Channel and signal bandwidth

3.3 BANDWIDTH OF A SIGNAL

Bandwidth can be defined as the portion of the electromagnetic spectrum occupied by the signal

It may also be defined as the frequency range over which a signal is transmitted.

Different types of signals have different bandwidth. Ex. Voice signal, music signal, etc

Bandwidth of analog and digital signals are calculated in separate ways; analog signal bandwidth is measured in terms of its frequency (hz) but digital signal bandwidth is measured in terms of bit rate (bits per second, bps)

Bandwidth of signal is different from bandwidth of the medium/channel

3.3.1 Bandwidth of an analog signal

Bandwidth of an analog signal is expressed in terms of its frequencies.

It is defined as the range of frequencies that the composite analog signal carries.

It is calculated by the difference between the maximum frequency and the minimum frequency.

Consider the signal shown in the diagram below:

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The signal shown in the diagram is an composite analog signal with many component signals.
It has a minimum frequency of F1 = 30Hz and maximum frequency of F2 = 90Hz.
Hence the bandwidth is given by F2 – F1 = 90 – 30 = 60 Hz

3.3.2 Bandwidth of a digital signal

It is defined as the maximum bit rate of the signal to be transmitted.
It is measured in bits per second.

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3.4 BANDWIDTH OF A CHANNEL

A channel is the medium through which the signal carrying information will be passed.

In terms of analog signal, bandwidth of the channel is the range of frequencies that the channel can carry.

In terms of digital signal, bandwidth of the channel is the maximum bit rate supported by the channel. i.e. the maximum amount of data that the channel can carry per second.

The bandwidth of the medium should always be greater than the bandwidth of the signal to be transmitted else the transmitted signal will be either attenuated or distorted or both leading in loss of information.

The channel bandwidth determines the type of signal to be transmitted i.e. analog or digital.

3.5 THE MAXIMUM DATA RATE OF A CHANNEL

Data rate depends on three factors: 1. The bandwidth available 2. The level of the signals we use 3. The quality of the channel (the level of noise) The quality of the channel indicates two types:

a) **A Noiseless or Perfect Channel**
An ideal channel with no noise.
The Nyquist Bit rate derived by Henry Nyquist gives the bit rate for a Noiseless Channel.

b) A Noisy Channel
A realistic channel that has some noise.
The Shannon Capacity formulated by Claude Shannon gives the bit rate for a Noisy Channel

3.5.1 Nyquist Bit Rate The Nyquist bit rate formula defines the theoretical maximum bit rate for a noiseless channel

Bitrate = 2 x Bandwidth x Log2 L

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Where,

Bitrate is the bitrate of the channel in bits per second
Bandwidth is the bandwidth of the channel
L is the number of signal levels.

Example What is the maximum bit rate of a noiseless channel with a bandwidth of 5000 Hz transmitting a signal with two signal levels. **Solution:** The bit rate for a noiseless channel according to Nyquist Bit rate can be calculated as follows: BitRate = 2 x Bandwidth x $\log_2$ L = 2 x 5000 x $\log_2$ 2 =**10000 bps 3.5.2 Shannon Capacity** The Shannon Capacity defines the theoretical maximum bit rate for a noisy channel

Capacity=bandwidth X $\log_2$ (1 +SNR)

Where,

Capacity is the capacity of the channel in bits per second
Bandwidth is the bandwidth of the channel
SNR is the Signal to Noise Ratio

Shannon Capacity for calculating the maximum bit rate for a noisy channel does not consider the number of levels of the signals being transmitted as done in the Nyquist bit rate. Example: Calculate the bit rate for a noisy channel with SNR 300 and bandwidth of 3000Hz Solution: The bit rate for a noisy channel according to Shannon Capacity can be calculated as follows: Capacity=bandwidth X $\log_2$ (1 +SNR) = 3000 x $\log_2$ (1 + 300) = 3000 x $\log_2$ (301) = 3000 x 8.23 = **24,690bps**