**MODULE 1**

1. What is the channel capacity of a tele-printer channel with a 300-Hz bandwidth and a signal-to-noise ratio of 3 dB, where the noise is white thermal noise?

**Answer**

Bandwidth B = 300Hz,

SNRdb = 3dB.

SNRdb = 10 \* log(SNR)

3 = 10 \* log(SNR),

log(SNR) = 0.3

SNR = log-1(0.3)

SNR = 100.3

SNR = 1.995.

Channel Capacity C = B \* log2(1+SNR)

C = 300 \* log2(1+1.995)

C = 300 \* log2(2.995)

**C = 474.76**

1. What is bandwidth? A periodic signal has a bandwidth of 20 Hz. The highest frequency is 60 Hz. What is the lowest frequency? Draw the spectrum if the signal contains all frequencies of same amplitude.

**Answer**

Bandwidth is the difference between the upper and lower frequencies in a continuous band of frequencies. It is typically measured in [hertz](https://en.wikipedia.org/wiki/Hertz), and depending on context, may specifically refer to passband bandwidth or baseband bandwidth. Passband bandwidth is the difference between the upper and lower [cutoff frequencies](https://en.wikipedia.org/wiki/Cutoff_frequencies) of, for example, a [band-pass filter](https://en.wikipedia.org/wiki/Band-pass_filter), a [communication channel](https://en.wikipedia.org/wiki/Communication_channel), or a [signal spectrum](https://en.wikipedia.org/wiki/Signal_spectrum). Baseband bandwidth applies to a [low-pass filter](https://en.wikipedia.org/wiki/Low-pass_filter) or [baseband signal](https://en.wikipedia.org/wiki/Baseband_signal); the bandwidth is equal to its upper cutoff frequency.

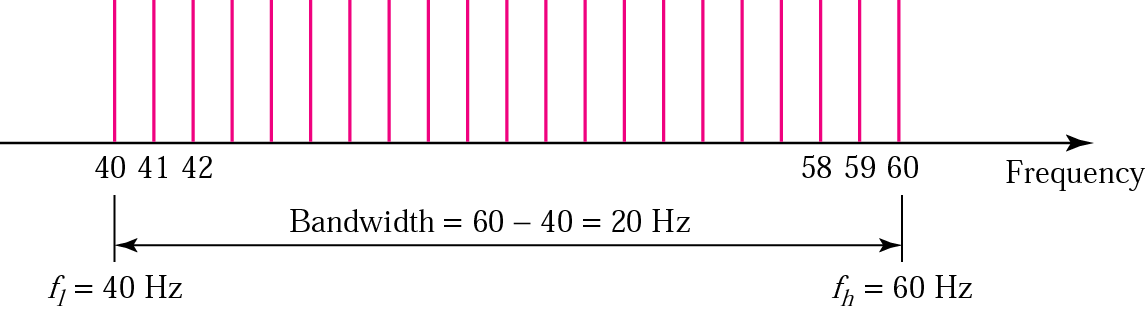
Bandwidth in hertz is a central concept in many fields, including [electronics](https://en.wikipedia.org/wiki/Electronics), [information theory](https://en.wikipedia.org/wiki/Information_theory), [digital communications](https://en.wikipedia.org/wiki/Digital_communication), [radio communications](https://en.wikipedia.org/wiki/Radio_communication), [signal processing](https://en.wikipedia.org/wiki/Signal_processing), and [spectroscopy](https://en.wikipedia.org/wiki/Spectroscopy) and is one of the determinants of the capacity of a given communication channel.

B = fh - fl

20 = 60 - fl

fl = 60 - 20 = 40 Hz

Lowest frequency = 40 Hz.



1. a) Differentiate between attenuation and delay distortion.

b) For a parabolic reflective antenna operating at 12 GHz with

a diameter of 2 m, calculate the effective area and antenna gain.

**Answer**

a)

|  |  |  |
| --- | --- | --- |
| **BASIS FOR COMPARISON** | **ATTENUATION** | **DISTORTION** |
| Shape of wave form | Does not change | Altered |
| Obliteration of the effects. | Easily removed | Harder |
| Relationship | Reduction in amplitude, and cause of distortion. | Attenuation occurs in different amount. |

b)

face area, A = π r2 = π m2

effective area, Ae = 0.56 A = 0.56 π m2

wavelength, λ = c/f = 3x108/12x109 = 0.025 m

then Gain, G = 4 π Ae/ λ2 = 35,180,

or GdB = 10log10(35,180) = 45.46 dB

**Antenna Gain = 45.46 dB**

1. Assume that a TV picture is to be transmitted over a

channel with 4.5 MHz bandwidth and a 35 dB SNR ratio.

Find the capacity of the channel.

**Answer**

B = 4.5 x 106 Hz,

SNR = 35 dB = 1035/10 = 3162,

therefore C = 4.5 x 106 log2 (1 + 3162)

C = 4.5 x 106 log2 (3163) = (4.5 x 106 x 11.63)

**C= 52.335 x 106 bps.**

1. What is the thermal noise level of a channel with a Bandwidth of 10 KHz carrying a 1000Watts power operating at 50°C?

**Answer**

B = 10Khz = 10 x 103 Hz

T = 50C

SNR = ?

N = kTB

= (1.3803x10-23)x(273+50)x(10000)

= (1.3803x10-23)x(3.2 x 106) = 4.5x10-17

SNRdB = 10log10(SNR)

= 10log10(1000/4.5x10-17)

**SNRdB =** **193.5 dB**

1. Define simplex, half duplex, full duplex transmission mode.

Give one example for each.

**Answer**

**The simplex** transmission is the one that travels in only one direction. Signal travels in only one direction from microphone to speaker. This way of transmission can be also called unidirectional or one-way transmission. Eg. Radio

**The half-duplex** transmission is capable of sending signal in both directions, but in only one direction at a time. Some networks use half-duplex transmission, but it is required to specify this requirement for all the nodes in the network.

Eg. Walkie Talkie

**Full Duplex** transmission allows signal transmission in both directions simultaneously. This type of transmission can also be called bidirectional transmission.

Eg. Telephone communication.

1. List and explain different factors which determine the

performance of communication in a network?

**Answer**

Bandwidth commonly measured in bits/second is the maximum rate that information can be transferred.

Throughput is the actual rate that information is transferred.

Latency the delay between the sender and the receiver decoding it, this is mainly a function of the signals travel time, and processing time at any nodes the information traverses.

Jitter variation in packet delay at the receiver of the information.

Error rate the number of corrupted bits expressed as a percentage or fraction of the total sent.

1. a) Explain time domain and frequency domain concept of a

signal in a communication system.

b) List various impairments and explain how they affect

information carrying capacity of a communication link?

**Answer**

1. The time-domain representation gives the amplitudes of the signal at the instants of time during which it was sampled. Time domain shows changes in signal amplitude with respect to time. It is an amplitude vs. time plot. Phase is not explicitly shown on a time domain plot .The time domain representation displays a signal using time-domain plot, which shows changes in signal amplitude with time. The time-domain plot can be visualized with the help of an oscilloscope.

The relationship between amplitude and frequency is provided by frequency domain representation, which can be displayed with the help of spectrum analyzer.

A frequency-domain graph shows how much of the signal lies within each given frequency band over a range of frequencies. A frequency-domain representation can also include information on the [phase](https://en.wikipedia.org/wiki/Phase_(waves)) shift that must be applied to each [sinusoid](https://en.wikipedia.org/wiki/Sine_wave) in order to be able to recombine the frequency components to recover the original time signal. Time domain and frequency domain representations of sine waves frequencies are given below.



b) With any communications system, it must be recognized that the received signal will differ from the transmitted signal due to various transmission impairments. For analog signals, these impairments introduce various random modifications that degrade the signal quality. For digital signals, bit errors are introduced

The most significant communication impairments are

1) Attenuation

2) Distortion

3) Noise

**Attenuation-**Attenuation means a loss of energy. The strength of a signal falls off with distance over any transmission medium. For guided media, this reduction in strength, or attenuation, is generally logarithmic and is thus typically expressed as a constant number of decibels per unit distance.



**Distortion-**Distortion means that the signal changes its form or shape. Delay distortion is a phenomenon peculiar to guided transmission media. The distortion is caused by the fact that the velocity of propagation of a signal through a guided medium varies with frequency. For a band limited signal, the velocity tends to be highest near the centre frequency and lower toward the two edges of the band.

Thus, various frequency components of a signal will arrive at the receiver at different times.

This effect is referred to as delay distortion, as the received signal is distorted due to variable delay in its components.

Noise is refers to any unwanted signal. For any data transmission event, the received signal will consist of the transmitted signal, modified by the various distortions imposed by the transmission system, plus additional unwanted signals that are inserted somewhere between transmission and reception; the latter, undesired signals are referred to as noise-a major limiting factor in communications system performance.

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1. Define channel capacity. What key factors affect highest

data rate for noiseless channel and noisy channel? Signal to

noise ratio is often given in decibels. Assume SNRdB=36 and

the channel bandwidth is 2MHz. Calculate theoretical channel capacity.

**Answer**

The rate at which data can be transmitted over a given communication path, under given conditions channel capacity is the tightest upper bound on the rate of information that can be reliably transmitted over a communication channel.

The highest rate of information that can be transmitted through a channel is called channel capacity.

A very important consideration in data communications is how fast we can send data, in bits per second, over 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)

Channel capacity C= B log2 (1+SNR)

Given ,

SNRdB = 36

Bandwidth B = 2MHz = 2×106 Hz

SNRdb = 10 log10 (SNR)

SNR = log-1 (SNRdB /10)

= log-1 (36/10)

= log-1 (3.6) = 3981.07

Channel capacity C = B log2 (1+SNR)

= 2×106 × log2 (1+3981.07)

**C= 24 Mbps**

1. What are the three parameters that represent a general sine

wave ? Explain with suitable figures.

**Answer**

The only waveforms that exist in the frequency domain are sine waves. We should also be familiar with the description of a sine wave in the time domain. It is a well-defined mathematical curve that has three terms that fully characterize absolutely everything you could ever ask about it.

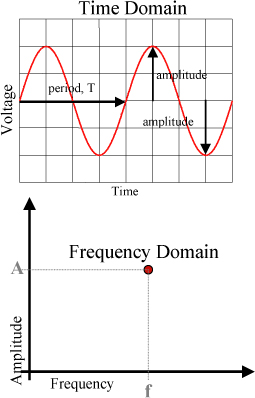
The following three terms fully describe a sine wave:

* Frequency
* Amplitude
* Phase

The frequency, usually identified using a small f, is the number of complete cycles per second made by the sine wave, in Hertz. Angular frequency is measured in radians per second. A radian is like degrees, describing a fraction of a cycle. There are 2 x p radians in one complete cycle. The Greek letter w is often used to refer to the angular frequency, measured in radians per second. The sine-wave frequency and the angular frequency are related by: ω = 2π **x** f

where:

* ω = angular frequency, in radians/sec
* π = constant, 3.14159...
* f = sine-wave frequency, in Hz



1. Discuss the significance of SNR in determining the

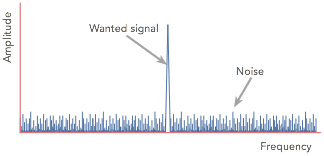
performance of a data communication system.

**Answer**

The signal to noise ratio, SNR or S/N ratio is one of the most straightforward methods of measuring radio receiver sensitivity.

It defines the difference in level between the signal and the noise for a given signal level. The lower the noise generated by the receiver, the better the signal to noise ratio.

As with any sensitivity measurement, the performance of the overall radio receiver is determined by the performance of the front end RF amplifier stage. Any noise introduced by the first RF amplifier will be added to the signal and amplified by subsequent amplifiers in the receiver. As the noise introduced by the first RF amplifier will be amplified the most, this RF amplifier becomes the most critical in terms of radio receiver sensitivity performance. Thus the first amplifier of any radio receiver should be a low noise amplifier.



SNR = Psignal/pnoise

1. a) Explain the role of Shannon capacity formula in

determining the channel capacity.

b) Suppose the spectrum of a channel is between 3 MHz and

4MHz, SNRdB=24 dB. What is the capacity of the channel?

Based on Nyquist’s formula, how many signaling levels are

required?

**Answer**

a)Shannon–Hartley theorem tells the maximum rate at which information can be transmitted over a communications channel of a specified [bandwidth](https://en.wikipedia.org/wiki/Bandwidth_(signal_processing)) in the presence of [noise](https://en.wikipedia.org/wiki/Noise_(electronics)). Shannon's [channel capacity](https://en.wikipedia.org/wiki/Channel_capacity) for such a communication link, a bound on the maximum amount of error-free [information](https://en.wikipedia.org/wiki/Information) per time unit that can be transmitted with a specified [bandwidth](https://en.wikipedia.org/wiki/Bandwidth_(signal_processing)) in the presence of the noise interference, assuming that the signal power is bounded, and that the Gaussian noise process is characterized by a known power or power spectral density. The Shannon–Hartley theorem states the [channel capacity](https://en.wikipedia.org/wiki/Channel_capacity) {\displaystyle C}, meaning the theoretical tightest upper bound on the [information rate](https://en.wikipedia.org/wiki/Information_rate) of data that can be communicated at an arbitrarily low [error rate](https://en.wikipedia.org/wiki/Bit_error_rate) using an average received signal power {\displaystyle S} through an analog communication channel subject to [additive white Gaussian noise](https://en.wikipedia.org/wiki/Additive_white_Gaussian_noise) of power {\displaystyle N}:

{\displaystyle C=B\log \_{2}\left(1+{\frac {S}{N}}\right)} C = B **x** log2(1+S/N)

Where,

* {\displaystyle C}C is the [channel capacity](https://en.wikipedia.org/wiki/Channel_capacity) in [bits per second](https://en.wikipedia.org/wiki/Bits_per_second), a theoretical upper bound on the [net bit rate](https://en.wikipedia.org/wiki/Net_bit_rate) excluding error-correction codes;
* {\displaystyle B}B is the [bandwidth](https://en.wikipedia.org/wiki/Bandwidth_(signal_processing)) of the channel in [hertz](https://en.wikipedia.org/wiki/Hertz) ;
* {\displaystyle S}S is the average received signal power over the bandwidth, measured in watts ;
* {\displaystyle N}N is the average power of the noise and interference over the bandwidth, measured in watts ; and
* {\displaystyle S/N}S/N is the [signal-to-noise ratio](https://en.wikipedia.org/wiki/Signal-to-noise_ratio) (SNR) or the [carrier-to-noise ratio](https://en.wikipedia.org/wiki/Carrier-to-noise_ratio) (CNR) of the communication signal to the noise and interference at the receiver.

1. B = 4 – 3 =1 MHz

SNRdb = 24 dB = 10 log(SNR)

**SNR = 251.19**

C = B log2 (1+SNR)

C = 106 log2(251.19) = 8 Mbps(approx).

Nyquist C= 2B log2M

8 x 106 = 2 x 106 log2M

**M = 16**

1. Explain Nyquist Bit rate and Shannon Capacity theorems.

**Answer**

The **Nyquist** Theorem, also known as the sampling theorem, is a

principle that engineers follow in the digitization of analog signals. For

analog-to-digital conversion (ADC) to result in a faithful reproduction of

the signal, slices, called samples, of the analog waveform must be taken

frequently. The number of samples per second is called the sampling rate

or sampling frequency. Nyquist gives the channel capacity in more of

theoretical interference concept and gives the channel capacity by the

formula 2Blog2(L).

The **Shannon-Hartley** Capacity Theorem, more commonly known as the

Shannon-Hartley theorem or Shannon's Law, relates the system capacity

of a channel with the averaged received signal power, the average noise

power and the bandwidth.

Shannon formula gives the channel capacity in more of practical

backgrounds considering the noise that is present in the media and thus

gives a more practical result. This capacity relationship can be stated as:

Channel capacity = B log2(1+S/N).