ANALYSIS OF MODULATION AND DATA TRANSMISSION TECHNIQUES

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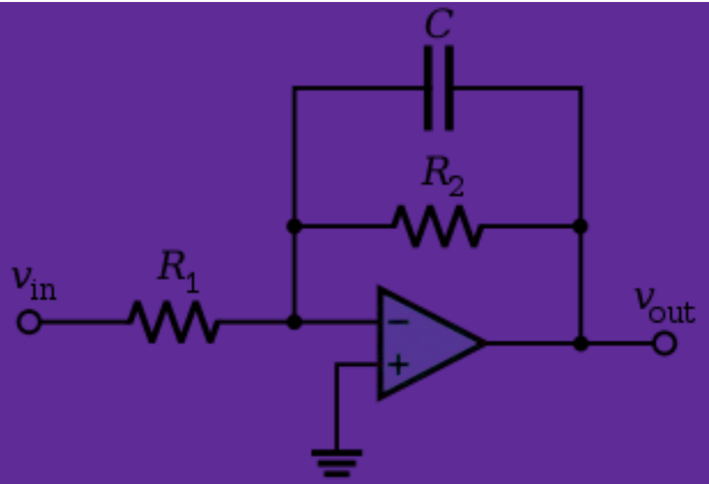
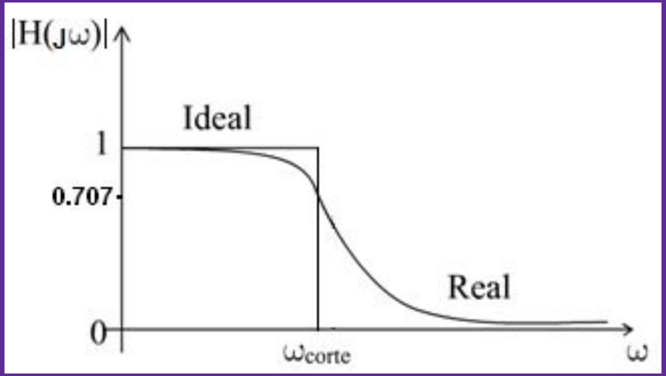
Topics to be Presented

Our work is the presentation of our capabilities

- Time-Division Multiplexing
- Frequency-Division Multiplexing
- QAM
- Phase Shift Keying
- Low Pass Filtering
- FFT & IFFT
- Orthogonal functions
- OFDMA
- SC-FDMA
- Channel Bandwidth

Low Pass Filtering



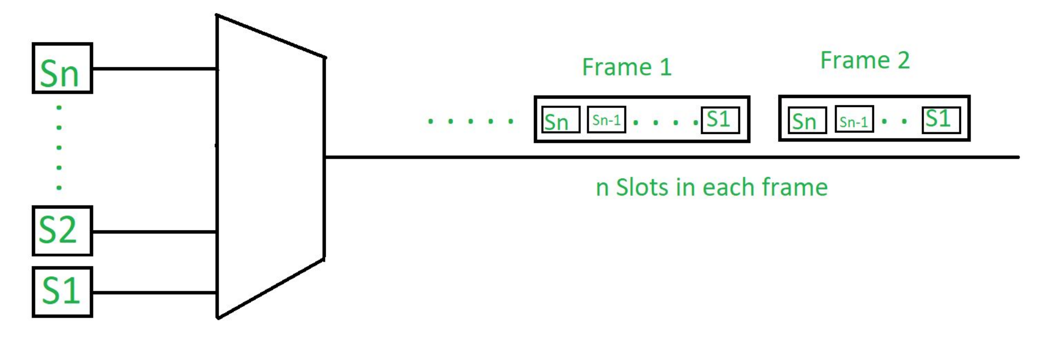


Time-Division Multiplexing

TDM is a method of transmitting and receiving independent signals over a common signal path by means of synchronized switches at each end of the transmission line so that each signal appears on the line only a fraction of time in an alternating pattern

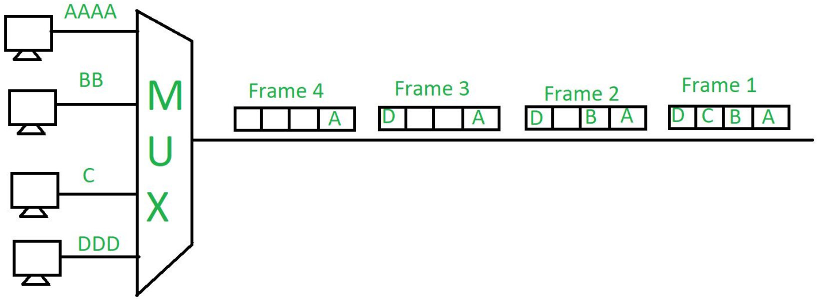
This happens when data transmission rate of media is greater than that of the source, and each signal is allotted a definite amount of time

These slots are so small that all transmissions appear to be parallel

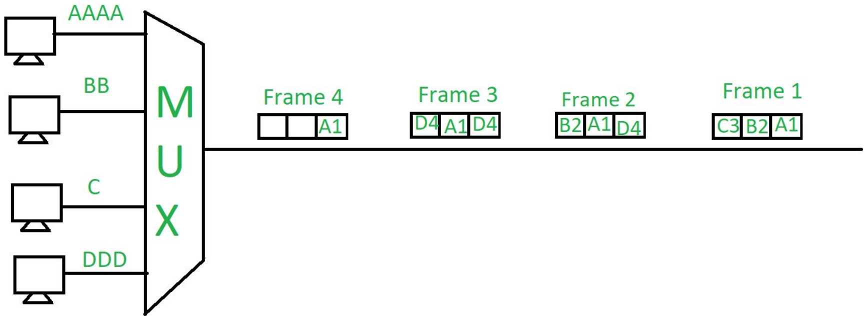


Synchronous TDM vs Asynchronous TDM

- Provides a certain amount of time slots to all users
- guarantees the users data will be transmitted within the time period
- time slots may get wasted
- Their rate of data transmission is same. Thus the name **'synchronous'**



- Provides time slots to only active users
- no guarantee the users data will when be transmitted
- saves any wastage of time slots
- If the devices have nothing to transmit, then their time slot is allocated to another device



Channel Bandwidth

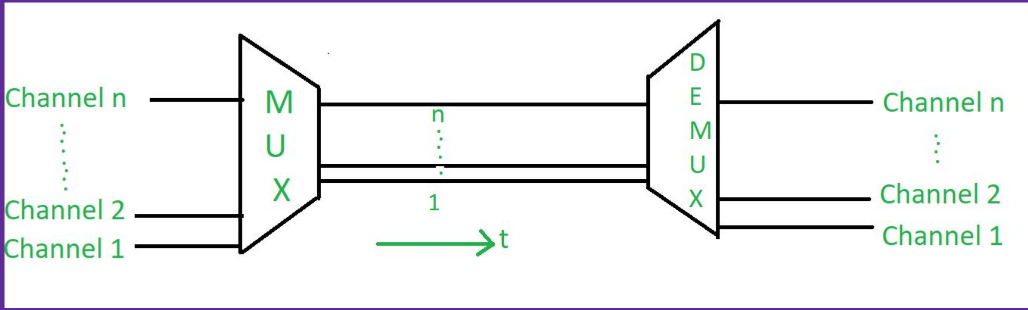
Channel is a medium through which information is transmitted between transmitter and receiver. Channel bandwidth is the frequency range that constitutes the channel. Generally, centre frequency is specified and then we say a 'bandwidth of m Hz centered about a frequency fc Hz'

Frequency-Division Multiplexing

Frequency division multiplexing (FDM) is a technique of multiplexing which means combining more than one signal over a shared medium.

There is a suitable frequency gap between the 2 adjacent signals to avoid overlapping\

Frequency spectrum is divided into several logical channels, in which every user feels that they possess a particular bandwidth



TDM vs FDM

TDM

- Divides certain time periods to each channel
- Each signal uses all of the bandwidth some of the time
- More flexible in allocating more time period to signals who need to send more data at that time

FDM

- Divides the channel into two or more frequency ranges that do not overlap
- Each signal uses a small portion of the bandwidth all of the time
- Cannot have this flexibility as certain bandwidths are allocated for each signal all the time

Applications:

TDM

- To control internet traffic
- To transmit signal slowly compared to speed in which it is processed
- Digitally transmitting several telephone conversations over the same four-wire copper cable

FDM

- Since, FDM will take less time to transmit a signal, so used in places where time is of utmost priority like real time data sending.

Orthogonal functions

Functions whose vector product is zero. The vector product will be defined as integral of their multiplication in the real line. Eg - sin,cos

Two signals are said to be orthogonal if they are mutually independent. This in practice means that they do not interfere with each other or that their effects on each other cancel out.

Orthogonal FDM

In FDM systems carriers are far apart with respect to each other and in OFDM systems carriers are densely packed and are orthogonal to the other carriers.
Orthogonal means peak of one carrier occurs at null of the other. Hence OFDM system is bandwidth efficient compare to FDM system. The orthogonality requires that the sub-carrier spacing is

$$\boxed{\Delta f = \frac{k}{T_U}}$$

where TU seconds is the useful symbol duration (the receiver-side window size), and k is a positive integer, typically equal to 1.

Orthogonal frequency-division multiple access

Multiple access is achieved in OFDMA by assigning subsets of subcarriers to individual users.

This allows simultaneous low-data-rate transmission from several users. IN TDM several users could send information but with some queuing system i.e. there used to be a time lag to send the data. Here it could be send simultaneously.

SC-FDMA

(Single Carrier frequency-division multiple access)

In it various users can transmit info simultaneously. This is divided into the various frequencies and transferred rather than providing separate bandwidths to various users.

Quadrature Amplitude Modulation

Method of combining two amplitude-modulated (AM) signals into a single channel, thereby doubling the effective bandwidth

The two carrier waves of the same frequency are out of phase with each other by 90°, a condition known as orthogonality and as quadrature.
Being the same frequency, the modulated carriers add together, but can be coherently separated (demodulated) because of their orthogonality property

In a QAM signal, one carrier lags the other by 90°, and its amplitude modulation is customarily referred to as the in-phase component, denoted by I(t). The other modulating function is the quadrature component, Q(t).

The composite waveform is mathematically modeled as:

$$s_s(t) \triangleq \sin(2\pi f_c t) \cdot I(t) \; + \; \underbrace{\sin\left(2\pi f_c t + \tfrac{\pi}{2}\right)}_{\cos(2\pi f_c t)} \cdot Q(t),$$

where f_c is the carrier frequency. At the receiver, a coherent demodulator multiplies the received signal separately with both a cosine and sine signal to produce the received estimates of $I(t)$ and $Q(t)$.

For example:

$$r(t) \triangleq s_c(t)\cos(2\pi f_c t) = I(t)\cdot\cos(2\pi f_c t)\cos(2\pi f_c t) - Q(t)\cdot\sin(2\pi f_c t)\cos(2\pi f_c t).$$

$$\begin{aligned} r(t) &= \tfrac{1}{2}I(t)\left[1+\cos(4\pi f_c t)\right] - \tfrac{1}{2}Q(t)\sin(4\pi f_c t) \\ &= \tfrac{1}{2}I(t) + \tfrac{1}{2}[I(t)\cos(4\pi f_c t) - Q(t)\sin(4\pi f_c t)]. \end{aligned}$$

FFT (Fast Fourier Transform)

a faster way to calculate discrete fourier transform of a sample of signals

IFFT (Inverse Fast Fourier Transform)

$$\boxed{x_n = \frac{1}{N} \sum_{k=0}^{N-1} X_k \cdot e^{i2\pi kn/N}}$$

Phase Shift Keying

the digital modulation technique in which the phase of the carrier signal is changed by varying the sine and cosine inputs at a particular time

Types

- BPSK
  (Binary Phase Shift Keying)
- QPSK
  (Quadrature Phase shift keying)

Binary Phase Shift Keying

It uses two phases which are separated by 180° and so can also be termed 2-PSK. As it uses just one phase, it will handle noise more efficiently as other forms of PSKs.However, it will handle only one bit/symbol.The phases are:

$$\boxed{s_0(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi ft + \pi) = -\sqrt{\frac{2E_b}{T_b}}\cos(2\pi ft)}$$

$$\boxed{s_1(t) = \sqrt{\frac{2E_b}{T_b}}\cos(2\pi ft)}$$

Thus the signal can be specified using one basis function:

$$\boxed{\phi(t) = \sqrt{\frac{2}{T_b}}\cos(2\pi ft)}$$

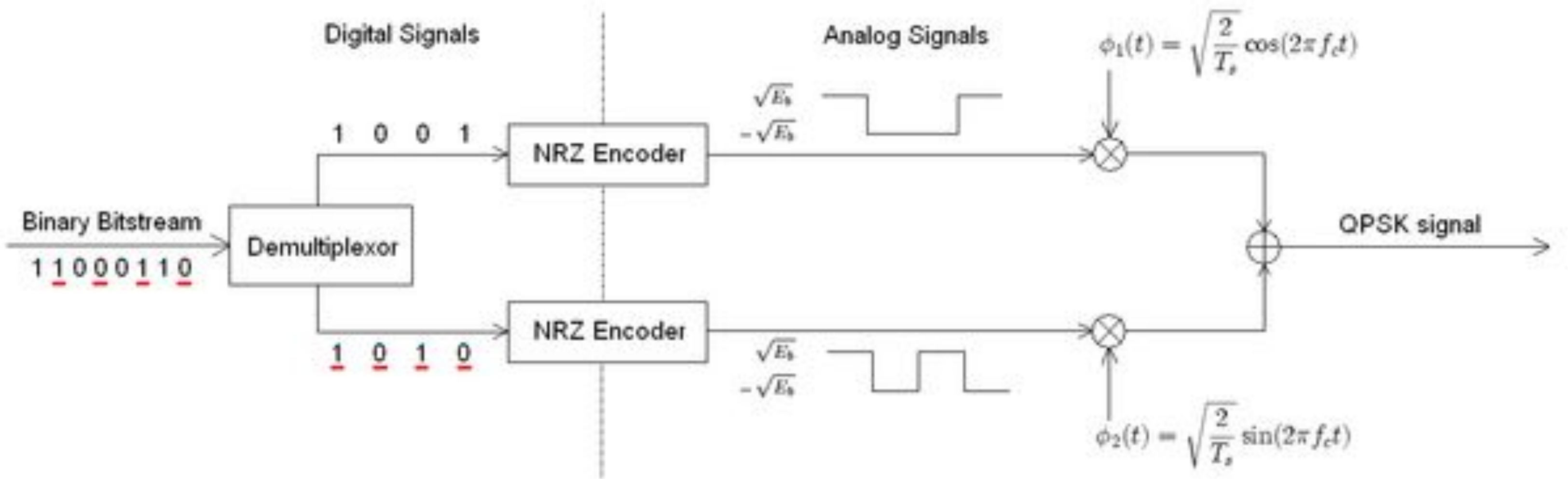
Quadrature Phase shift keying

Uses 4 phases separated by 90 deg . So can handle 2 bits/symbol.
Thus QPSK can be used either to double the data rate compared with a BPSK system while maintaining the same bandwidth of the signal, or to maintain the data-rate of BPSK but halving the bandwidth needed.

Thus, signal can be represented as:

$$\boxed{s_n(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right), \quad n = 1, 2, 3, 4.}$$

Thus we will have two basis functions for representing the signal



The binary data stream is split into the in-phase and quadrature-phase components. These are then separately modulated onto two orthogonal basis functions. In this implementation, two sinusoids are used. Afterwards, the two signals are superimposed, and the resulting signal is the QPSK signal.

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THANK YOU