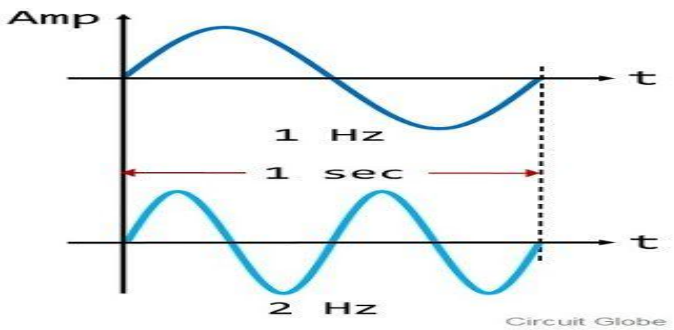
Frequency and Bandwidth

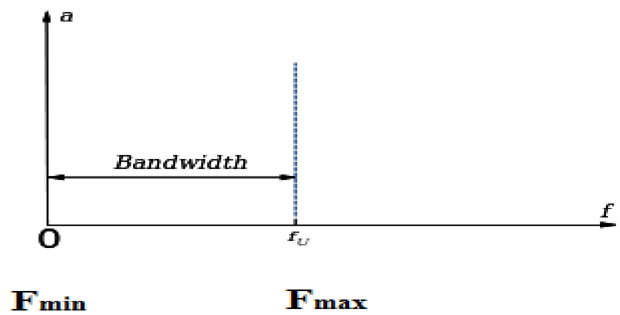
Both **frequency** and **bandwidth** are the two major terms related to data transmission.The major difference between **frequency** and **bandwidth** is

- The **frequency** shows the number of complete cycles appearing in unit time.
- The **bandwidth** is the overall amount of data transmitted in a unit time

Frequency is defined as the total number of wave cycles present in each second of a waveform. And measured in Hz



The **bandwidth of a signal** is defined as band of frequencies, that can be calculate as the difference between the upper and lower frequencies of a **signal** generated. ... It is measured in terms of Hertz (Hz).



Name	Frequency Range	Application
Low frequency	30 to 300 kHz	Navigation
Medium frequency	300 kHz to 3 MHz	Marine/Aircraft navigation, AM broadcast
High frequency	3 to 30 MHz	Broadcasting, mobile radio
Very high frequency	30 to 300 MHz	FM broadcast
Ultra-high frequency	300 MHz to 3 GHz	Cell phones, mobile radio, WLAN
Super-high frequency	3 to 30 GHz	Radar, TV

Sampling theorem

The **sampling theorem** specifies the minimum-sampling rate at which a continuous-time signal needs to be uniformly sampled so that the original signal can be completely recovered or reconstructed by these samples alone. This is usually referred to as Shannon's sampling theorem in the literature.

$$f_s \geq 2f_m$$

Where

f_s represent sampling frequency ,

f_m represent the message frequency

$$\mathbf{T = \frac{1}{Fs}}$$

$$\mathbf{F_s = \frac{1}{T}}$$

$$\boldsymbol{\omega_m = 2\pi f_m}$$

Example 1: The sampling frequency of a signal is Fs = 2000 samples per second. Find its Nyquist interval.

Answer:

Given Fs = 2000 samples per second

Nyquist interval, $T = \frac{1}{Fs} = \frac{1}{2000} = 0.5$ msec.

Example 2: Find the Nyquist rate and Nyquist interval for the signal

$f(t) = 1 + \text{sinc}\ \mathbf{300\pi}\ t$.

Answer:

Frequency, $\omega_m = 300\pi$

But $\omega_m = 2\pi f_m$

$2\pi f_m = 300\pi$

$2f_m = 300$ Hz

Nyquist rate, $Fs = 2f_m = 300$ Hz

Nyquist interval, $T = \frac{1}{Fs} = \frac{1}{300} = 3.3$ msec

Example 3: Find the Nyquist rate and Nyquist interval of sin (2πt).

Answer

Here $\omega_m = 2\pi$

But $\omega_m = 2\pi f_m$

$2\pi f_m = 2\pi$

$\therefore f_m = 1$ Hz

Nyquist rate, $Fs = 2f_m = 2$ Hz

Nyquist interval, $T = \frac{1}{Fs} = \frac{1}{2} = 0.5$ sec

Example 4: Determine the Nyquist rate of the signal x(t) = 1 + cos 2000πt + sin 4000πt.

Answer

$$x(t) = 1 + \cos 2000\pi t + \sin 4000\pi t$$

Highest frequency component in 1 is zero

Highest frequency component in cos2000πt is $\omega m1 = 2000\pi$

Highest frequency component in sin4000πt is $\omega m2 = 4000\pi$

So the maximum frequency component in x(t) is $\omega m = 4000\pi$

$\therefore 2\pi fm = 4000\pi$

$2fm = 4000$

Nyquist rate, Fs = 2fm = 4000 Hz

Classwork

1. A periodic signal completes one cycle in 0.001 s. What is the frequency?
2. What is the bandwidth of a signal that ranges from 1 MHz to 4 MHz?
3. The _____ of a composite signal is the difference between the highest and the lowest frequencies contained in that signal