Unit 1 Introduction to data communications and networking
Signals

2.1 INTRODUCTION

Computer networks are designed to transfer data from one point to another. During transit data is in the form of electromagnetic signals. Hence it is important to study data and signals before we move to further concepts in data communication.

2.2 DATA & SIGNALS

To be transmitted, data must be transformed to electromagnetic signals.

2.2.1. Data can be Analog or Digital.

1. Analog data refers to information that is continuous; ex. sounds made by a human voice

2. Digital data refers to information that has discrete states. Digital data take on discrete values.

3. For example, data are stored in computer memory in the form of Os and 1s

2.2.2. Signals can be of two types:

1. Analog Signal: They have infinite values in a range.

2. Digital Signal: They have limited number of defined values

Figure: a. Analog Signal b. Digital Signal*

2.2.3. Periodic & Non Periodic Signals

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Signals which repeat itself after a fixed time period are called Periodic Signals.

Signals which do not repeat itself after a fixed time period are called Non-Periodic Signals.

In data communications, we commonly use periodic analog signals and non-periodic digital signals.

2.3 ANALOG SIGNAL

An analog signal has infinitely many levels of intensity over a period of time.

As the wave moves from value *A* to value *B,* it passes through and includes an infinite number of values along its path as it can be seen in the figure below.

A simple analog signal is a sine wave that cannot be further decomposed into simpler signals.

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1. Peak Amplitude 2. Frequency 3. Phase **2.3.1 Characteristics of an Analog Signal**

2.3.1.1 Peak Amplitude

The amplitude of a signal is the absolute value of its intensity at time t

The peak amplitude of a signal is the absolute value of the highest intensity.

The amplitude of a signal is proportional to the energy carried by the signal

2.3.1.2. Frequency

Frequency refers to the number of cycles completed by the wave in one second.

Period refers to the time taken by the wave to complete one second.

Fig: Frequency & Period of a sine wave

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2.3.1.3. Phase

Phase describes the position of the waveform with respect to time (specifically relative to time O).

Fig: Phase of a sine wave*

Phase indicates the forward or backward shift of the waveform from the axis

It is measured in degrees or radian

The figure above shows the sine waves with same amplitude and frequency but different phases

2.3.2 Relation between Frequency & Period

Frequency & Period are inverse of each other.

It is indicated by the following formula:

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Example1. A wave has a frequency of 100hz. Its period(T) is given by T = 1/ F = 1/ 100 = 0.01 sec Example2. A wave completes its one cycle in 0.25 seconds. Its frequency is given by F = 1 / T = 1 / 0.25 = 4 Hz

2.3.3 Wavelength

The wavelength of a signal refers to the relationship between frequency (or period) and propagation speed of the wave through a medium.

The wavelength is the distance a signal travels in one period.

It is given by

Wavelength = Propagation Speed X Period

OR

Wavelength =Propagation Speed X 1 Frequency

It is represented by the symbol : λ (pronounced as lamda)

It is measured in micrometers

It varies from one medium to another.

2.3.4. Time Domain and Frequency domain representation of signals

A sine wave can be represented either in the time domain or frequency domain.

The **time-domain plot** shows changes in signal amplitude with respect to time. It indicates time and amplitude relation of a signal.

The **frequency-domain plot** shows signal frequency and peak amplitude.

The figure below show time and frequency domain plots of three sine waves.

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Fig: Time domain and frequency domain plots of three sine waves*

A complete sine wave in the time domain can be represented by one single spike in the frequency domain

2.3.5. Composite Signal

A composite signal is a combination of two or more simple sine waves with different frequency, phase and amplitude.

If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies; if the composite signal is non-periodic, the decomposition gives a combination of sine waves with continuous frequencies.

Fig: A Composite signal with three component signals

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For data communication a simple sine wave is not useful, what is used is a composite signal which is a combination of many simple sine waves.

According to French Mathematician, Jean Baptist, any composite signal is a combination of simple sine waves with different amplitudes and frequencies and phases.

Composite signals can be periodic or non periodic.

A periodic composite signal can be decomposed into a series of signals with discrete frequencies.

A non-periodic signal when decomposed gives a combination of sine waves with continuous frequencies.

Fig The time and frequency domains of a non-periodic composite analog signal 2.4 Digital Signal Information can also be explained in the form of a digital signal. A digital signal can be explained with the help of following points:

2.4.1 Definition:-

A digital is a signal that has discrete values.

The signal will have value that is not continuous.

2.4.2 LEVEL

Information in a digital signal can be represented in the form of voltage levels.

Ex. In the signal shown below, a ‗1‘ is represented by a positive voltage and a ‗0‘ is represented by a Zero voltage.

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Fig: A digital signal with Two levels. „1" represented by a positive voltage and „0" represented by a negative voltage

A Signal can have more than two levels

11 10 01 00 00 01 10 10

LEVEL 4

LEVEL 3

LEVEL 2

LEVEL 1

Fig: A digital signal with four levels

In general, if a signal has L levels then, each level need Log_2L bits

Example: Consider a digital Signal with four levels, how many bits are required per level?

Answer: Number of bits per level = Log_2L = Log_24 = 2 Hence, 2 bits are required per level for a signal with four levels. **2.4.3 BIT LENGTH or Bit Interval (T_b)**

It is the time required to send one bit.

It is measured in seconds.

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2.4.4 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 **2.4.5 Baud Rate**

It is the rate of Signal Speed, i.e the rate at which the signal changes.

A digital signal with two levels ‗0‘ & ‗1‘ will have the same baud rate and bit rate & bit rate.

The diagram below shows three signal of period (T) 1 second

a) Signal with a bit rate of 8 bits/ sec and baud rate of 8 baud/sec

b) Signal with a bit rate of 16 bits/ sec and baud rate of 8 baud/sec

c) Signal with a bit rate of 16 bits/ sec and baud rate of 4 baud/sec

Fig: Three signals with different bit rates and baud rates

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2.5 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: **2.5.1 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.

2.5.2 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.

Fig: Lowpass Channel & Bandpass Channel 2.6 Transmission of Digital signal Digital signal can be transmitted in the following two ways: **2.6.1 Baseband Transmission**

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.

Ex. Consider a Baseband channel with lower frequency 0Hz and higher frequency 100Hz, hence its bandwidth is 100 (Bandwidth is calculated by getting the difference between the highest and lowest frequency).

We can easily transmit a signal with frequency below 100Hz, such a channel whose bandwidth is more than the bandwidth of the signal is called **Wideband** channel

Logically a signal with frequency say 120Hz will be blocked resulting in loss of information, such a channel whose bandwidth is less than the bandwidth of the signal is called **Narrowband** channel

2.6.2 Broad band Transmission

Given a bandpass channel, a digital signal cannot be transmitted directly through it

In broadband transmission we use modulation, i.e we change the signal to analog signal before transmitting it.

The digital signal is first converted to an analog signal, since we have a bandpass channel we cannot directly send this signal through the available channel. Ex. Consider the bandpass channel with lower frequency 50Hz and higher frequency 80Hz, and the signal to be transmitted has frequency 10Hz.

To pass the analog signal through the bandpass channel, the signal is modulated using a carrier frequency. Ex. The analog signal (10Hz) is modulated by a carrier frequency of 50Hz resulting in an signal of frequency 60Hz which can pass through our bandpass channel.

The signal is demodulated and again converted into an digital signal at the other end as shown in the figure below.