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TENET TECHNETRONICS

BASIC MODULATION TECHNIQUES

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INTRODUCTION

The main purpose of communication system is to convey information through a medium or communication channel. The information is often represented as a baseband signal, i.e. a signal whose spectrum extends from 0 to some maximum frequency. Proper utilization of the communication channel often requires a shift of the range of baseband frequencies into other frequency ranges suitable for transmission, and a corresponding shift back to the original frequency range after reception. Lower frequency baseband signals have high wavelength. And the height of the antenna used is proportional to the wavelength of modulating signal, thus lower the frequency of the signal, higher will be the antenna height. This gives the main reason for why modulation is required.

Modulation: A shift of the range of frequencies in a signal is accomplished by using modulation, which is defined as the process by which some characteristic of a carrier is varied in accordance with a modulating (signal) wave signal.

Types of Modulation

Analog Modulation

- Amplitude Modulation, AM
- Frequency Modulation, FM
- Double and Single Sideband, DSB and SSB

Digital Modulation

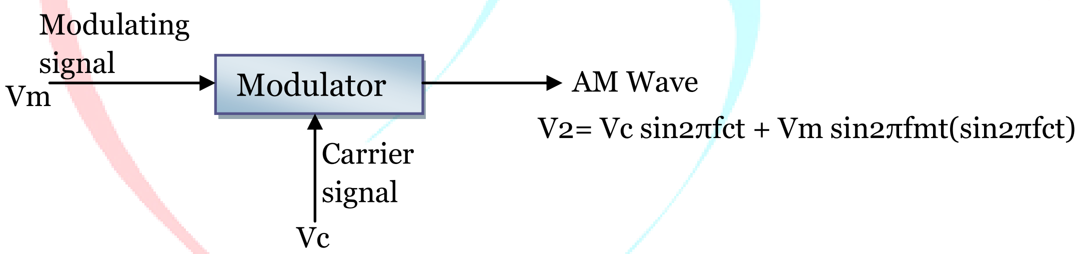
- Amplitude Shift Keying, ASK
- Phase Shift Keying: BPSK, QPSK, MSK
- Frequency Shift Keying, FSK
- Quadrature Amplitude Modulation, QAM

Analog Modulation

A common form of the carrier is a sinusoidal wave, also called as continuous-wave modulation. The baseband signal is referred to as the **modulating wave**, and the result of the modulation process is referred to as the **modulated wave.** Modulation is performed at the transmitting end. At the receiving end, we require the original baseband signal to be restored. This is accomplished by using a process known as demodulation, which is the reverse of the modulation process.

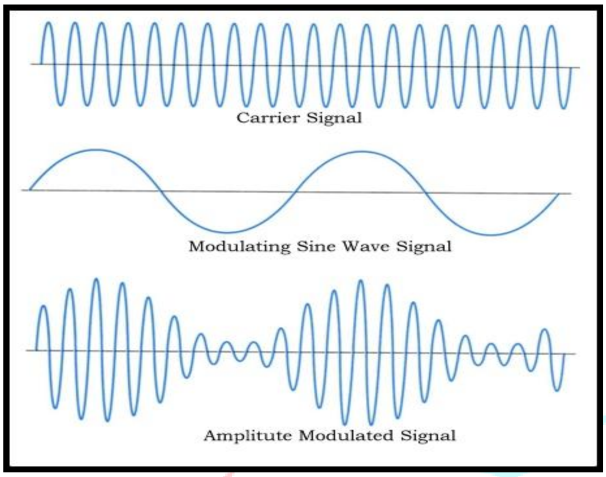
- **Amplitude Modulation, AM**

In AM, the information signal varies amplitude of the carrier sine wave. To avoid distortion of the signal, always carrier frequency should be greater than frequency of modulating signal i.e. **fm < fc.** Increase or decrease in amplitude of modulating signal causes increase or decrease in amplitude of carrier signal.



Thus AM is the product of carrier and modulating signal. The circuit which converts lower frequency baseband signal to higher frequency signal is called modulator.

The frequency that occur as sum and difference of carrier and modulating frequency is called sideband frequency. There are two sideband frequencies for a signal tone modulating signal. These are called upper sideband frequency (f_{USB}) and lower sideband frequency (f_{LSB}). Bandwidth of AM wave is calculated as difference of f_{USB} and f_{LSB} .



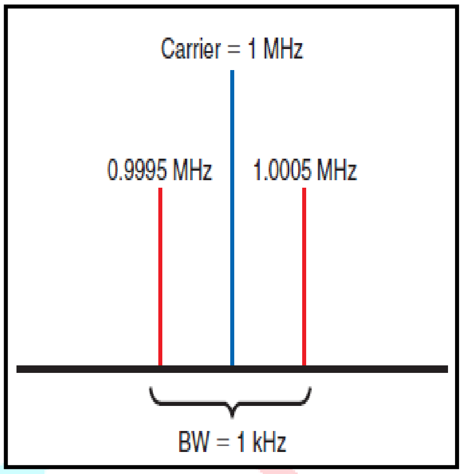


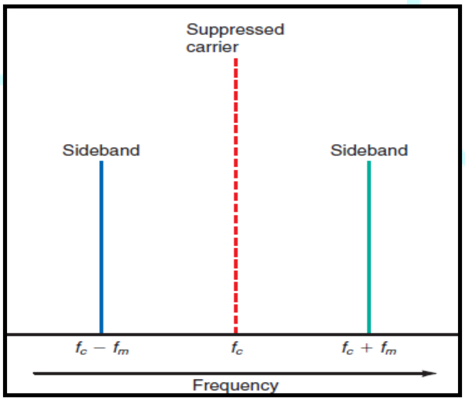
Fig: AM modulated signal

Fig: spectral diagram of AM

- **Double and Single Sideband, DSB and SSB**

In AM, 2/3 rd of the transmitted power is carrier, which conveys no information. To increase the efficiency we have to suppress carrier and eliminate one of the sideband frequency.

Double sideband: The first step in generating an SSB signal is to suppress the carrier, leaving the upper and lower sidebands. This type of signal is referred to as a double-sideband suppressed carrier (DSSC or DSB) signal. The benefit, of course, is that no power is wasted on the carrier. The envelope of this waveform is not the same as that of the modulating signal, as it is in a pure AM signal with carrier. A unique characteristic of the DSB signal is the phase transitions that occur at the lower-amplitude portions of the wave.



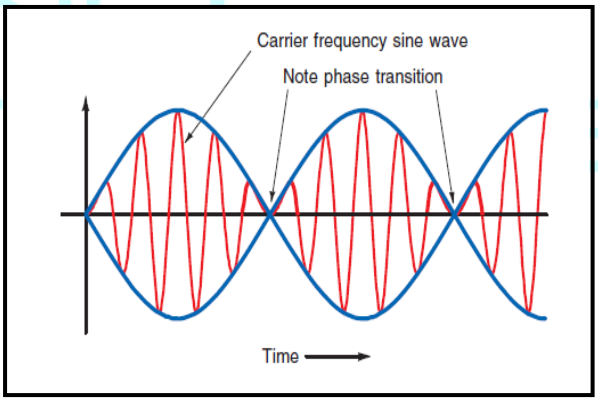


Fig : spectrum of DSB

Fig: DSB signal

DSB is generated by a balanced modulator. The main disadvantage of DSB is the it's difficult to demodulate at the receiver side. It is mainly used to transmit color information in TV signal.

Single Sideband: In DSB transmission, since the sidebands are the sum and difference of the carrier and modulating signals, the information is contained in both sidebands. As it turns out, there is no reason to transmit both sidebands in order to convey the information. One sideband can be suppressed; the remaining sideband is called a single-sideband suppressed carrier (SSSC or SSB) signal. SSB signals offer four major benefits.

- The primary benefit of an SSB signal is that the spectrum space it occupies is only one-half that of AM and DSB signals. This greatly conserves spectrum space and allows more signals to be transmitted in the same frequency range.
- All the power previously devoted to the carrier and the other sideband can be channeled into the single sideband, producing a stronger signal that should carry farther and be more reliably received at greater distances. Alternatively, SSB transmitters can be made smaller and lighter than an equivalent AM or DSB transmitter because less circuitry and power are used.
- Because SSB signals occupy a narrower bandwidth, the amount of noise in the signal is reduced.
- There is less selective fading of an SSB signal over long distances.

The main disadvantage of SSB is that as there is no carrier it's difficult to recover, thus sometimes low level carrier is transmitted in SSB, this is called pilot carrier.

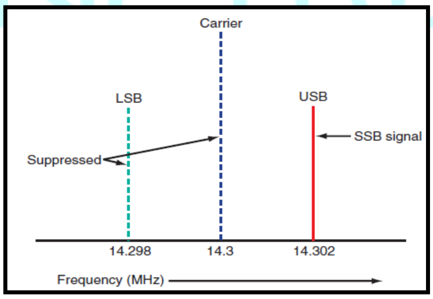


Fig: SSB spectrum

Frequency Modulation:

In Frequency modulation frequency of the carrier is varied in accordance with modulating signal frequency. Frequency deviation measures the change in transmitter output frequency to input carrier frequency. Frequency deviation is proportional to the amplitude of the modulating signal. There are two methods to generate FM signal:

- Direct method: Here FM signal is directly produced using a frequency modulated oscillator (FMO). FMO contains varactor diode, capacitor when reverse biased. It can convert an input voltage into varying oscillator output frequency.
- Indirect method: Here FM is generated using PM (Phase Modulated) signal. This is shown in figure below.

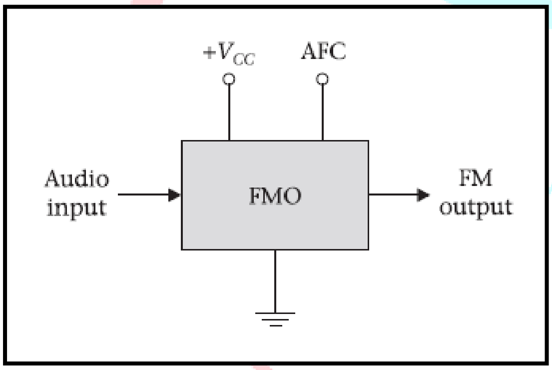


Fig: Direct Method

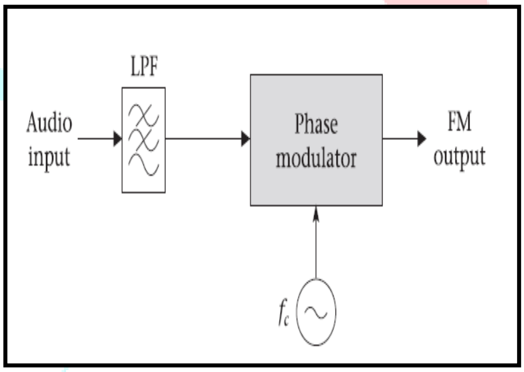


Fig: Indirect Method

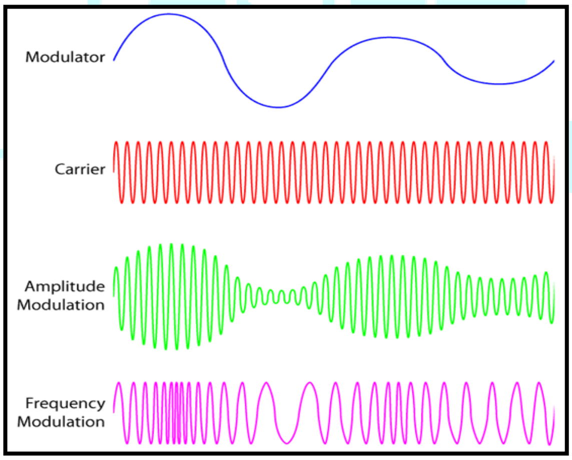


Fig: Frequency modulation

Difference between AM and FM:

- AM has poorer sound quality as compared to FM, but it's cheaper and can be transmitted over long distance. It has a lower bandwidth so it can have more stations available in any frequency range.
- AM radio ranges from 535-1705 KHZ or upto 1200bps. FM radio ranges from 88-108MHZ or upto 1200-2400 bps.
- Bandwidth required for AM is 2fm, for FM is 2(frequency deviation + fm).
- AM is more susceptible to Noise than FM.

Digital Modulation

In a digital communication system, the source to be transmitted is discrete both in time and amplitude. Digital information carrying signals must be first converted to an analog waveform prior to transmission. At the receiving end, analog signals are converted back to a digital format before presentation to the end user. The conversion process at the transmitting end is known as modulation. The receiving end is known as demodulation or detection. In digital wireless communication systems, the modulating signal may be represented as a time sequence of symbols or pulses, where each symbol has m finite states. Each symbol represents n bits of information where n = log2m bits/symbol.

For a better quality and efficient communication, digital modulation technique is employed. The main advantages of the digital modulation over analog modulation include available bandwidth, high noise immunity and permissible power. In digital modulation, a message signal is converted from analog to digital message, and then modulated by using a carrier wave. The carrier wave is switched on and off to create pulses such that the signal is modulated. Similar to the analog, in this system, the type of the digital modulation is decided by the variation of the carrier wave parameters like amplitude, phase and frequency.

Amplitude shift keying (ASK): In ASK amplitude of the carrier is changed in accordance with information and all else is kept unchanged. Bit 1 is transmitted by a carrier of particular amplitude; Bit 0 is transmitted with same frequency by different Amplitude carrier. On off keying (OOK) is one special type of ASK where no amplitude is transmitted for bit 0.

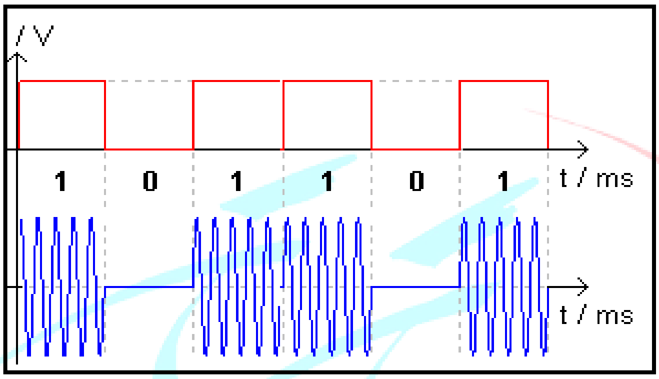


Fig: ASK signal

Frequency shift keying (FSK): When two different frequencies are used to represent two different symbols, then the modulation technique is termed as BFSK (Binary FSK).BFSK can be a wideband or a narrow band digital modulation technique depending upon the separation between the two carrier frequencies, though cost effective and provides simple implementations but is not a bandwidth efficient technique and is normally ruled out because of the receiver design complexities.

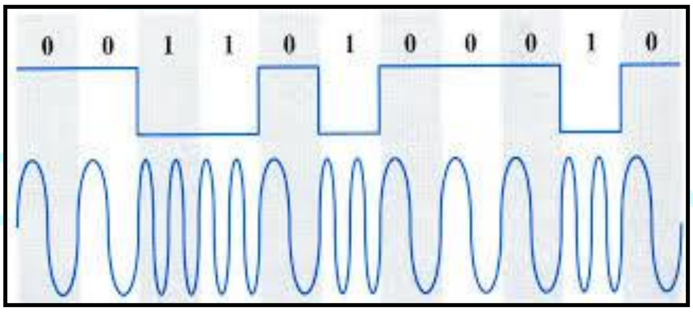


Fig: FSK signal

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Phase shift keying (PSK): When the phase of the carrier wave is altered with reference of the modulating signal then the resultant modulation scheme is termed as Phase Shift Keying. It is normally used for high speed data transfer application, provides a 3dB power advantage over the BASK modulation technique and is robust and simple in implementation but proves to be an inefficient user of the provided bandwidth and is normally termed as a non-linear modulation scheme. It provides small error rates than any other systems. The modulation techniques provide a number of derivatives.

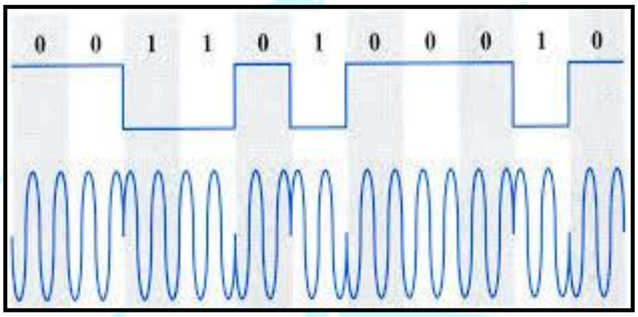

Fig: PSK signal

Quadrature shift keying (QPSK): QPSK uses two basic functions namely sine and a cosine. But BPSK uses only one basic function. By varying the phase of each of these carriers, we can transmit 2 bits per each signal. Thus QPSK is called 2-D function because it uses 2 basic functions, not because it transmits 2 bits. QPSK has four message points in the constellation diagram and so it becomes a highly bandwidth efficient digital modulation technique.

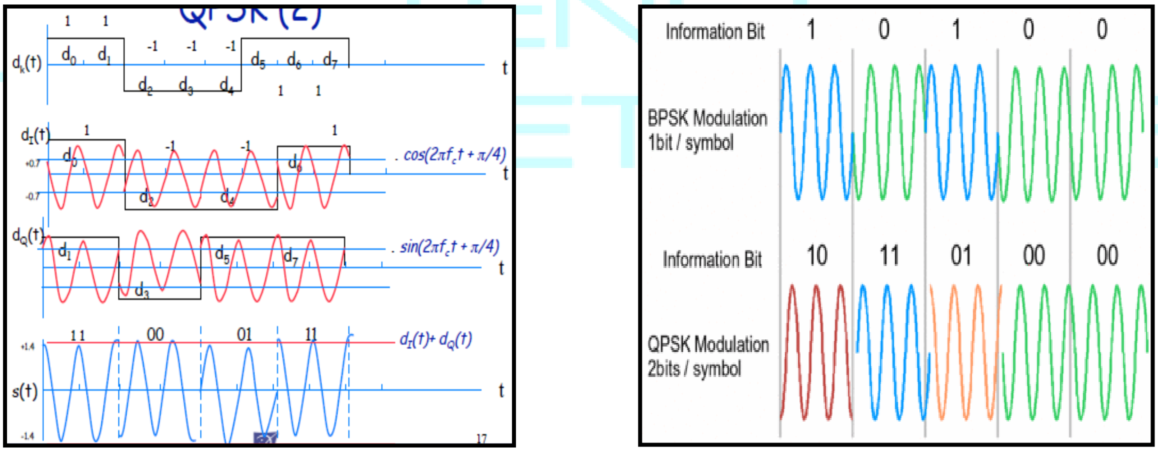

Fig: QPSK signal

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Offset QPSK (OQPSK): this is a type of QPSK where Q channel is shifted by half a symbol time so that I and Q channel signals don't transition at same time. This avoids inter symbol interferences (ISI).

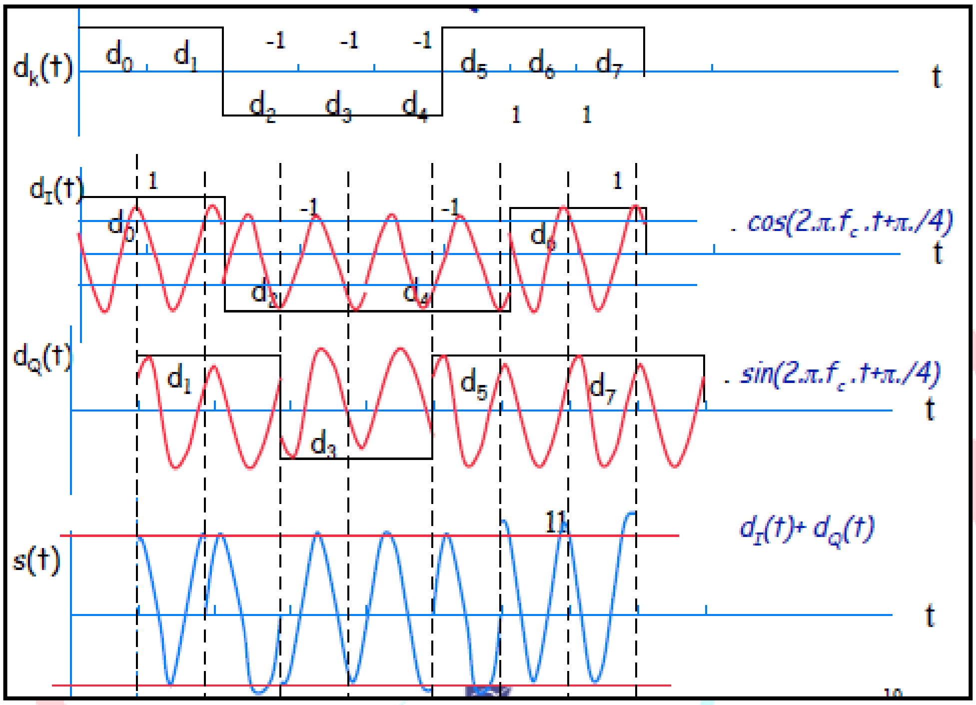

Fig: OQPSK signal

Differential PSK (DPSK): DPSK is non-coherent form of phase shift keying which avoids the need for a coherent reference signal at the receiver. Input binary sequence is first differentially encoded and then modulation using a BPSK modulator. Differentially encoded sequence $\{d_k\}$ is generated from the input binary sequence $\{m_k\}$ by complementing the modulo-sum of m_k and d_k^{-1}. For the transmission of a symbol 1, the phase is unchanged whereas for transmission of symbol 0, the phase of the signal is advanced by 180° .

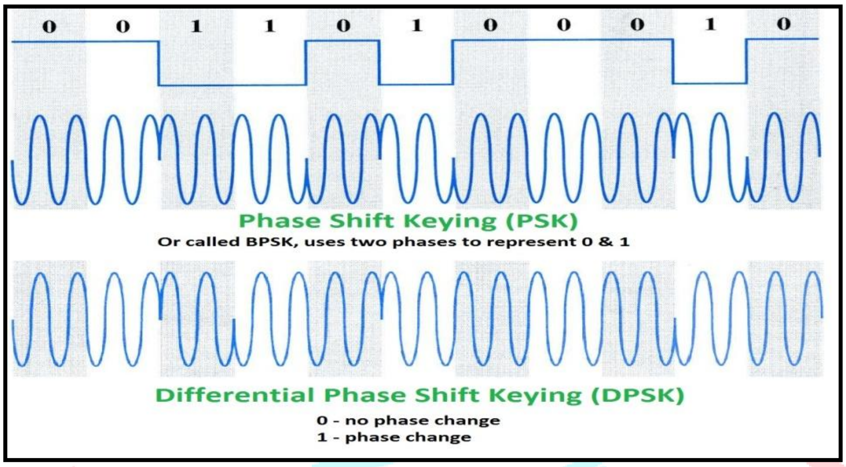

Fig: DPSK and PSK signal

Minimum shift keying (MSK): MSK is derived from OQPSK. OQPSK uses square root raised cosine pulse for waveform shaping, whereas MSK uses half cycle sinusoid. It is also called continuous phase FSK (CPFSK) with modulation index=0.5. This results in minimum frequency separation such that modulation frequencies are still orthogonal.

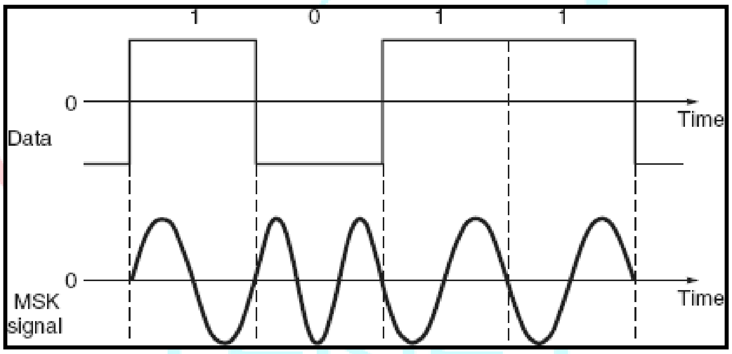

Fig: MSK signal

Gaussian MSK (GMSK): GMSK is a continuous phase frequency shift keying (CPFSK) modulation scheme. Here data stream is first shaped with a Gaussian filter by applying a frequency modulator. GMSK signals have lower side lobe and narrower main lobe as compared to QPSK and MSK. Since GMSK signals have reduced side lobe power thus interferences will be less. There is no phase discontinuity because the frequency changes occur at carrier zero crossing. Logic 1 to Logic 0 difference is half the data rate. Bandwidth of GMSK depends on Pre filter Bandwidth B and bit period T_B.

Orthogonal Frequency division Multiplexing (OFDM): OFDM is a modulation scheme having multicarrier transmission. Available carrier spectrum is divided into many carriers each one being modulated at a low rate data stream using QAM, PSK modulation. The spacing between the sub- carriers is closer and the sub- carriers are orthogonal to one another preventing interferences between the closely spaced carriers. Thus OFDM is said to be a combination of modulation and multiplexing techniques. The serial data is split to parallel data streams for easy transmission.

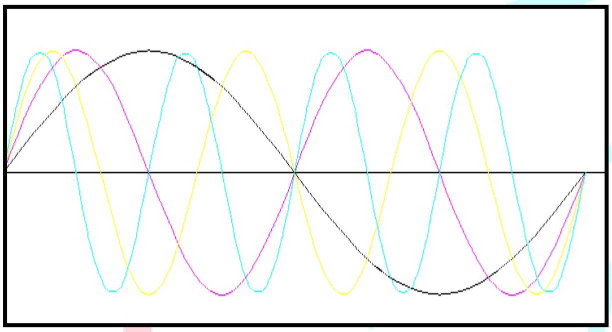

Fig: OFDM signal in Time domain

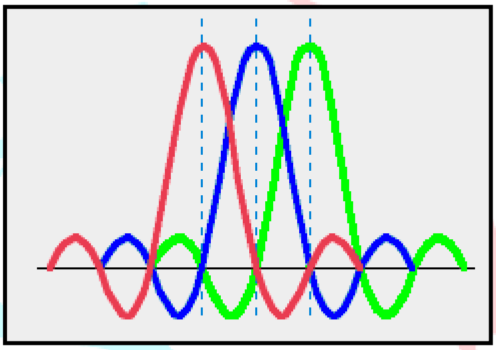

Fig: OFDM signal in Frequency domain

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