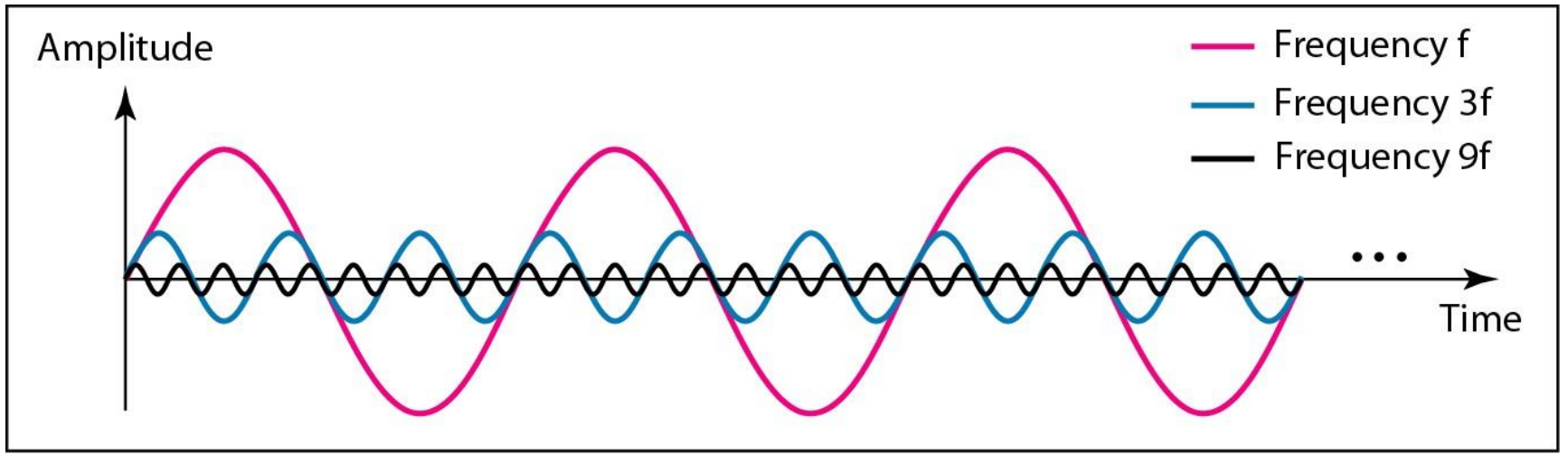
Lecture (4)

" Data Communication”

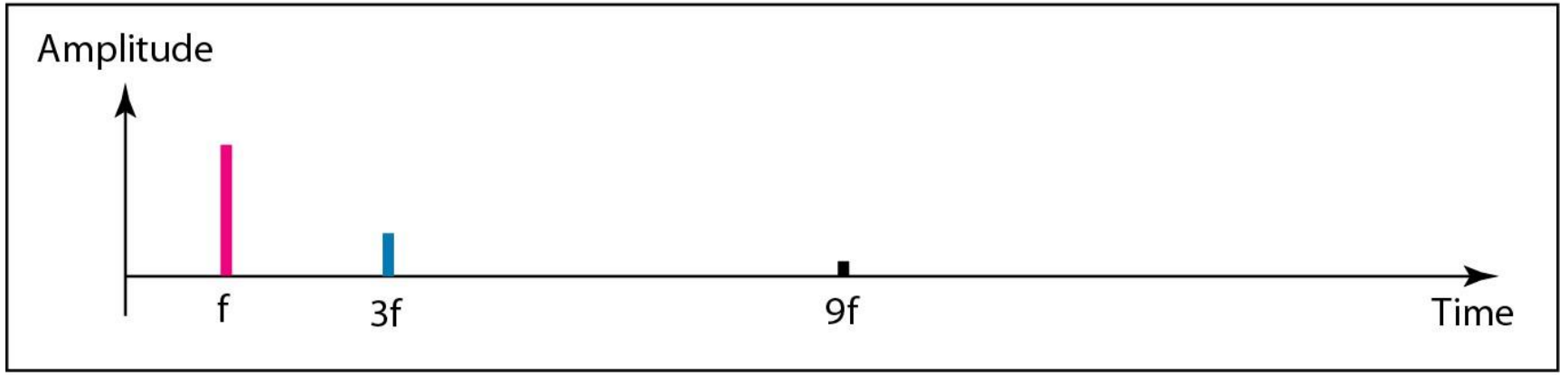
Data and Signals

Presented by : Dr. Maha Fathy

DECOMPOSITION OF A COMPOSITE PERIODIC SIGNAL IN THE TIME AND FREQUENCY DOMAIN



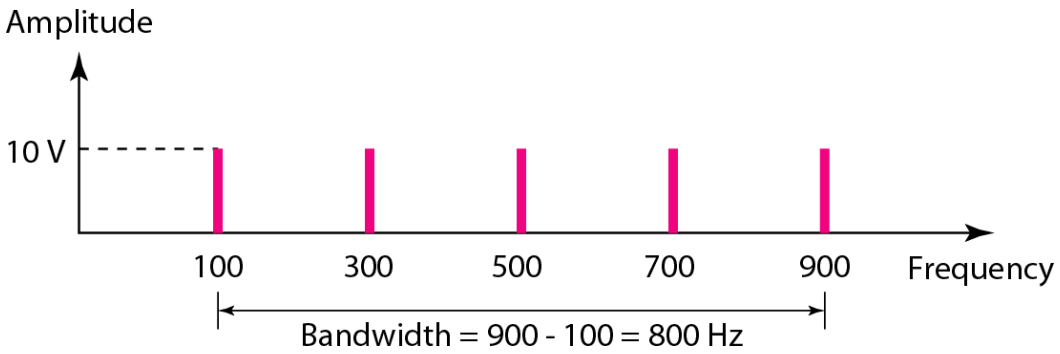
a. Time-domain decomposition of a composite signal



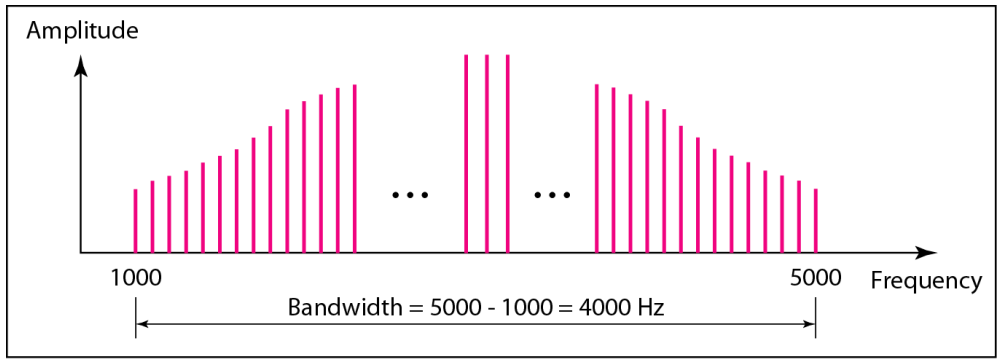
b. Frequency-domain decomposition of the composite signal

Band width of the composite signal

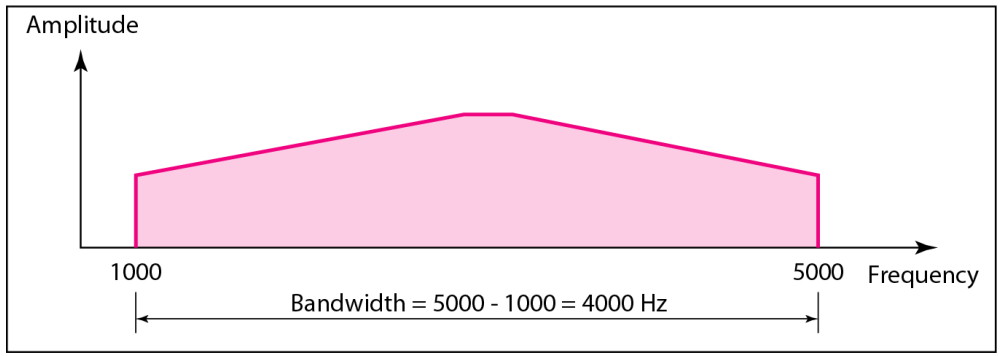
The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.



$$B = f_h - f_l = 900 - 100 = 800 \text{ Hz}$$



a. Bandwidth of a periodic signal



b. Bandwidth of a nonperiodic signal

CHARACTERISTICS OF DIGITAL SIGNAL

- **Levels :** Distinct values (high and low).
- **Bit Length or Bit Interval :**Time taken to send one bit.
- **Bit Rate :**Number of bits transmitted per second.

- **Example:**
- A bit rate of 1000 bps (bits per second).

BIT LENGTH OR BIT INTERVAL (TB)

BIT LENGTH or Bit Interval (Tb)

- It is the time required to send one bit.
- It is measured in seconds.

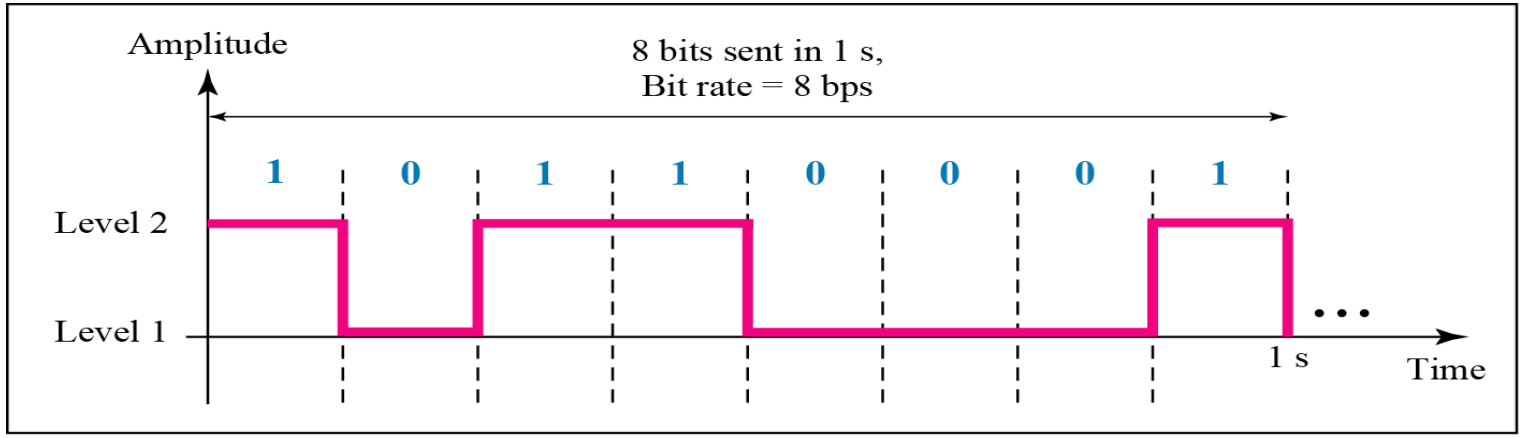
BIT RATE

- It is the number of bits transmitted in one second.
- It is expressed as bits per second (bps).
- Relation between bit rate and bit interval can be as follows

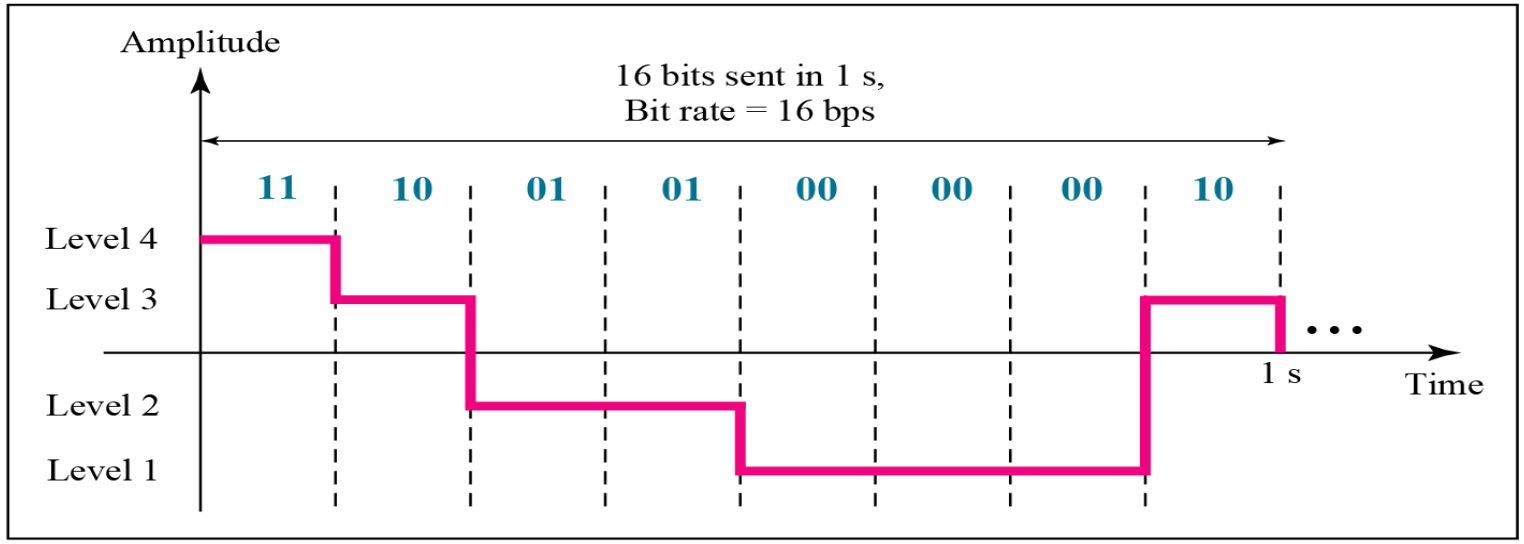
Bit rate = 1 / Bit interval

TWO DIGITAL SIGNALS: ONE WITH TWO SIGNAL LEVELS AND THE OTHER WITH FOUR SIGNAL LEVELS

In general,if a signal has L levels then, each level need Log2L bits



a. A digital signal with two levels



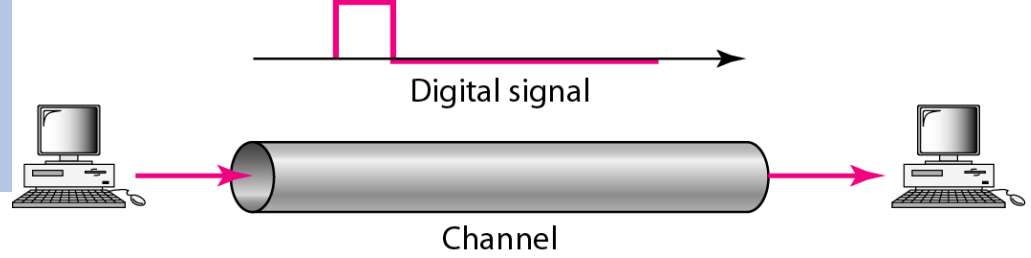
b. A digital signal with four levels

LEVELS

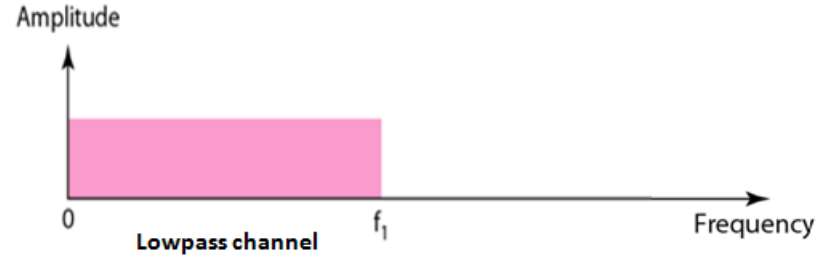
- In general 2^n levels require *n* bits.
- 8 levels require three binary digits, or bits; 16 levels require four bits; and 256 levels require eight bits.

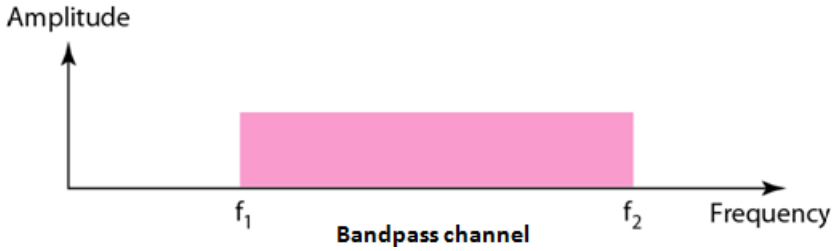
quantization level	binary code
0	000
1	001
2	010
3	011
4	100
5	101
6	110
7	111

TYPES OF CHANNELS:



- Each composite signal has a lowest possible(minimum) frequency and a highest possible (maximum) frequency.
- From the point of view of transmission,there are two types of channels:
  - **Low pass Channel**
  - **Band pass channel**





TYPES OF CHANNELS:

Low pass Channel

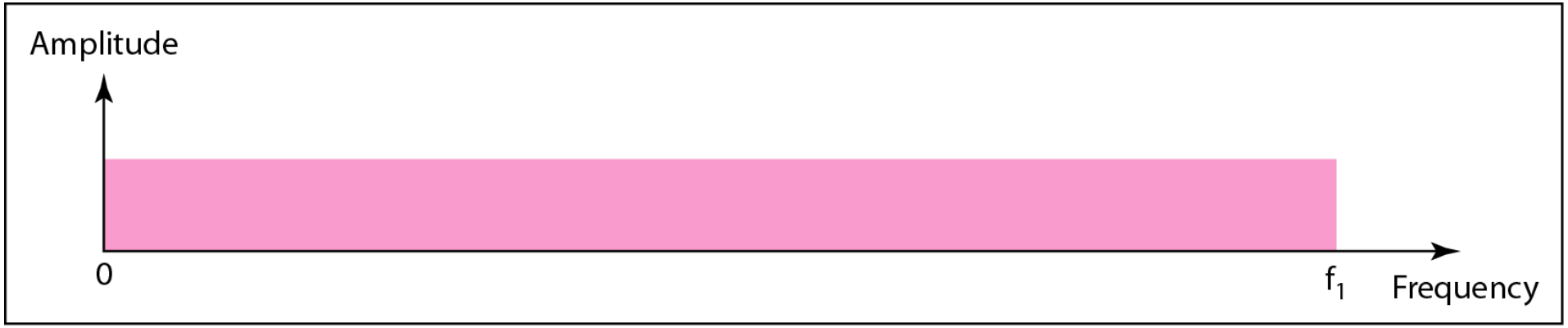
- This channel has the lowest frequency as _0‘ and highest frequency as some non-zero frequency _f1‘.
- This channel can pass all the frequencies in the range 0 to f1.

Band pass channel

- This channel has the lowest frequency as some non-zero frequency _f1‘ and highest frequency as some non-zero frequency _f2‘.
- This channel can pass all the frequencies in the range f1 to f2.

TYPES OF THE CHANNELS:

Low pass Channel :



a. Low-pass channel, wide bandwidth



b. Low-pass channel, narrow bandwidth

LOW-PASS CHANNEL WITH WIDE BANDWIDTH

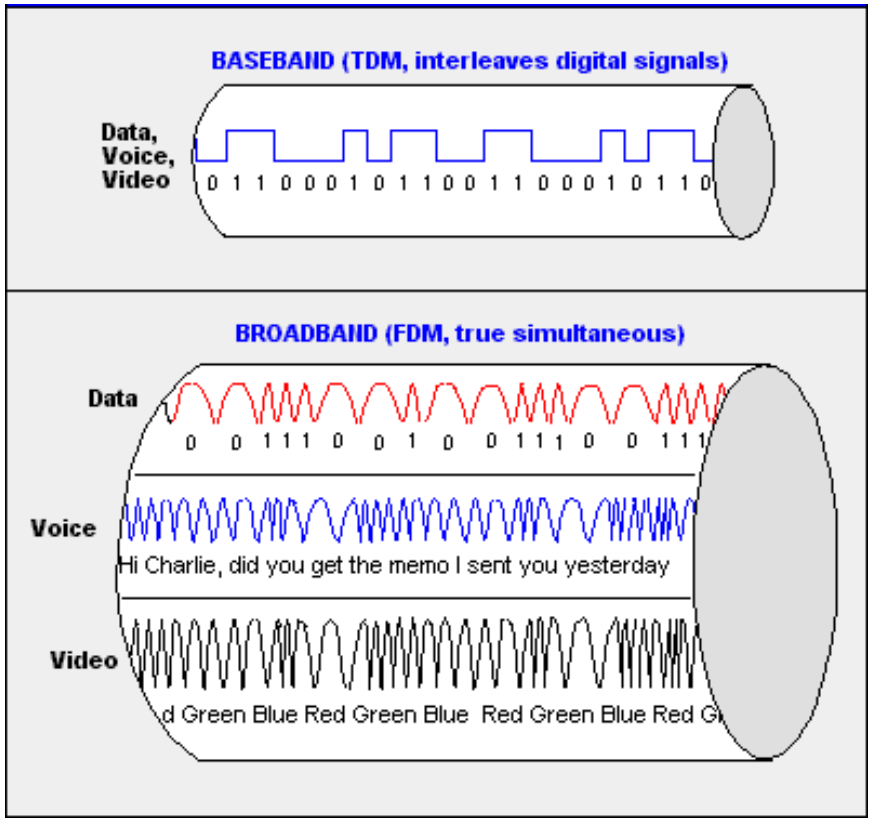
- **Definition**: A low-pass channel allows signals with frequencies below a certain cutoff frequency to pass while attenuating higher frequencies. A wide bandwidth means the cutoff frequency is relatively high.
- **Example**:
- **Application**: Audio processing or telecommunications where high-quality audio or complex waveforms are transmitted.
- **Bandwidth**: For instance, a low-pass filter with a cutoff frequency of 20 kHz can transmit audio signals effectively, covering the full range of human hearing (20 Hz to 20 kHz).

LOW-PASS CHANNEL WITH LOW BANDWIDTH

- **Definition**:A low-pass channel with low bandwidth has a low cutoff frequency, meaning it allows only lower frequencies to pass while significantly attenuating higher frequencies.
- **Example**:
- **Application**:Simple control systems where only slow-changing signals are relevant.
- **Bandwidth**:A low-pass filter with a cutoff frequency of 1 kHz will only allow signals below that frequency to pass, which is suitable for monitoring slow temperature changes but not for high-frequency signals like audio.

TRANSMISSION OF DIGITAL SIGNAL

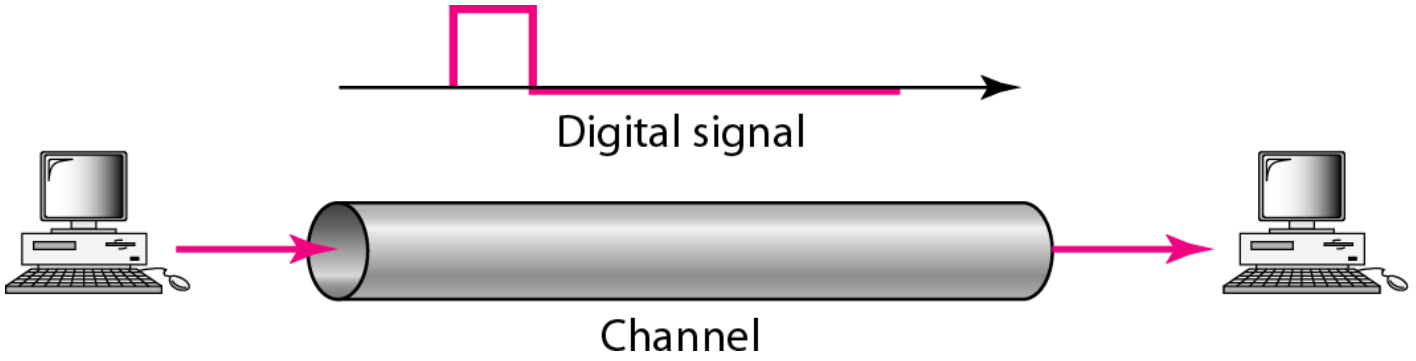
- Digital signal can be transmitted in the following two ways:
  - **BasebandTransmission**
  - **Broad bandTransmission**



BASEBANDTRANSMISSION

- The signal is transmitted without making any change to it (ie.Without modulation)

- In baseband transmission, the bandwidth of the signal to be transmitted has to be less than the bandwidth of the channel.



Note

If the available channel is a bandpass channel, we cannot send the digital signal directly to the channel; we need to convert the digital signal to an analog signal (modulation) before transmission.

BANDWIDTH IN DIGITAL

- **What is Bandwidth?** The maximum rate at which data can be transferred over a network connection in a given time period.
- **Unit of Measurement:** Typically measured in bits per second (bps), kilobits per second (kbps), megabits per second (Mbps), or gigabits per second (Gbps).

BANDWIDTH VS. THROUGHPUT

- **Bandwidth:**
  - The maximum possible data transfer rate.
- **Throughput:**
  - The actual rate of data transfer achieved in practice.
- **Example:**
  - A network may have a bandwidth of 100 Mbps but only achieve a throughput of 80 Mbps due to overhead and network congestion.

Example

- A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?

The throughput is almost one-fifth of the bandwidth in this case. How!!! See next slide

To calculate the throughput of the network, you can use the formula:

$$\text{Throughput} = \frac{\text{Total bits transmitted}}{\text{Total time taken}}$$

Step 1: Calculate the total bits transmitted per minute

Given:

- Average frames per minute = 12,000
- Average bits per frame = 10,000 bits

Total bits transmitted in one minute:

$$\text{Total bits} = 12,000\,\text{frames/min} \times 10,000\,\text{bits/frame} = 120,000,000\,\text{bits/min}$$

Step 2: Convert time from minutes to seconds

Since throughput is typically measured in bits per second (bps), we need to convert the time:

$$1\,\text{minute} = 60\,\text{seconds}$$

Step 3: Calculate throughput in bps

$$\text{Throughput} = \frac{120,000,000\,\text{bits}}{60\,\text{seconds}} = 2,000,000\,\text{bps}$$

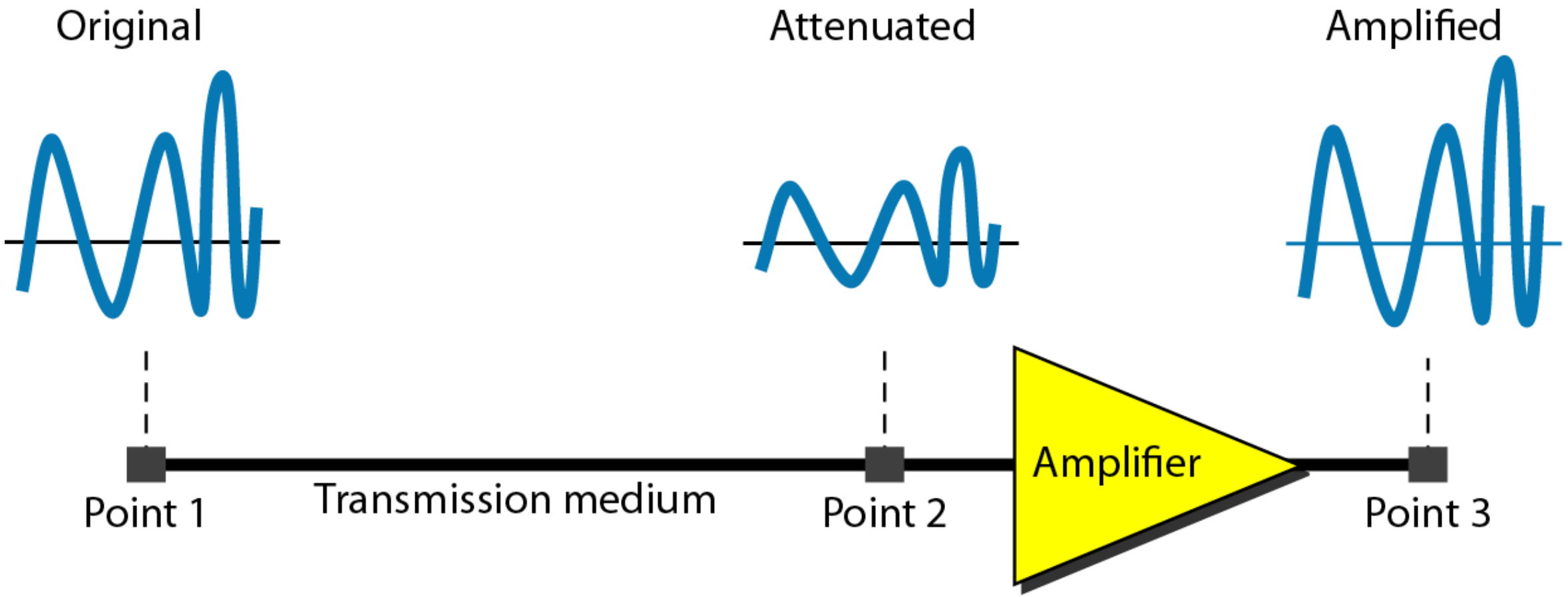
Result:

The throughput of the network is **2 Mbps**.

ATTENUATION

- **Definition:**
  - The loss of signal strength as it travels through a medium.
- **Factors Influencing Attenuation:**
  - Distance, medium type (copper, fiber optics), frequency of the signal.
- **Example:**
  - A long-distance telephone call may have reduced audio quality due to attenuation.

ATTENUATION



ATTENUATION EXPRESSION

Attenuation can be expressed in decibels (dB) using the formula:

$$\text{Attenuation (dB)} = 10 \log_{10} \left(\frac{P_1}{P_2} \right)$$

ATTENUATION EXAMPLE

Suppose a signal travels through a transmission medium and its power is reduced to one-half. This means that P_2 is (1/2)P1. In this case, the attenuation (loss of power) can be calculated as

Given that $P_2 = \frac{1}{2}P_1$, we can substitute this into the formula:

$$\text{Attenuation (dB)} = 10 \log_{10} \left(\frac{P_1}{\frac{1}{2}P_1} \right) = 10 \log_{10}(2)$$

Now, we can calculate $\log_{10}(2)$:

$$\log_{10}(2) \approx 0.3010$$

Substituting this value back:

$$\text{Attenuation (dB)} = 10 \times 0.3010 = 3.010 \, \text{dB}$$

Result:

The attenuation (loss of power) is approximately **3.01 dB**.

A signal travels through an amplifier, and its power is increased 10 times. This means that $P_2 = 10P_1$. In this case, the amplification (gain of power) can be calculated as

To calculate the amplification (gain) in decibels (dB) when the power of a signal increases, you can use the formula:

$$\text{Gain (dB)} = 10 \log_{10} \left(\frac{P_2}{P_1} \right)$$

Given that $P_2 = 10P_1$, we can substitute this into the formula:

$$\text{Gain (dB)} = 10 \log_{10} \left(\frac{10P_1}{P_1} \right) = 10 \log_{10}(10)$$

Now, since $\log_{10}(10) = 1$:

$$\text{Gain (dB)} = 10 \times 1 = 10 \, \text{dB}$$

Result:

The amplification (gain of power) is **10 dB**.

Question Of the Lecture!! Think!!

What is modulation? And its advantages in communication system.

Thank you!