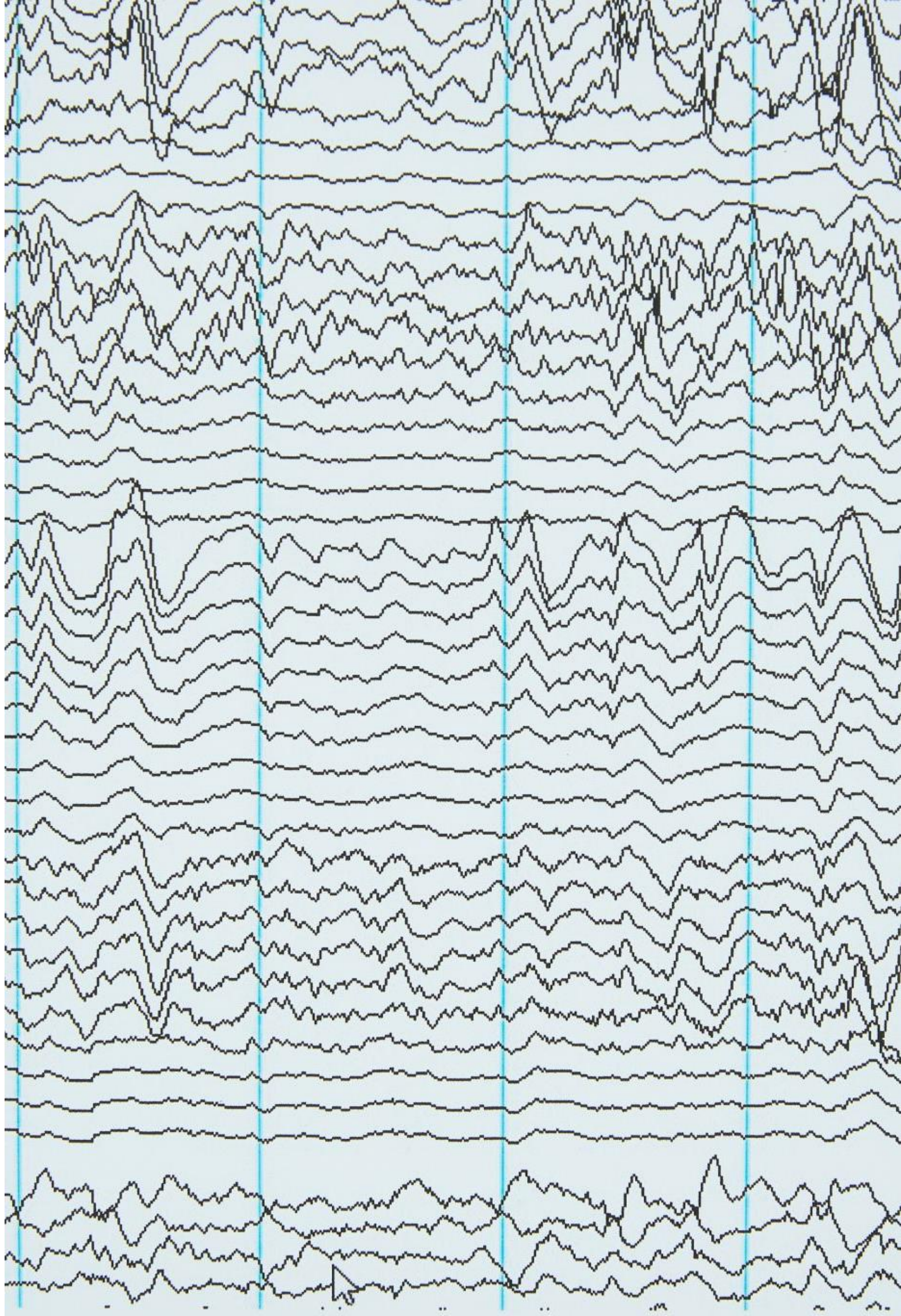


WE WANT (MACHINE) THIS SIGNAL

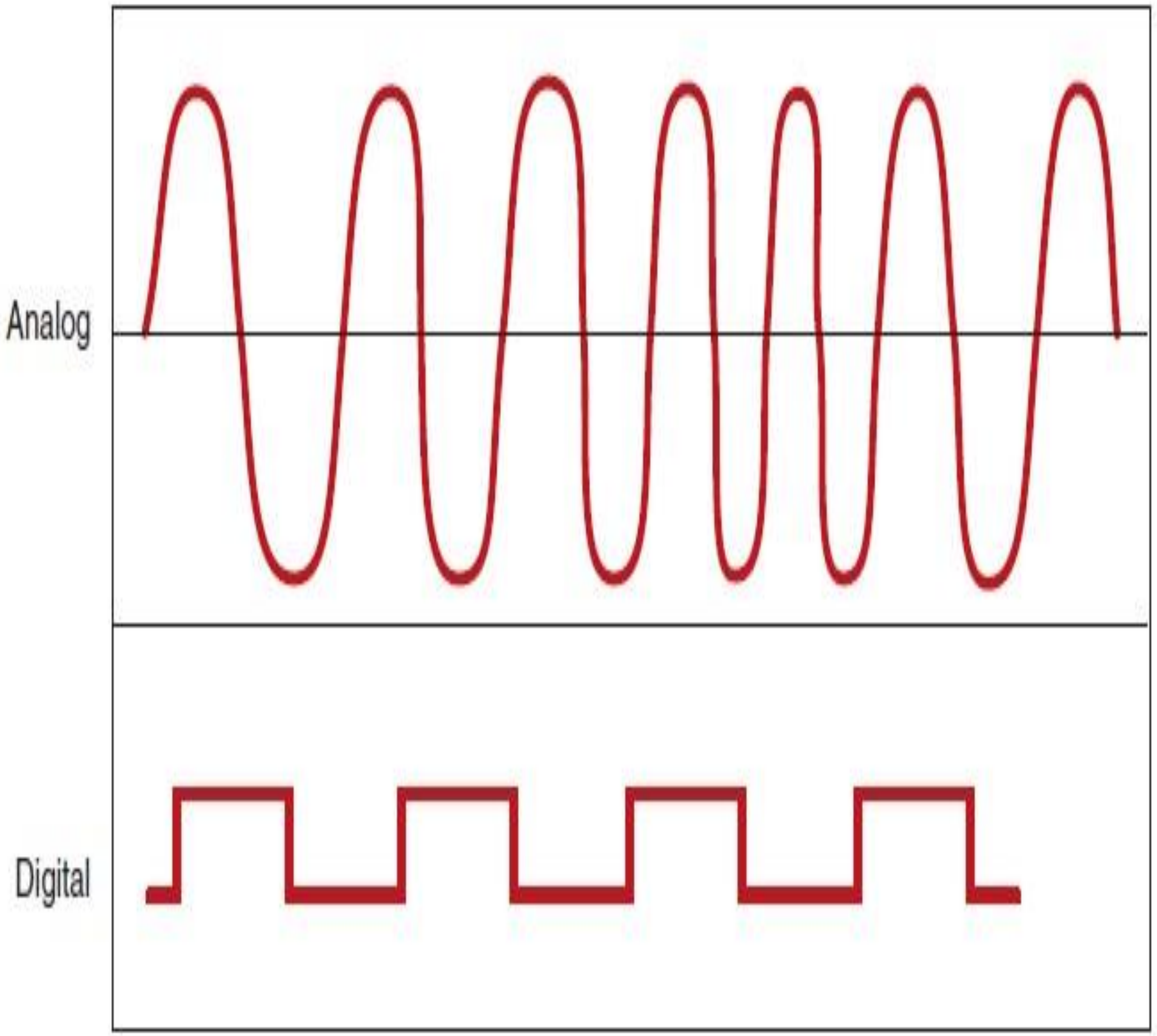
SO HOW TO DELIVER THE BITS OVER THE ANALOG SIGNAL ?

SIGNALS

- » To be transmitted, data must be transformed to electromagnetic signals.
- » Signals can be analog or digital. Analog signals can have an infinite number of values in a range; digital signals can have only a limited number of values.
- » In data communication, we commonly use periodic analog signals and aperiodic digital signals.



- A continuous signal is one in which the signal intensity varies in a smooth fashion over time.
- A discrete signal is one in which the signal intensity maintains a constant level for some period of time and then changes to another constant



PERIODIC SIGNALS

A signal is defined to be periodic if and only if:

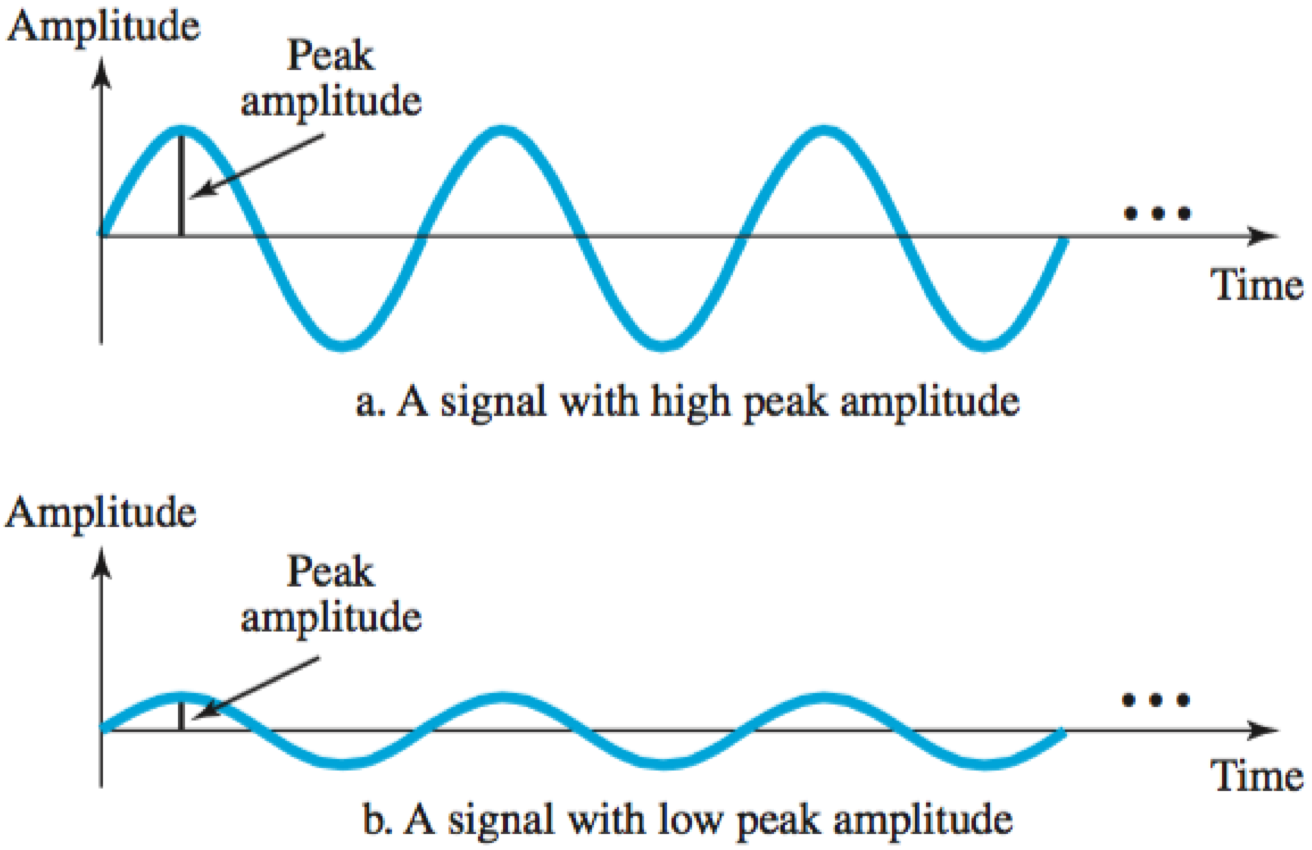
$x(t) = x(t+T)$ true for all positive and negative values of T.

T is the period

SINE WAVE

- The sine wave is the fundamental continuous signal. A general sine wave can be represented by three parameters:
- » **amplitude, frequency ,phase**
- The amplitude is the peak value or strength of the signal over time; typically, this value is measured in volts or watts.

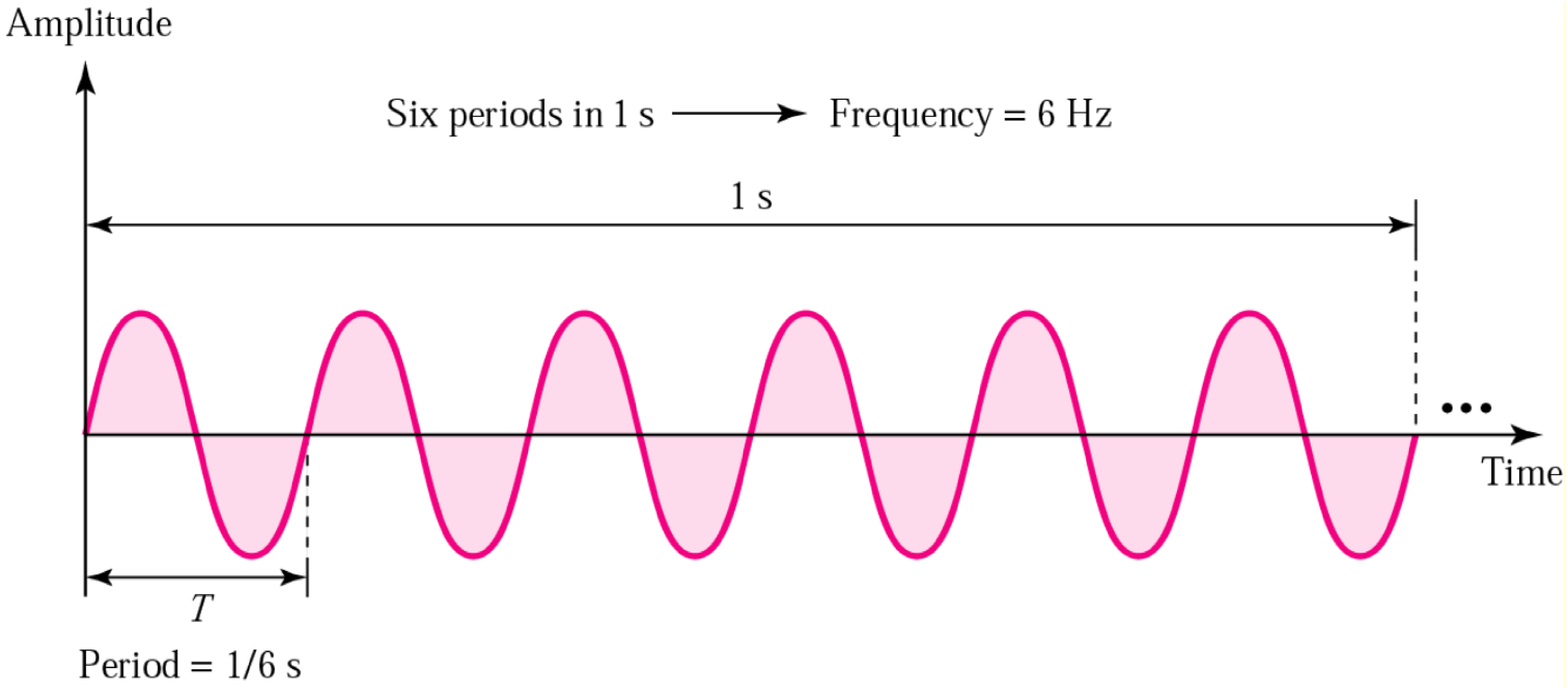
AMPLITUDE


Amplitude
Peak
amplitude
• • •
Time
a. A signal with high peak amplitude
Amplitude
Peak
amplitude
• • •
Time
b. A signal with low peak amplitude

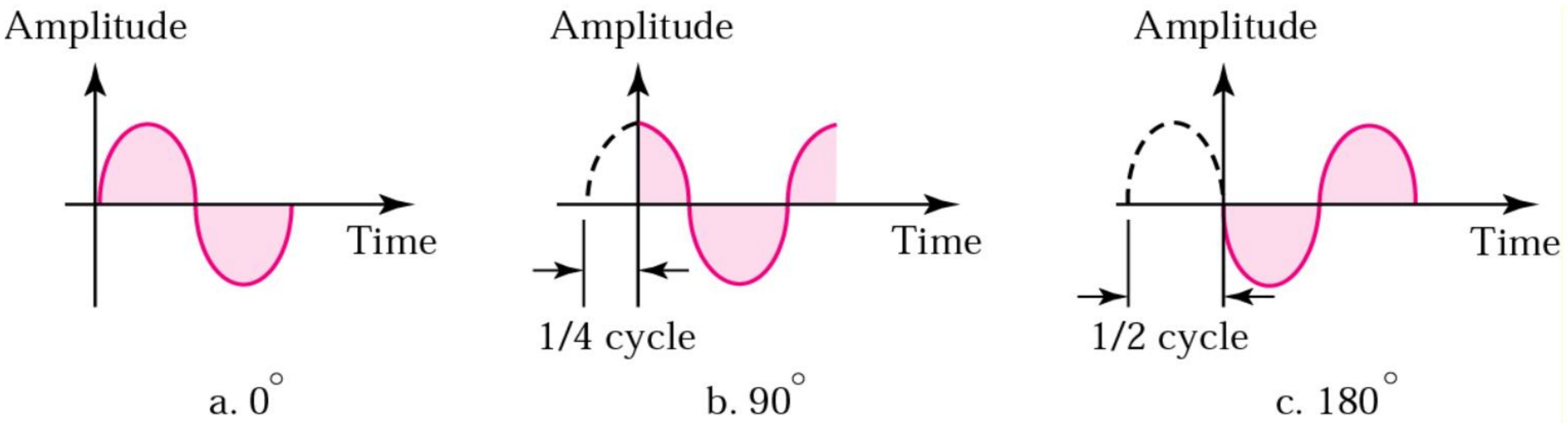
SINE WAVE

- The frequency is the rate (in cycles per second, or Hertz (Hz)) at which the signal repeats. An equivalent parameter is the period (T) of a signal, which is the amount of time it takes for one repetition; therefore,
- Frequency = 1/period = number of cycles/time
- $f = 1/T = N/t$
  T = period, the time which is required for one cycle
  N = a particular number of cycles
  t = a particular amount of time
- If a signal does not change at all, its frequency is zero. If a signal changes instantaneously, its frequency is infinite.

PERIODS AND FREQUENCY

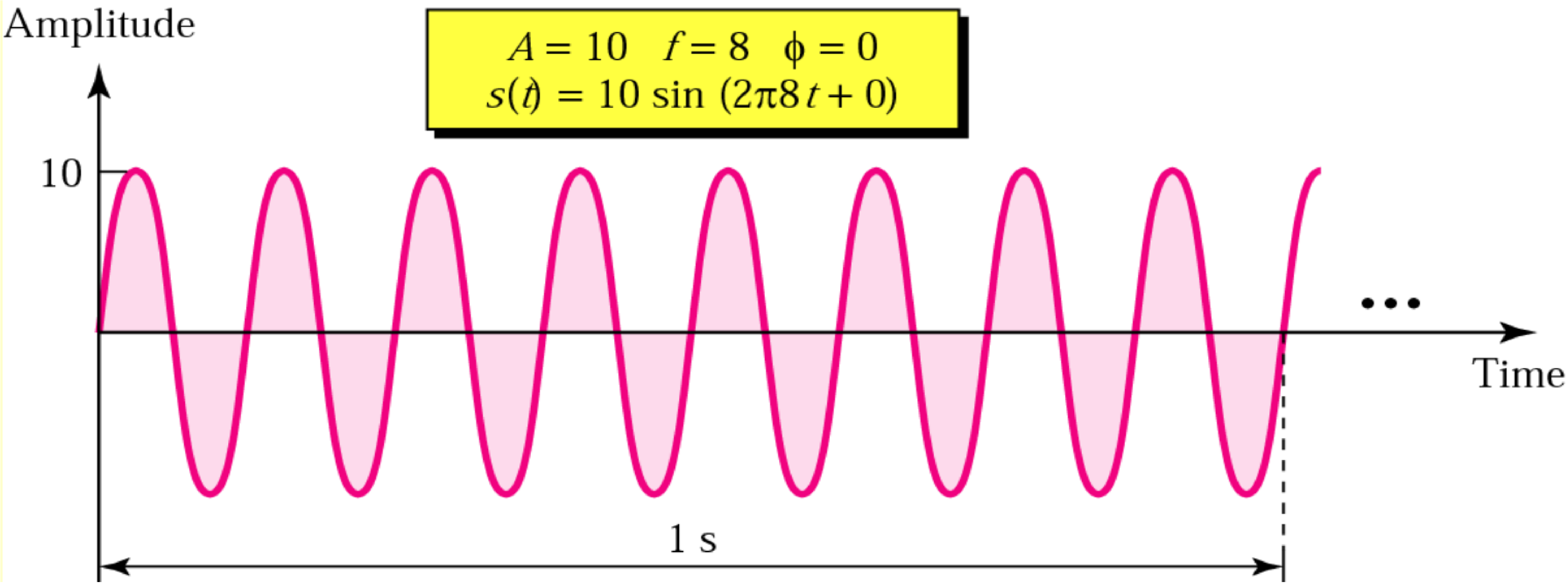


PHASE

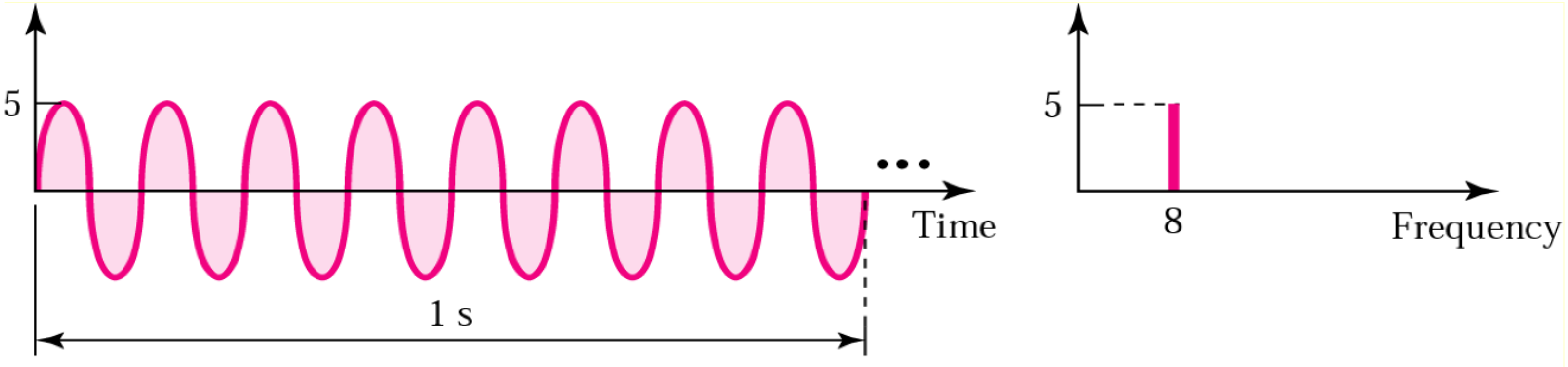


Phase describes the position of the waveform relative to time zero.

AMPLITUDE PHASE FREQ



TIME AND FREQUENCY DOMAINS



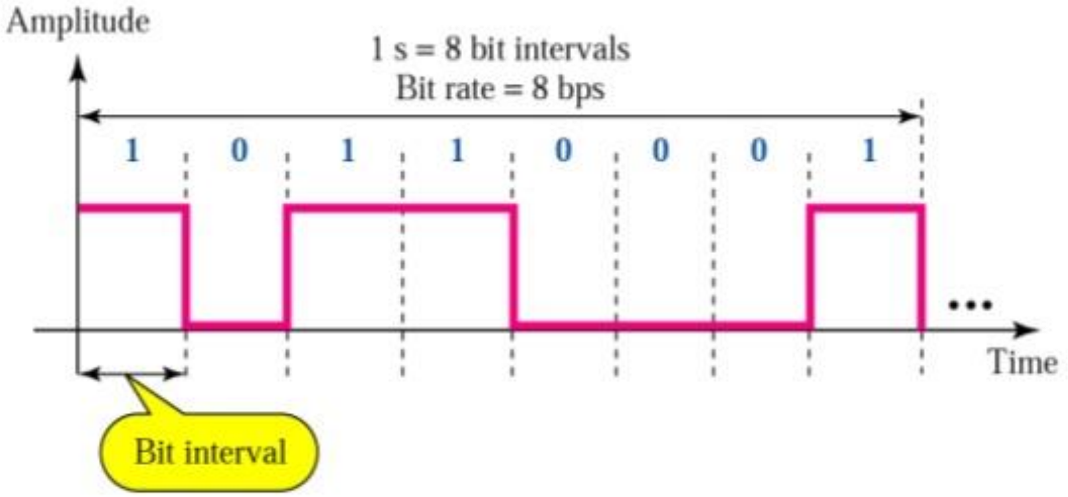
An analog signal is best represented in the frequency domain.
a time-**domain** graph shows how a signal changes over time, whereas a **frequency-domain** graph shows how much of the signal lies within each given **frequency** band over a range of **frequencies**.

BASEBAND AND PASSBAND

- **Difference between Meaning** Baseband signal, as the name suggests, refers to the original transmission signal generated from the message source with no modulation of high frequency carrier whatsoever.

- Passband signal, on the other hand, is yet another form of digital transmission that uses modulation meaning the frequency or phase of the carrier signal is modulated to transmit the bits. It is based on the concept of digital data transmission post modulation of high frequency sinusoidal carrier.

Bit rate and bit interval



BIT RATE AND BAUD RATE

- Bit rate, N, is the number of bits per second (bps).
- Baud rate (S) is the number of signal elements (smallest possible unit of the signal) per second (bauds).
- In the analog transmission of digital data, the signal or baud rate is less than or equal to the bit rate.
- $S=N \times 1/r$ bauds
- Where r is the number of data bits per signal element.

MODULATION

- Modulation - process (or result of the process) of translation the baseband message signal to bandpass (modulated carrier) signal at frequencies that are very high compared to the baseband frequencies.
- Demodulation is the process of extracting the baseband message back the modulated carrier.
- An information-bearing signal (carrier) is non-deterministic, i.e. it changes in an unpredictable manner.


1
2
3
4
5
6

WHY MODULATION

- The baseband signals are incompatible for direct transmission. For such a signal, to travel longer distances, its strength has to be increased by modulating with a high frequency carrier wave, which doesn’t affect the parameters of the modulating signal.

DIGITAL TO ANALOG CONVERSION

- Digital data needs to be carried on an analog signal.
- A carrier signal (frequency f_c) performs the function of transporting the digital data in an analog waveform.
- The analog carrier signal is manipulated to uniquely identify the digital data being carried.

ANALOG MODULATION

- Amplitude Modulation
  - AM radio
- Frequency Modulation
  - FM radio, TV audio signal
- Phase Modulation
  - TV color image signal (including Amplitude Modulation)


WOULD YOU LIKE
"AM" OR "FM"?

AM RADIO OR FM RADIO ?

- **FM** uses a higher frequency range and a bigger bandwidth **than AM**. ... Each **FM station** is allocated 150 kHz of bandwidth, which is aprox15 times that of an **AM station**. This means that an **FM station** can transmit 15 times as much information as an **AM station** and explains why music sounds so much **better** on **FM**.

MODULATION PROCESS

$$f = f(a_1, a_2, a_3, ... a_n, t) \dots\dots\dots\dots\dots\dots\dots\dots \text{carrier}$$
$$a_1, a_2, a_3, ... a_n \ \dots\dots\dots\dots. \ \text{modulation parameters}$$
$$t \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. \text{time}$$

- Modulation implies varying one or more characteristics (modulation parameters a_1, a_2, … a_n) of a carrier *f* in accordance with the information-bearing (modulating) baseband signal.
- Sinusoidal waves, pulse train, square wave, etc. can be used as carriers

CONTINUOUS CARRIER

Carrier: $A \sin[\omega t + \varphi]$

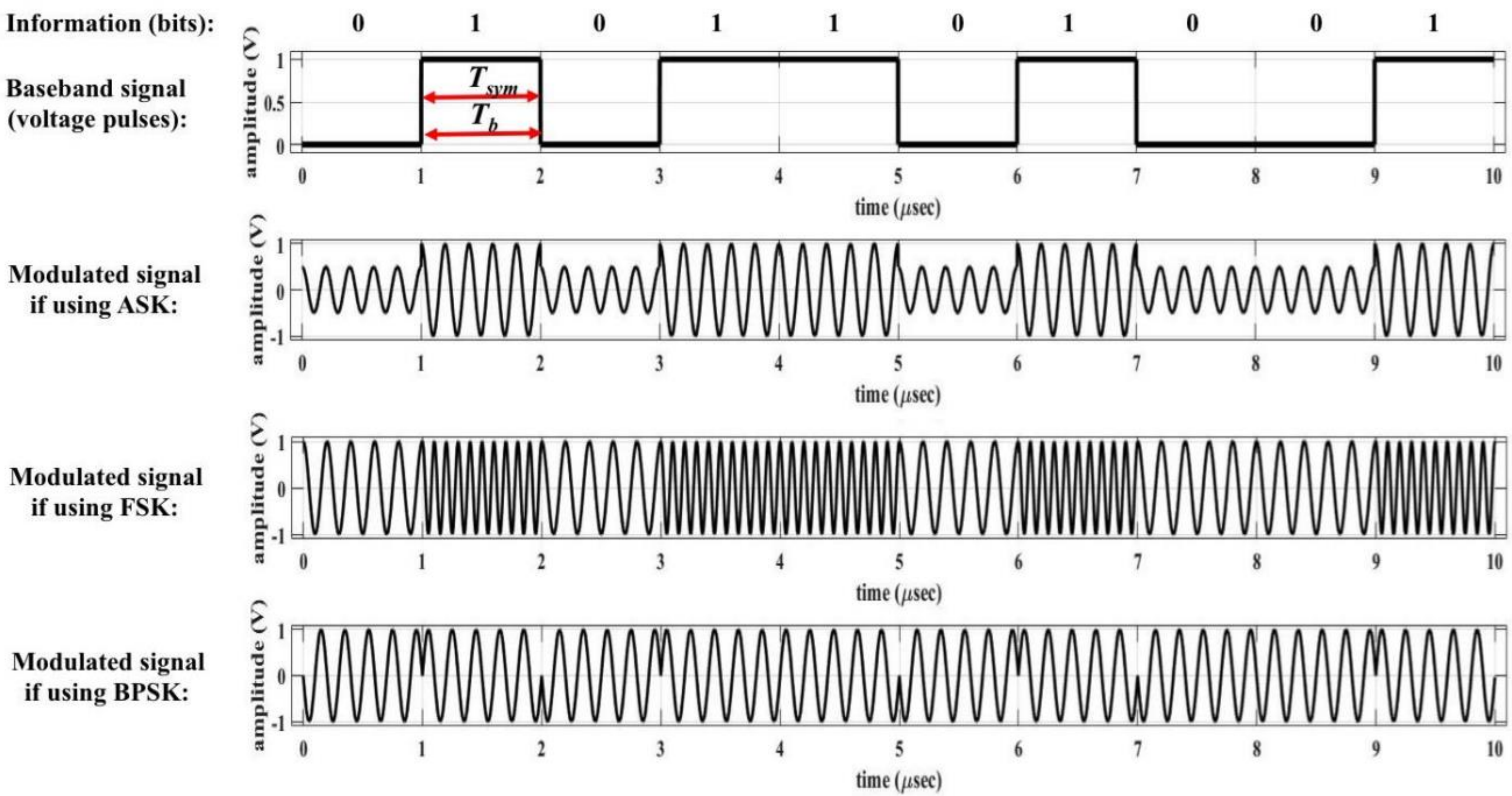
- A = const
- ω = const
- φ = const

- Amplitude modulation (AM)
  - A = A(t) – carries information
  - ω = const
  - φ = const

- Frequency modulation (FM)
  - A = const
  - $\omega = \omega(t)$– carries information
  - φ = const
- Phase modulation (PM)
  - A = const
  - ω = const
  - $\varphi = \varphi(t)$ – carries information

SHIFT KEYING

- **Binary digital modulation** refers to types of modulation where there are two symbols 0 or 1, and so each symbol carries one bit of information.
- Recall the equation for a high frequency carrier: Carrier: $A \sin[\omega t + \varphi]$
- We can use an information signal (message) to modulate a carrier by varying its amplitude, frequency, or phase. So, how do we go about representing digital information (1s and 0s) with modulation?
- Just as we can vary amplitude, frequency, and phase of a high frequency carrier in accordance with an analog information (message) waveform, we can do the same with a digital waveform. Since **bit values "shift" between 0s and 1s,** digital modulation techniques that vary the carrier's amplitude, frequency, and phase are referred to as "shift keying."

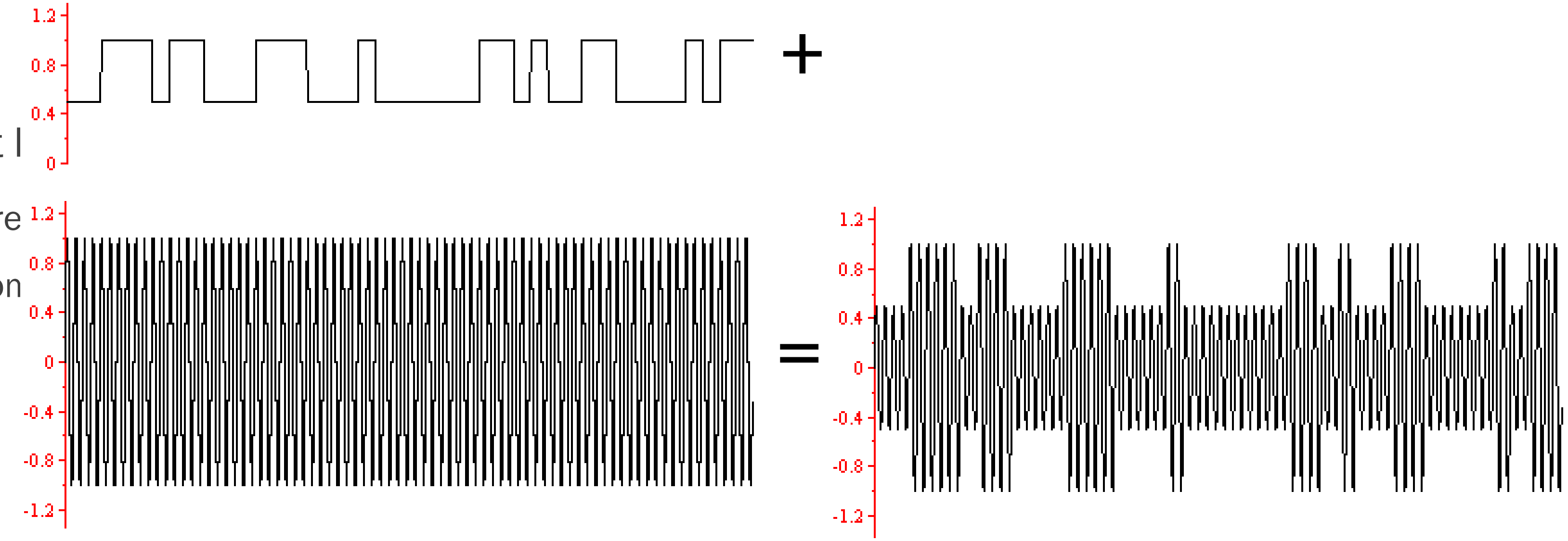

Information (bits):
0 1 0 1 1 0 1 0 0 1
Baseband signal (voltage pulses):
T_{sym}
T_b
Modulated signal if using ASK:
Modulated signal if using FSK:
Modulated signal if using BPSK:
amplitude (V)
time (μsec)

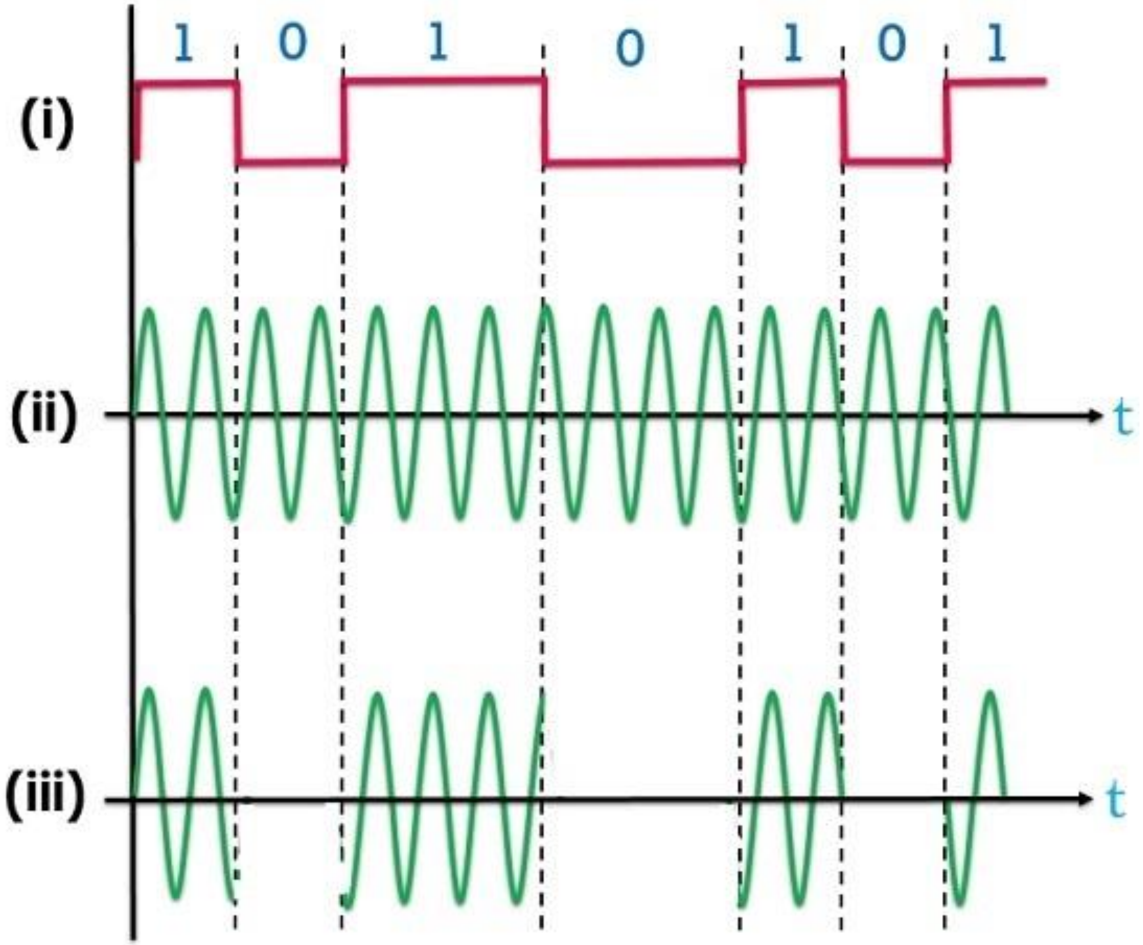
AMPLITUDE SHIFT KEYING (ASK)

- ASK is implemented by changing the amplitude of a carrier signal to reflect amplitude levels in the digital signal.
- For example: a digital “1” could not affect the signal, whereas a digital “0” would, by making it zero.
- The line encoding will determine the values of the analog waveform to reflect the digital data being carried.

ASK

- Amplitude shift l
  - 1’s or 0’s repre
  - Could be accon



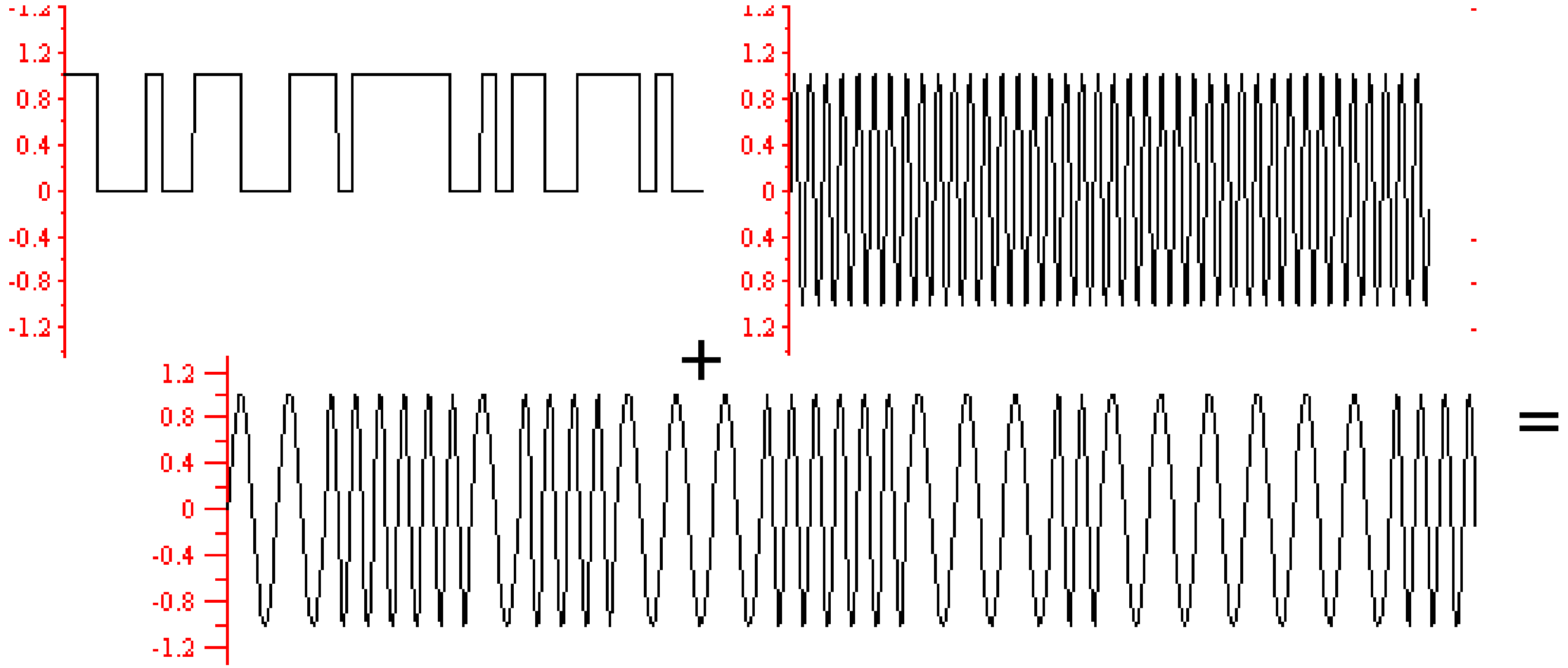


(i) = Digital bit sequence
(ii) = Carrier wave
(iii) = ASK modulated wave

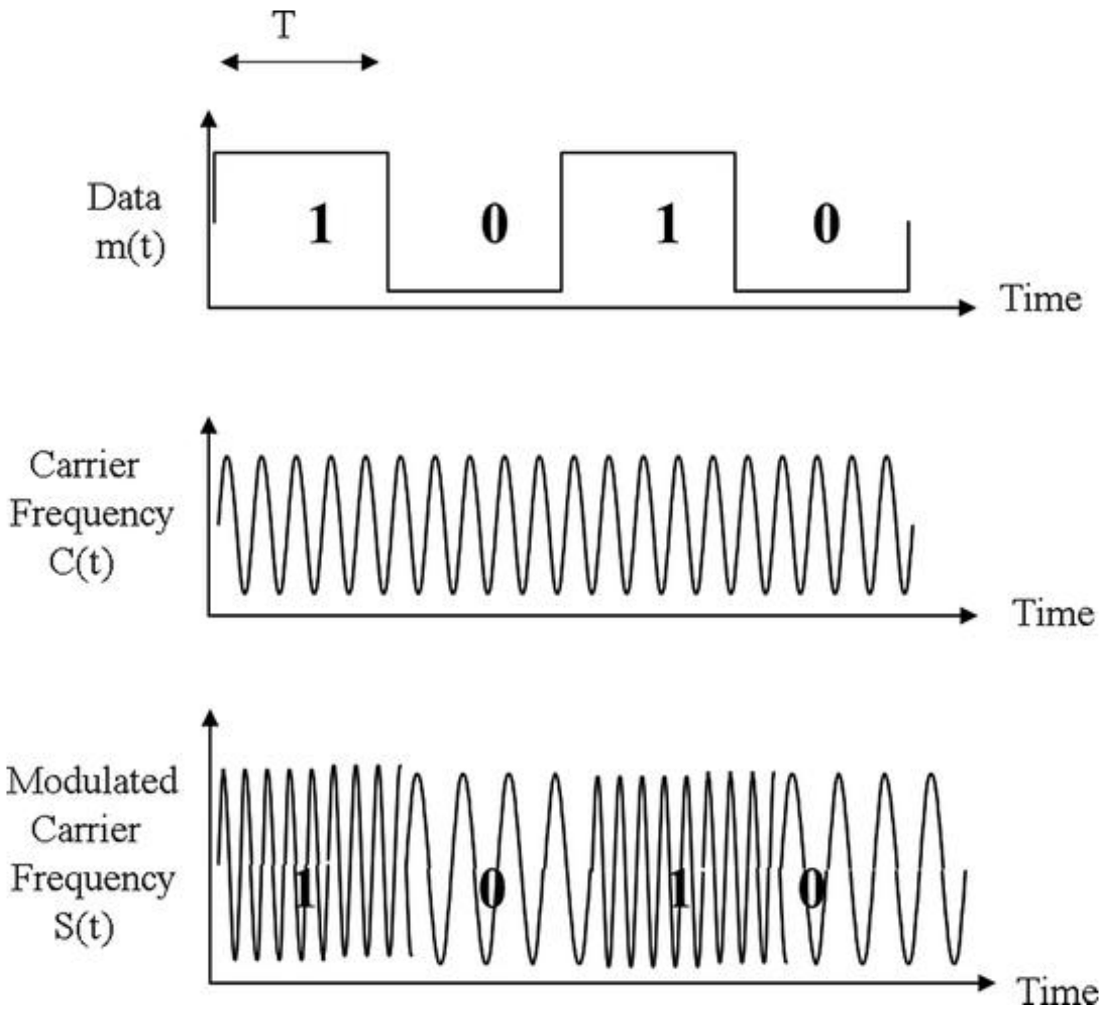
FREQUENCY SHIFT KEYING

- Frequency-shift keying (FSK) is a frequency modulation scheme in which digital information is transmitted through discrete frequency changes (shifts) of a carrier wave. The simplest form of FSK is Binary FSK (BFSK), in which a carrier's frequency is shifted to a low frequency or a high frequency to transmit 0s and 1s. The plot below shows a sample FSK signal along with the associated bits.
- The digital data stream changes the frequency of the carrier signal, f_c.
- For example, a "1" could be represented by $f_1=f_c+\Delta f$, and a "0" could be represented by $f_2=f_c-\Delta f$.

FSK



- Frequency shift keying
  - Select frequency based on each bit, 0 or 1
  - Could be done with simple FM system


T
Data
m(t)
1
0
1
0
Time
Carrier
Frequency
C(t)
Time
Modulated
Carrier
Frequency
S(t)
1
0
1
0
Time

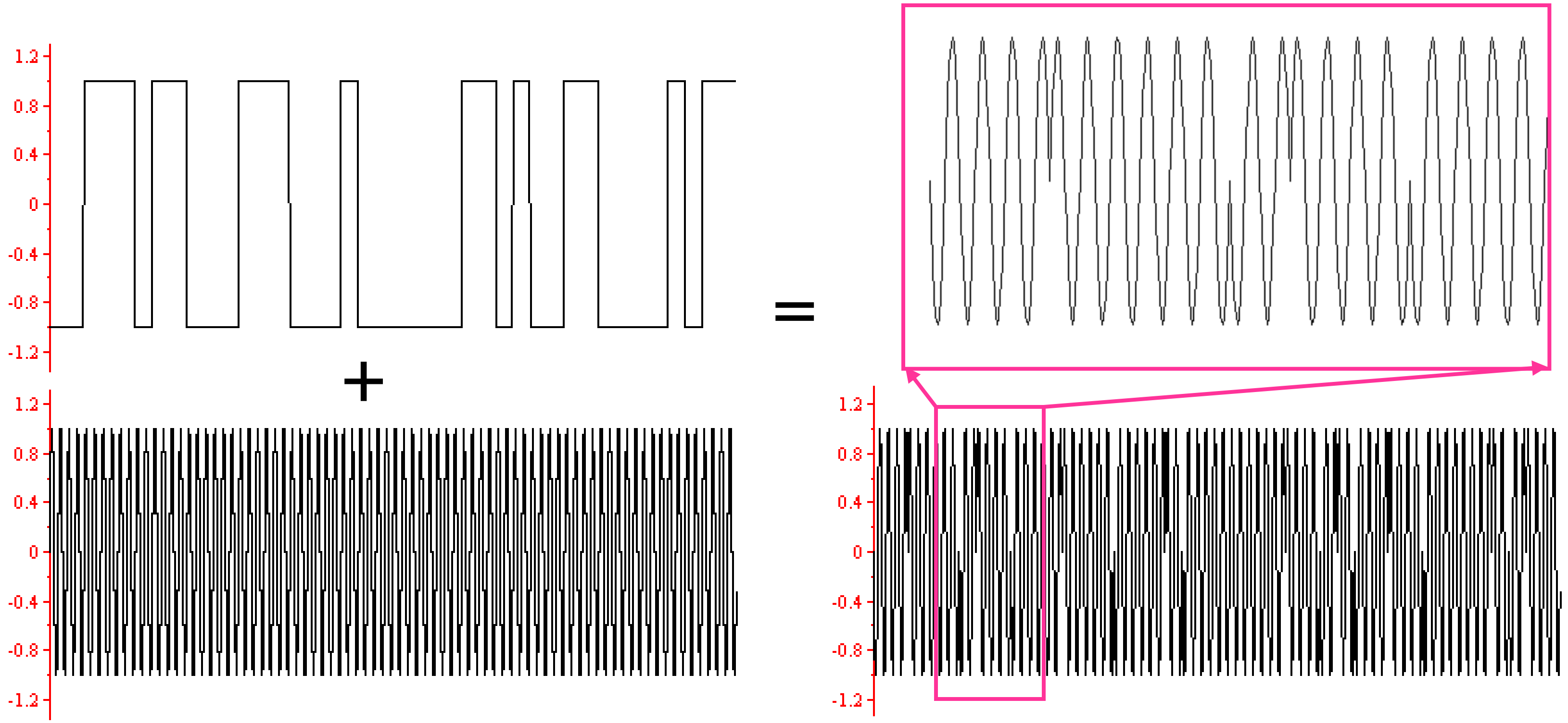
FSK

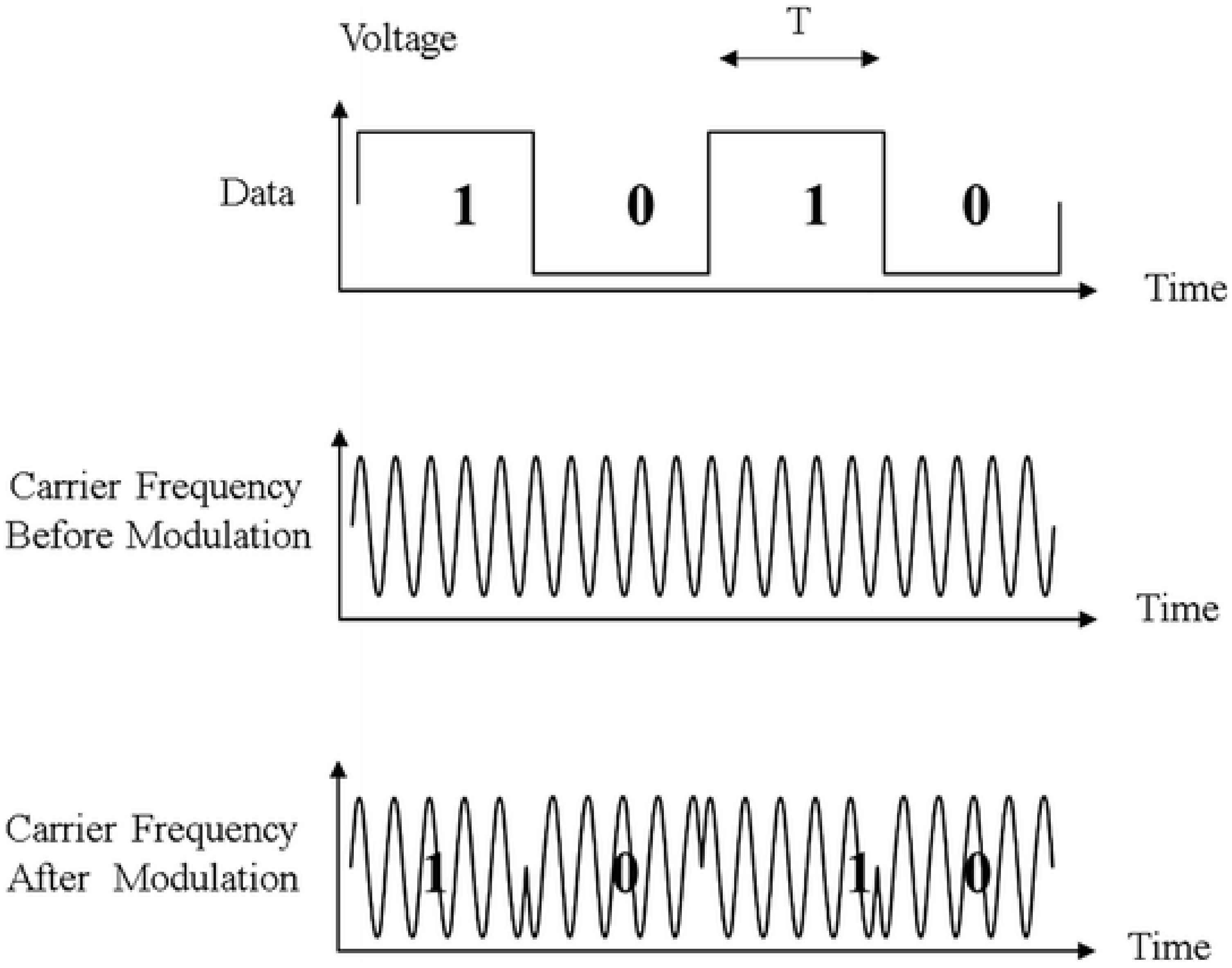
PHASE SHIFT KEYING (PSK)

- Binary Phase Shift Keying (BPSK) is a form of phase modulation where the carrier's phase shifts to one of a finite set of possible phases based on the bits that are input.
- For binary phase shift keying (BPSK), the carrier phase is shifted between one of only two phases
- (typically 0 and 180) depending on whether a 0-bit or a 1-bit is being transmitted. For example: 0-bit: the symbol transmitted in Carrier: A $\sin[\omega t + \varphi]$, where $\varphi=0$
- 1-bit: the symbol transmitted is A $\sin[\omega t + \varphi]$, where $\varphi=\pi$
- ω usually $2\pi f$

PSK

- Phase shift keying
  - At the bit transitions invert the phase by 180°




Voltage
T
Data
1
0
1
0
Time
Carrier Frequency
Before Modulation
Time
Carrier Frequency
After Modulation
1
0
1
0
Time

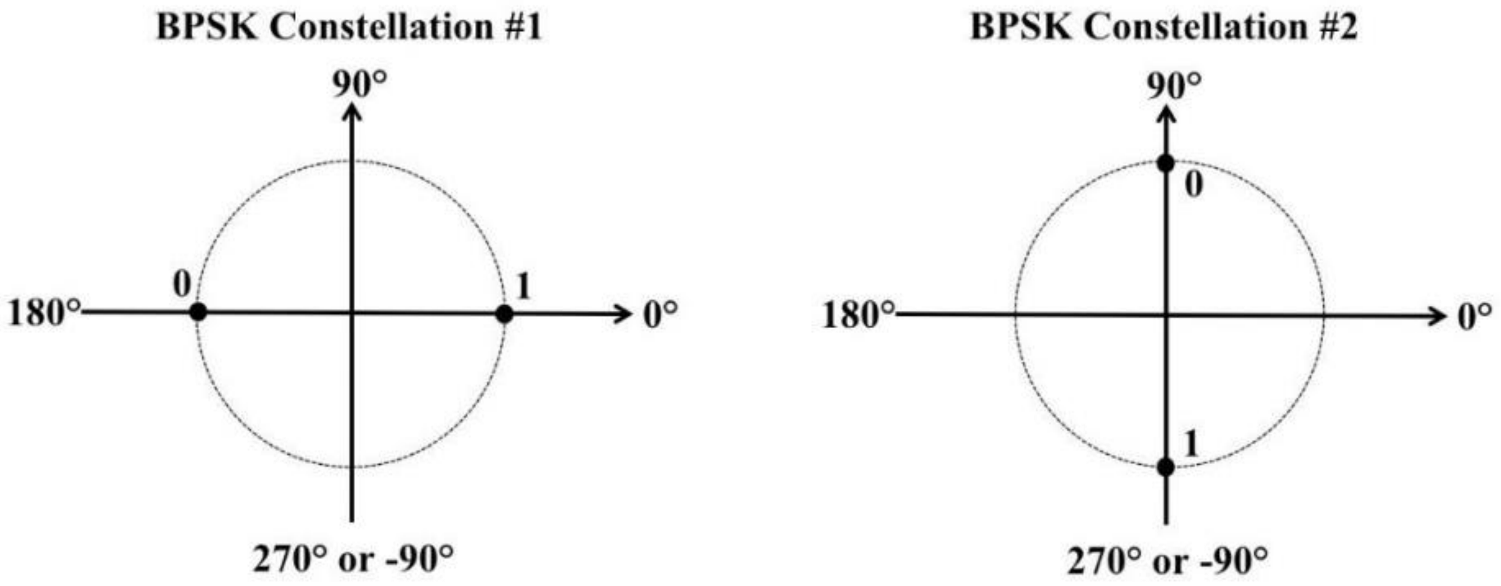
CONSTELLATION DIAGRAM ?

CONSTELLATION DIAGRAM

- Before launching into more complicated digital modulation, we'll introduce a graphical way to relate what the output symbols are, and the bits that each symbol represents. This is called a constellation diagram.
- A constellation diagram is a plot of the phase and relative amplitude of the output symbols for a digital modulation system, in polar coordinates. In terms of the symbol's phase, 0° is along the positive x-axis, and phase increases as you move counterclockwise around the x-y plane.
- The symbol's relative amplitude is measured as distance from the origin of the plot. The possible output symbols are represented with large dots, and adjacent to them are the bits they represent. Symbols that have the same amplitude are the same distance from the origin (you can think of them as laying on the same circle around the origin). All symbols with the same phase would fall on the same line segment that originates at the origin and goes out at a certain angle.

BPSK SYSTEMS' CONSTELLATION DIAGRAMS EXAMPLE

Here are two possible **BPSK systems' constellation diagrams**. In BPSK, the output symbols both have the same amplitude (both of the symbols are equidistant from the origin), but their phases are 180° apart. There are other possible combinations of two carrier phases that might be used (such as +90° and -90°), the transmitter and receiver use the same constellation.



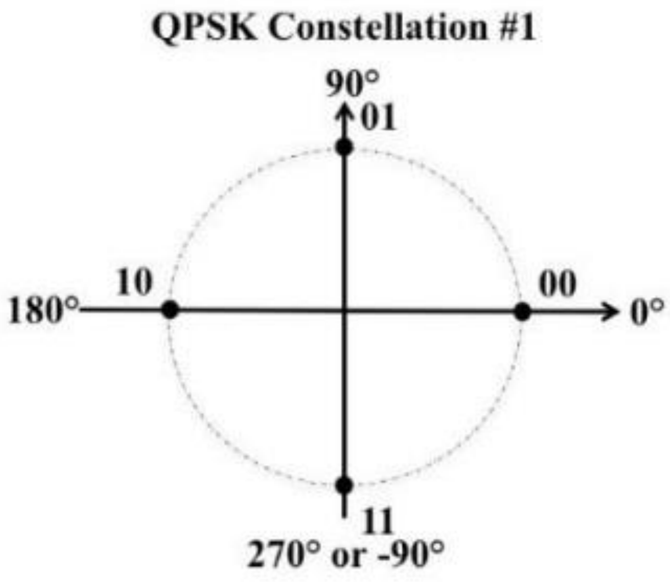
FASTER TRANSMISSION ! , YES PLEASE USE QPSK

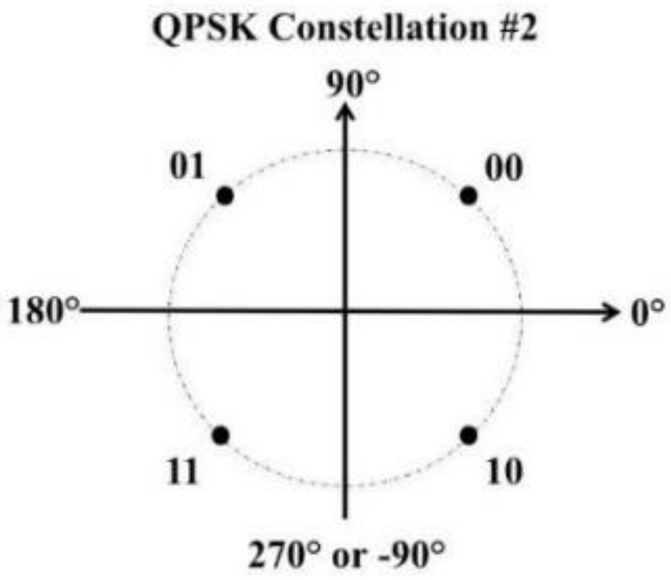
- Note that BPSK transmits 1 bit per symbol, so only one bit value is placed next to each symbol. If it is desired to get the information from the transmitter to the receiver faster, we could increase the number of bits per second (bps) that are transmitted. The cost of increasing the bitrate (besides requiring more complex components) is that it increases the transmission bandwidth, as **BW = 2R syb or twice the symbol rate, R is bit rate**
- Is there a way to transmit a higher bitrate but using a smaller transmission bandwidth? The answer is yes, using M-ary digital modulation.
- In M-ary modulation, we can preserve bandwidth if we keep the **symbol rate the same** and **increase the number of bits per symbol**. For example, instead of transmitting just 2 possible phase shifts (0˚and 180˚), we could transmit one of 4 possible phase shifts per symbol. This is called quadrature phase shift keying (**QPSK**).

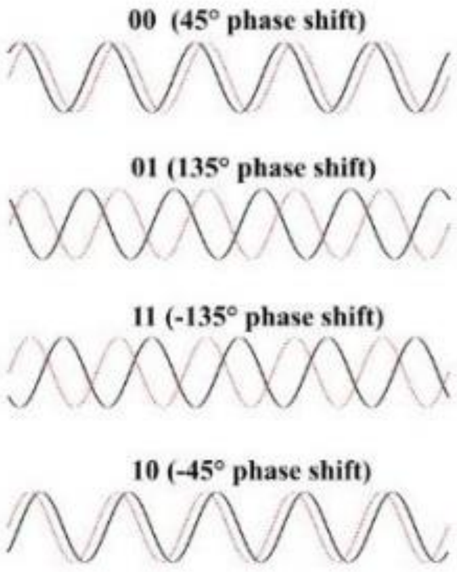
QPSK

- In QSPK, there are 4 symbols (M = 4) and there are 2 bits per symbol (N = 2 = log2M). Two of the possible constellation diagrams for QPSK are shown in the following figures , and the four symbols from QPSK Constellation #2 are shown to the right of this constellation. The carrier with a phase of 0˚ is plotted in a dashed line with each symbol for reference.

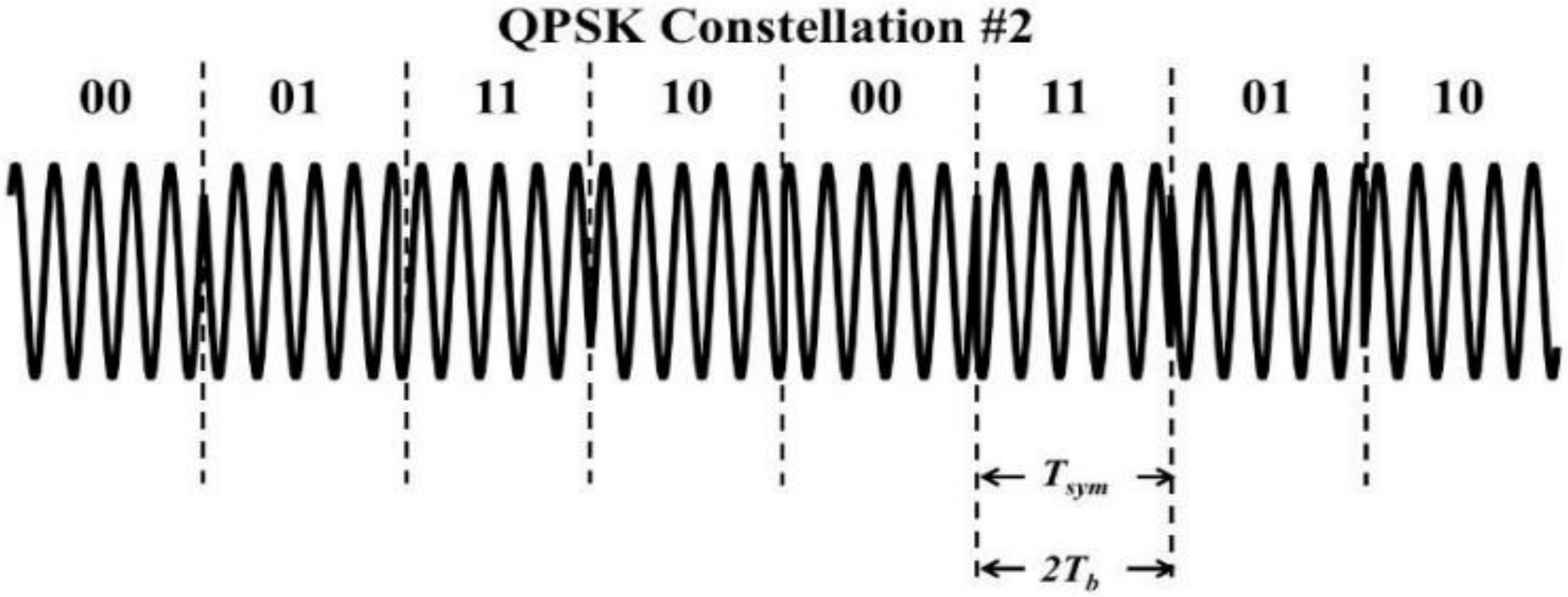
- The four symbols in the right-hand constellation are: A cos(2πfc t +45°), A cos(2πfc t +135°), A cos(2πfc t -135°) and A cos(2πfc t -45°).





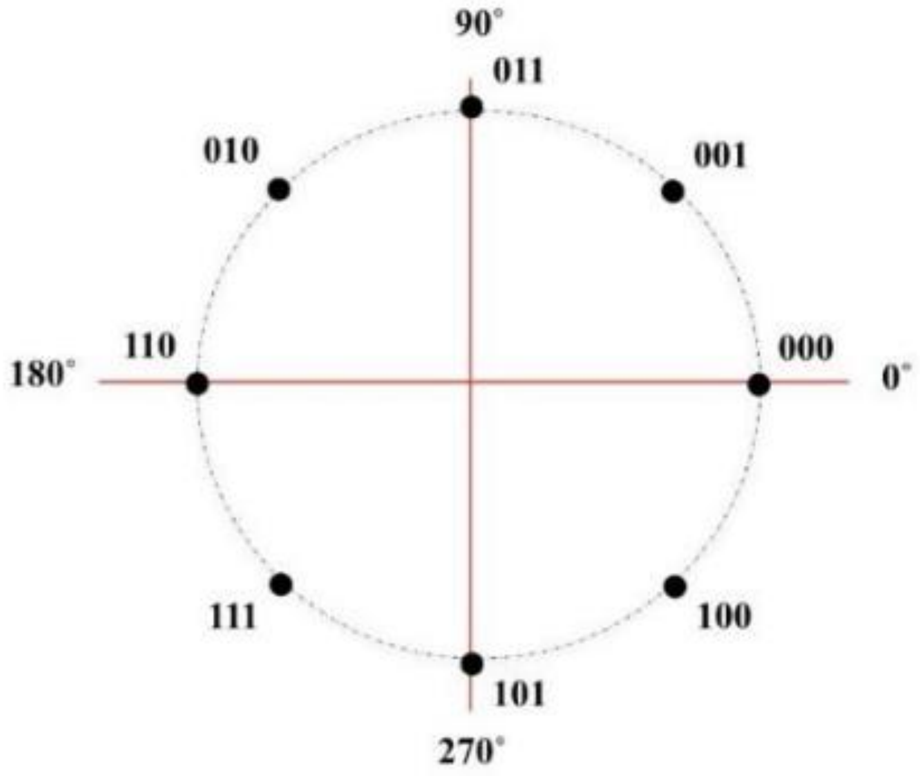


The following figure is a plot of the use of QPSK constellation #2 in the previous figure to transmit the bit stream 0001111000110110. Also shown is the bit duration, and the symbol duration for QPSK.



M-ARY PSK

- We can further increase the number of bits per symbol by increasing the number of possible phase shifts. The M in M-ary refers to the number of symbols.
- Consider the 8-PSK constellation to the right (one of many possible 8-PSK constellations).
- How many bits per symbol are transmitted? There are 8 symbols (M = 8), so N = log2M = log2 *8 = 3 bits/symbol. This is also evident from the diagram because the three bits associated with each symbol appear next to the symbol.



16, 32 OR 64 OR 128 PSK ………………… WHAT ABOUT NOISE?

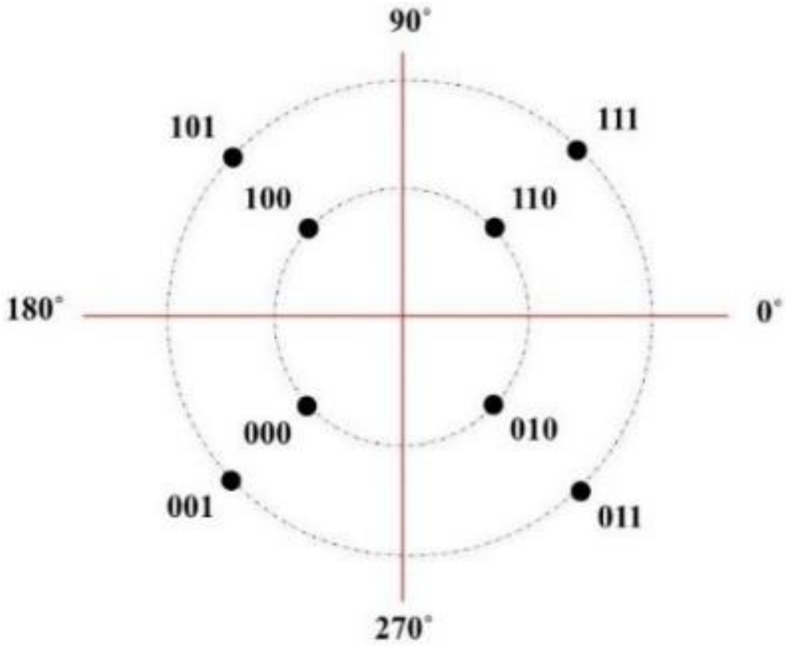
- We could further increase to 4 bits/symbol using 16-PSK. Here, M = 16 and N = 4 bits/symbol. A 16-PSK constellation is shown to the right, where each phase is separated by 360o /16 = 22.5o . More complex M-ary PSK modulation is possible: 32-PSK, 64-PSK, etc., but it becomes more susceptible to noise as the symbols get closer together.
- As a reminder, for PSK, all of the symbols have the same carrier frequency and amplitude; it is their phase that is different. For that reason, on a PSK constellation diagram, all of the symbols appear on a circle about the origin.

QUADRATURE AMPLITUDE MODULATION (QAM)

- In order to increase the distance between symbols in a constellation, another option is to modulate both the amplitude and the phase of the carrier. This is called Quadrature Amplitude Modulation (QAM).

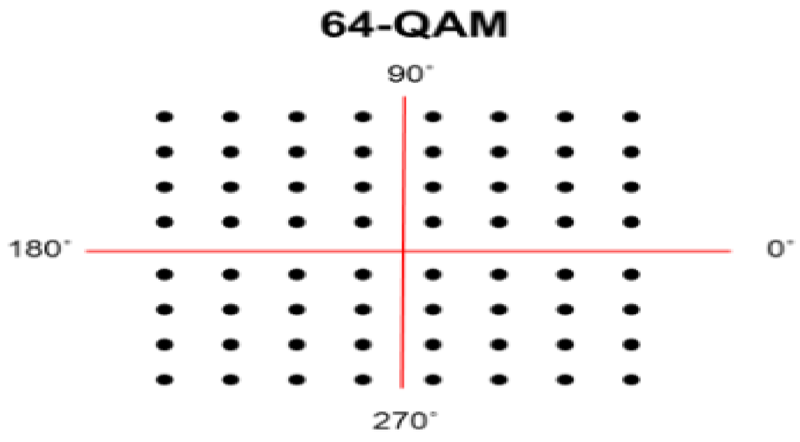
8-QAM

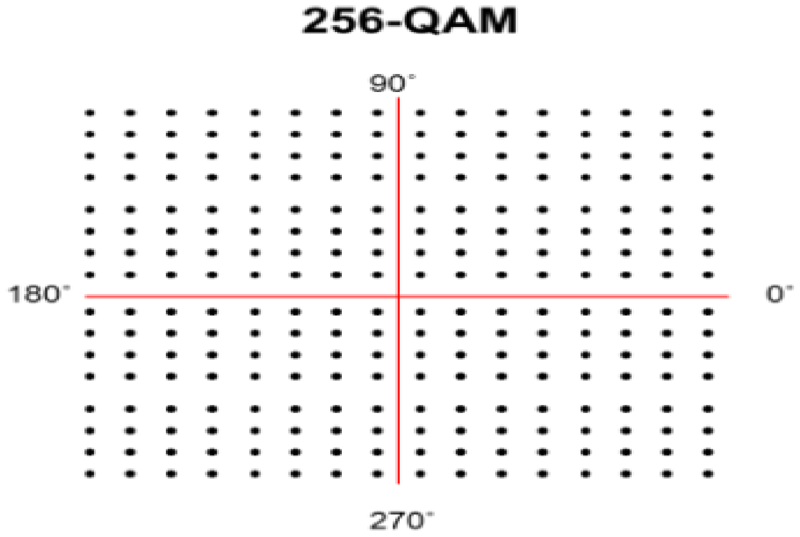
- An 8-QAM constellation is shown below (one of many possible 8-QAM constellations). The eight symbols along with the 3-bit digital words corresponding to each are shown to the right of the constellation.
- This system uses 2 possible amplitudes and 4 possible phases. In 8-QAM, the duration of a symbol is three times the duration of a bit (since each symbol carries 3 bits).
- Note that there are both phase and/or amplitude changes for each symbol. For the system with the constellation shown below, the eight output symbols might be **2** cos(2πfc t ±**45**°), 2 cos(2πfc t ±**135**°), **4** cos(2πfc t ±**45**°), and 4 cos(2πfc t ±**135**°).
- What is the bandwidth for 8-QAM? The same as for 8-PSK, since the bandwidth for all digital modulation types (except for FSK) is given by BW = 2R sym = 2R / N = 2R / 3



64-QAM OR 256-QAM ……

- QAM signaling can be extended to have a larger number of symbols, which then allows a much higher bit rate in the same bandwidth (because there are more bits per symbol). 64-QAM and 256-QAM are common in cable modems, satellites, and high-speed fixed broadband wireless. Some possible constellations are in the following figure.





In 256-QAM, you find that for each symbol you are transmitting (there are 256 symbols), there are 8 bits of information. Assuming the symbol rate remains constant, then for the same bandwidth you are sending 8 times more information when you use 256-QAM than when you use OOK, ASK or BPSK. For 256-QAM, if the bitrate is 600 kbps, the bandwidth is 2(600,000)/8 = 150 kHz.
Now that's powerful!

READING INSTRUCTIONS

- » Ch. 6: Make sure you understand the terms, e.g., Bit rate, Baud, Bandwidth, Lossy and less-less compression. Also, learn how a digital signal is converted to analog on a high level (steps and challenges, no need for deep understanding of these).
- » Ch. 7: Make sure you understand the difference between guided and unguided media, and have a high level understanding of the common technologies (e.g., twister pair, coaxial, fiber, radio). Make sure you understand the main points of 19-22.
- » Ch. 8: All » Ch. 9: 1-5, 10, 12. Also, make sure you understand the difference between synchronous and asynchronous transmission.
- » Ch. 10: 3-6, 9. The important part in this chapter is to understand how you can encode many bits per baud, i.e., a high level understanding of different ways to modulate.

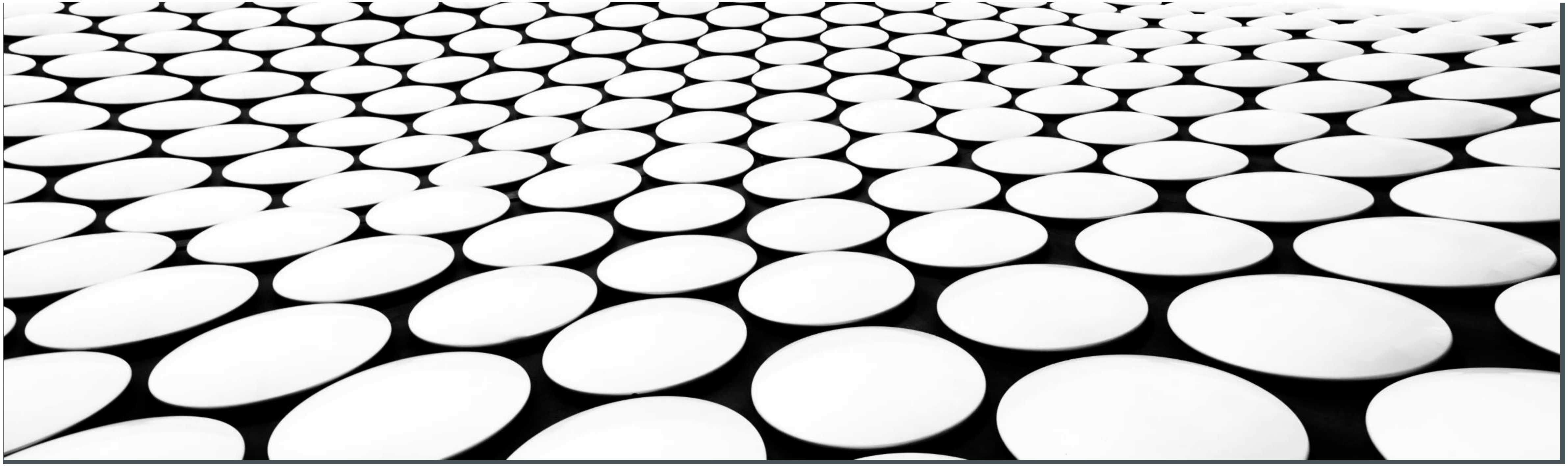
READING INSTRUCTIONS

- # Reading instructions
- Ch. 11: 1-4, 6, 8-14
- Ch. 13: All
- Ch. 14: 1-2, 5, 6
- Ch. 15: All

COMPUTER NETWORKS

SUBNETTING

HEMANT GHAYVAT, (hemant.ghayvat@lnu.se)



IP ADDRESS (IPV4)

- A unique 32-bit number
- Identifies an interface (on a host, on a router, …)
- Represented in dotted-quad notation (dotted decimal representation) (a.b.c.d)
  - » each quad is 8 bits or 1Byte (0-255 or 0x00-0xFF)
  - » e.g., 194.47.94.71

When we convert them in binary, we write them in terms of octave

NETWORK ADDRESS AND HOST ADDRESS IN AN IP ADDRESS

NETWORK ADDRESS

- Belongs to Network
- First address from left
- Its for router to route the data to the destination network
- In this all the host bits address are set to 0

HOST ADDRESS

- Belongs to individual devices
- Unique address in the subnet to identify the device
- Subnet mask defines how many host addresses are available

SUBNETTING

- Congestion reduction which is caused in big network by broadcast
- Enhance security by dividing

SUBNETTING

- It is performed by varying the default subnet mask by borrowing some of the bits from the host part
- Two addresses are reserved one to identify the subnet and other for the broadcasting the messages to all the host

SUBNETTING

Subnet Mask	11111111	11111111	11111111	00000000
	255	255	255	0

1 Network with 254 hosts

Lets borrow one bit from host part, 1 bit can represent two subnetwork

Subnet Mask	11111111	11111111	11111111	10000000
	255	255	255	128

2 Networks with 126 hosts

SUBNETTING

Lets borrow two bits from host part, 2 bit can represent four subnetwork

Subnet Mask	11111111	11111111	11111111	11000000
	255	**255**	**255**	**192**

4 Networks with 62 hosts

Lets borrow 3 bits from host part, 3 bit can represent 8 subnetwork

Subnet Mask	11111111	11111111	11111111	11100000
	255	**255**	**255**	**224**

8 Networks with 30 hosts

SUBNETTING

Lets borrow 4 bits from host part, 4 bit can represent 16 subnetwork

Subnet Mask	11111111	11111111	11111111	11110000
	255	**255**	**255**	**240**

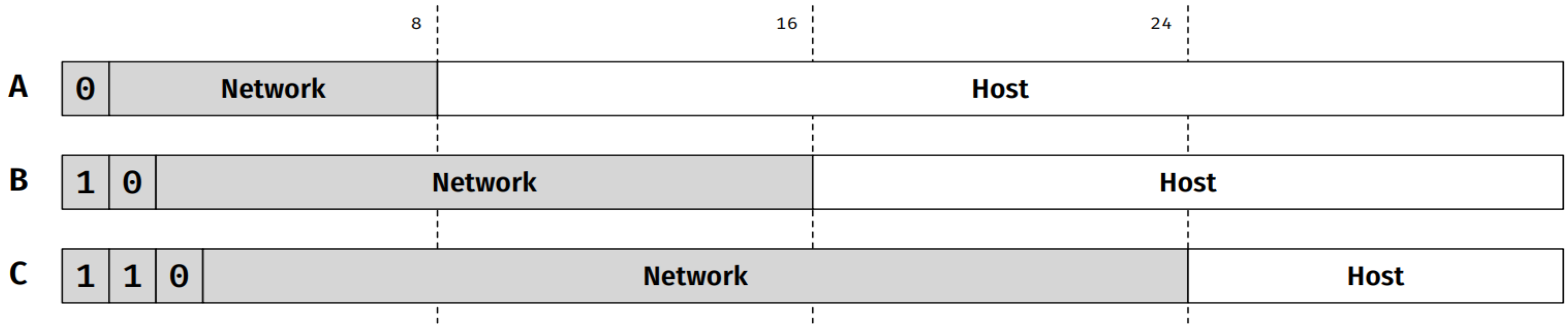
16 Networks with 14 hosts

Lets borrow 5 bits from host part, 5 bit can represent 32 subnetwork

Subnet Mask	11111111	11111111	11111111	11111000
	255	**255**	**255**	**252**

32 Networks with 6 hosts

CLASS-BASED ADDRESSING TO RESOLVE THE SCALABILITY ISSUE

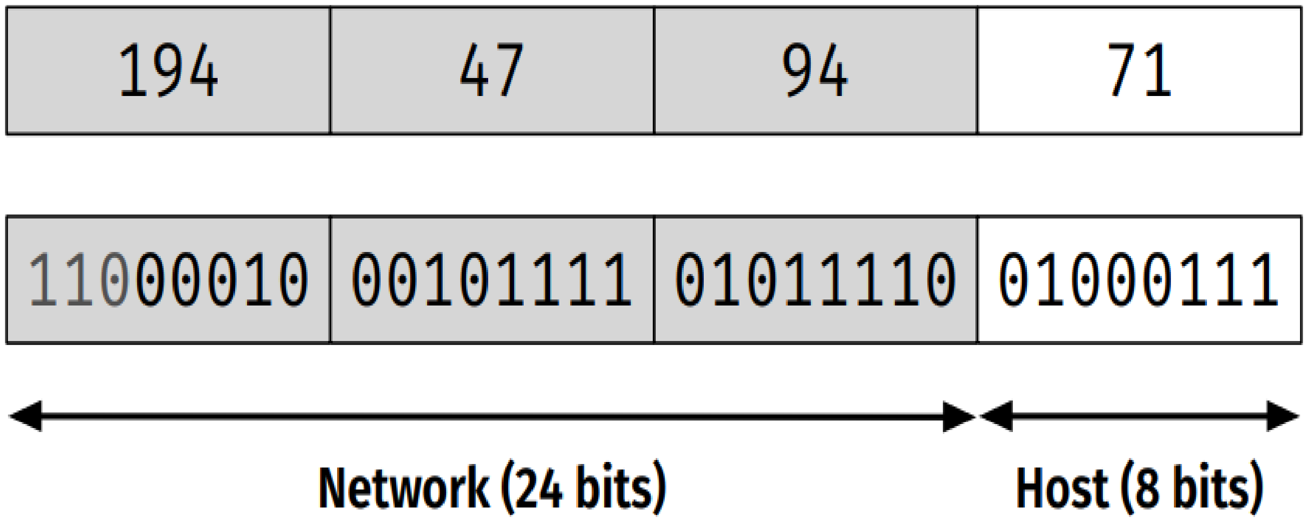


Class-based Addressing (RFC791) Address Formats:

```
High Order Bits    Format                            Class
---------------    -------------------------------   -----
      0             7 bits of net, 24 bits of host     a
      10           14 bits of net, 16 bits of host     b
      110          21 bits of net,  8 bits of host     c
      111          escape to extended addressing mode
```

HIERARCHICAL ADDRESSING: IP PREFIXES

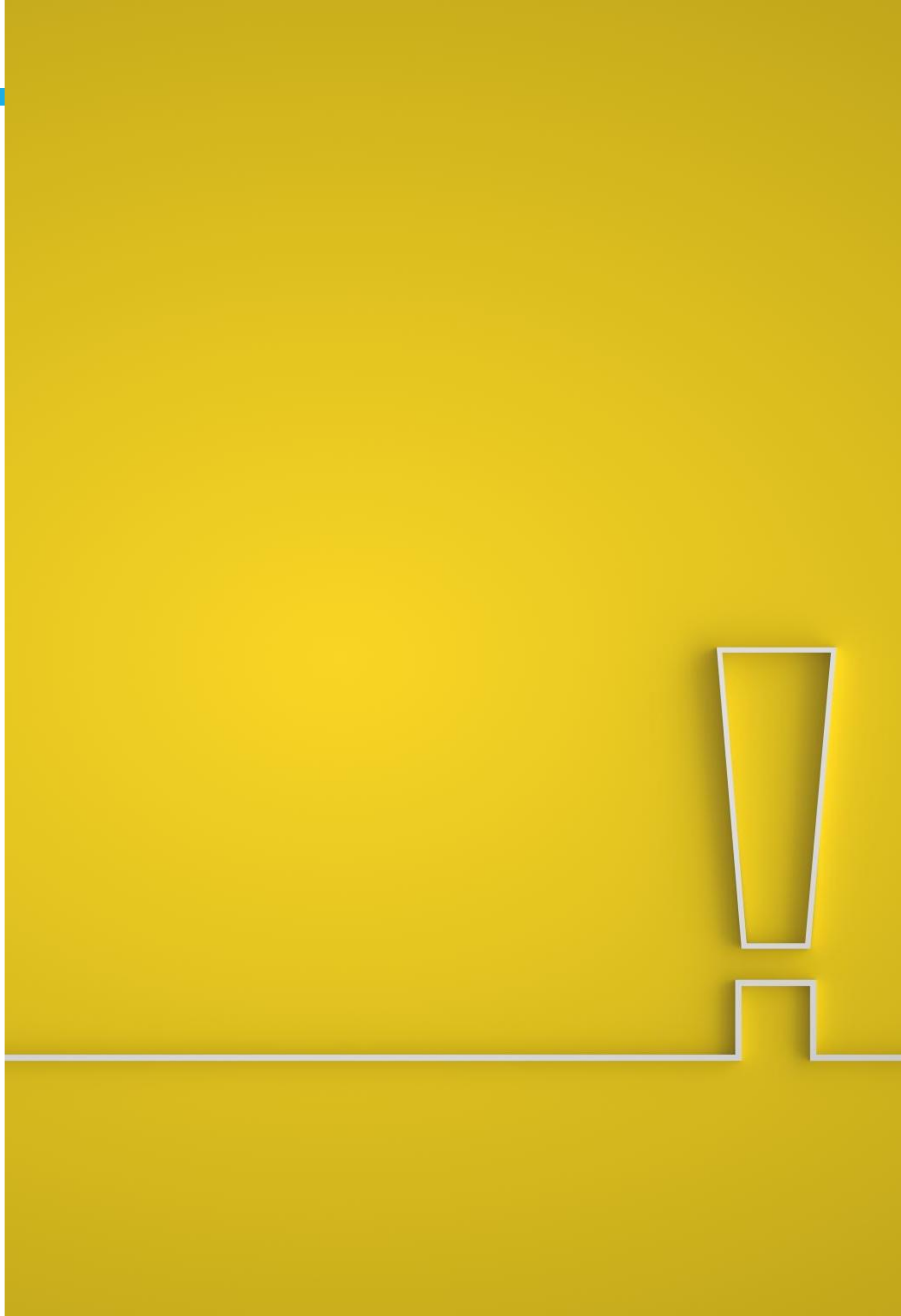
IP addresses can be divided into two parts: network (left) and host (right)



194.47.94.0/24 is a 24-bit prefix (class C) which covers 28 addresses (e.g., up to 255 hosts)

IP ADDRESS PROBLEM (1991)

- Class A, B and C all ranges from 24 to 8 bits address, which is not sufficient for the bigger network



CLASSLESS INTERDOMAIN ROUTING (CIDR), OR CIDR ADDRESS ASSIGNMENT STRATEGY OR SLASH NOTION

- Slash notation is the shortest way to write the subnet mask.
- With forward slash it shows number of 1's in the subnet mask
- 192.168.1.0/24 , i.e subnet mask has 24 1's (11111111 . 11111111. 11111111. 00000000)
- 192.168.1.0/25 , i.e subnet mask has 25 1's (11111111 . 11111111. 11111111. 10000000)
- 192.168.1.0/1 , i.e subnet mask has 25 1's (11111111 . 00000000. 00000000. 00000000)

In this way an organization can create multiple subnets within the allocated IP address space.

SUPERNETTING (ROUTE AGGREGATION OR CIDR (CLASSLESS INTER-DOMAIN ROUTING))

- Reduces routing table entries in routers
- Efficient use of IP addresses.

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