Communications

For

EC / IN

By

THE GATE ACADEMY©
A Forum of IIT / IISc Graduates

www.thegateacademy.com

✆080-40611000

Syllabus for Communications

Random Processes, Autocorrelation and Power Spectral Density, Properties of White Noise, Filtering of Random Signals Through LTI Systems, Analog Communications, Amplitude Modulation and Demodulation, Angle Modulation and Demodulation, Spectra of AM and FM, Super heterodyne Receivers, Circuits for Analog Communications, Information Theory, Entropy, Mutual Information and Channel Capacity Theorem, Digital Communications, PCM, DPCM, Digital Modulation Schemes, Amplitude, phase and Frequency Shift Keying (ASK, PSK, FSK), QAM, MAP and ML Decoding, Matched Filter Receiver, Calculation of Bandwidth, SNR and BER for Digital Modulation, Fundamentals of Error Correction, Hamming Codes, Timing and Frequency Synchronization, Inter-Symbol Interference and its Mitigation, Basics of TDMA, FDMA and CDMA.

Previous Year GATE Papers and Analysis

GATE Papers with answer key

thegateacademy.com/gate-papers

Subject wise Weightage Analysis

thegateacademy.com/gate-syllabus

Contents

	Chapters	Page No.
#1.	**Amplitude Modulation (AM)**	**1 – 15**
	• Introduction	1 – 2
	• Modulation	2 – 3
	• Amplitude Modulation	3 – 6
	• Single Tone Modulation of AM	6 – 7
	• Multi –Tone Modulation	7 – 9
	• Generation on AM Signals	9 – 10
	• Demodulation of AM signals	10 – 15
#2.	**DSBSC, SSB and VSB Modulation**	**16 – 35**
	• Introduction	16
	• Double-Sideband Suppressed Carrier (DSB-SC)	16 – 18
	• Generation of DSB-SC Signals	18 – 19
	• Demodulation of DSB Signals	20 – 21
	• Single Sideband Modulation	21 – 22
	• Generation of SSB Signals	22 – 23
	• Demodulation of SSB Signals	23 – 24
	• Vestigial Sideband (VSB) Modulation	24 – 31
	• Frequency Division Multiplexing	31 – 35
#3.	**Angle Modulation**	**36 – 57**
	• Introduction	36
	• Phase Modulation	36
	• Frequency Modulation	36 – 38
	• Narrow Band FM	38
	• Wideband FM	39 – 43
	• Pre Emphasis and De Emphasis	43 – 44
	• Demodulation of FM Signals	44 – 46
	• Foster-Seeley Discriminator	46 – 47
	• Ratio Detector	47 – 51
	• Phase Locked Loop	52 – 55
	• Theory Inclusion	56 – 57
#4.	**Receivers**	**58 – 69**
	• AM Receivers	58 – 59

- Characteristic Parameters of Receiver 59 – 69

#5. **Noise in Analog Modulation** **70 – 96**
- Noise 70 – 71
- Figure of Merit 72 – 74
- Noise in FM 74 – 75
- Channel Capacity Theorem (OR) Shannon – Hartley Law 75 – 76
- Capacity of AWGN(Additive White Gaussian Noise) Channel 76 – 78
- Random Variables 79 – 81
- Random Process 81
- Probability Density Function (PDF) 82 – 92
- Quantization Noise Power (N_q) 92 – 96

#6. **Digital Communications** **97 – 135**
- Introduction 97 – 98
- Pulse Analog Modulation 98 – 105
- Pulse Width Modulation (PWM) 105 – 106
- Pulse Position Modulation 106 – 107
- Pulse Code Modulation (PCM) 107 – 109
- DPCM (Differential Pulse Code Modulation) 109
- Delta Modulation (DM) 110 – 111
- Adaptive Delta Modulation (ADM) 111
- Electrical Representation of Binary Data 111 – 113
- Time Division Multiplexing (TDM) 114 – 119
- Differential Phase Shift Keying 119 – 131
- Quadrature Amplitude Modulation (QAM) 131 – 132
- Maximum a Posteriori (MAP) Decoding 132
- Decoding of Convolutional Codes 132 – 133
- Fundamental of Error Correction 133 – 135

Reference Books **136**

> "Nearly every man who develops an idea works it up to the point where it looks impossible, and then he gets discouraged. That's not the place to become discouraged."
>
> **....Thomas A. Edison**

CHAPTER 1

Amplitude Modulation (AM)

Learning Objectives

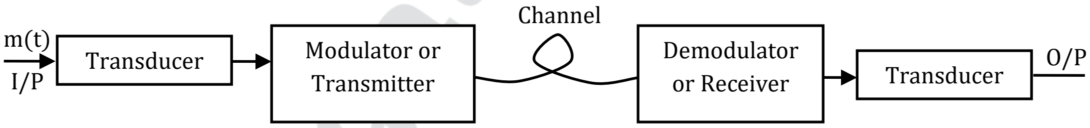
After reading this chapter, you will know:

1. Modulation, Amplitude Modulation, Single Tone Modulation of AM, Multi-Tone Modulation
2. Carrier & Side Band Power, Spectral Analysis, Generation, Demodulation Scheme
3. Generation of AM Signals, Demodulation of AM Signals

Introduction

Irrespective of the form of communication process being considered, there are three basic elements to every communication system, namely, Transmitter, Channel and Receiver. The transmitter is located at one point in space, the receiver is located at some other point separate from the transmitter and the channel is the physical medium that connects them. The purpose of the transmitter is to convert the message signal produced by the source of information into a form suitable for transmission over the channel.

Generalized Block Diagram



However, as the transmitted signal propagates along the channel, it is distorted due to channel imperfections. Moreover, noise and interfering signals are added to the channel output, with the result that the received signal is a corrupted version of the transmitted signal. The receiver has the task of operating on the received signal so as to reconstruct it to a recognizable form of the original message signal.

Normally used communication channels are twisted pair, coaxial cable, fiber optic cable and free space.

Primary Communication Resources

In a communication system, two primary resources are employed: Transmitted Power and Channel Bandwidth. The transmitted power is the average power of the transmitted signal. The channel bandwidth is defined as the band of frequencies allocated for the transmission of the message signal. A general system design objective is to use these two resources as efficiently as possible. In most communication channels, one source may be considered more important than the other. Therefore, communication channels are classified as power limited or band limited.

When the spectrum of a message signal extends down to zero or low frequencies, we define the bandwidth of the signal as that upper frequency above which the spectrum content of the signal is negligible and therefore unnecessary for transmitting information. The important point is unavoidable presence of noise in a communication system. Noise refers to unwanted waves that tend to disturb the transmission and processing of message signals in a communication system. The source of noise may be internal or external to the system.

A quantitative way to account for the effect of noise is to introduce Signal to Noise Ratio (SNR) as a system parameter. We may define the SNR at the receiver input as the ratio of the average signal power to the average noise power, both being measured at the same point.

Modulation

- Modulation is defined as "The process in which some characteristic parameter of a high frequency carrier is varied linearly with which contains information message signal".
- Generally, the carrier is represented by $c\ (t) = A_c \cos\ (2\pi f_c t\ +\ \phi)$.
- The three characteristic parameters of the carrier are A_c (peak amplitude), f_c (frequency) and ϕ (phase).

Accordingly, the three types of modulation are

1. Amplitude Modulation (AM)
2. Frequency Modulation (FM)
3. Phase Modulation (PM)

In frequency domain, modulation is defined as "The process of translating the spectrum of a signal from low frequency region to high frequency region".

Modulator Converts

- Low frequency signal to a high frequency signal.
- A wide band signal into narrow band signal.
- A baseband signal into band pass signal.

Need for Modulation

1. **To reduce the antenna height:**
   The antenna height required to transmit a signal depends on operating wavelength. For efficient radiation, the minimum height should be $\lambda/10$. To transmit a low frequency signal antenna height required is very high. To reduce the antenna height, the low frequency signal is converted into a high frequency signal by modulation.

2. **For multiplexing of signals:**
   Multiplexing allows transmission of more than one signal through the same communication channel. By modulation it is possible to allot different frequencies to various signals so that there is no interference.

3. **To reduce noise and interference:**
   Sometimes the effect of noise will be more at some frequencies and the effect will be less at some other frequencies. If the effect of noise is more at some particular frequency, by modulation the spectrum is shifted to higher frequencies where the effect of noise is less.

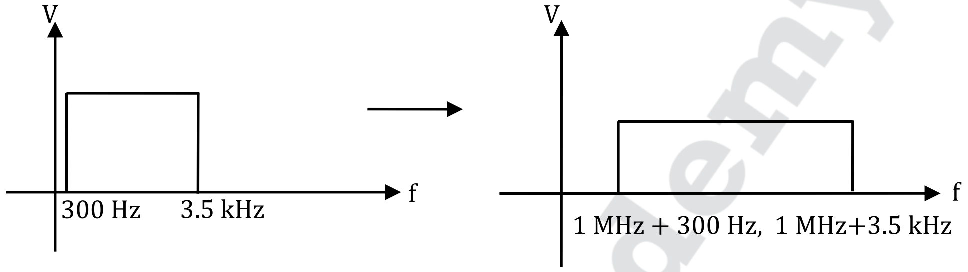
4. **For narrow banding of signals:**

Not only the antenna height, the antenna dimensions also depends on operating wavelength to transmit a wideband signal. Single antenna will not be sufficient because the ratio between the highest frequency to lowest frequency is very much greater than one. Modulation converts a wideband signal into a narrow band signal whose ratio between highest frequency to lowest frequency is approximately one and single antenna will be sufficient to transmit the signal.

$\frac{f_H}{f_L} \cong 1 \rightarrow$ Wide band signal

$\cong 1 \rightarrow$ Narrow band signal

Example:



Spectrum is Shifted by MHz using Modulator

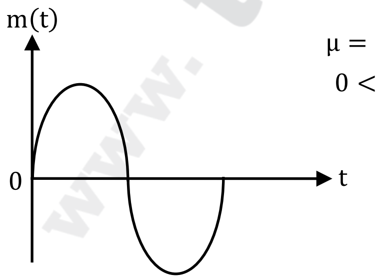
$\therefore \frac{f_H}{f_L} \cong 1$

5. **To overcome Equipment Limitation:**

The design of a communication system may be constrained by the cost and availability of hardware, whose performance often depends upon the frequencies involved. Modulation permits the designer to place a signal in some frequency range that avoids hardware limitations. A particular concern along this line is the question of fractional bandwidth, defined as the, absolute bandwidth divided by the center frequency. Hardware costs and complication are minimized if the fractional bandwidth is kept 1 to 10 percent. Fractional bandwidth considerations account for the fact that modulation units are found in receivers as well as in transmitters.

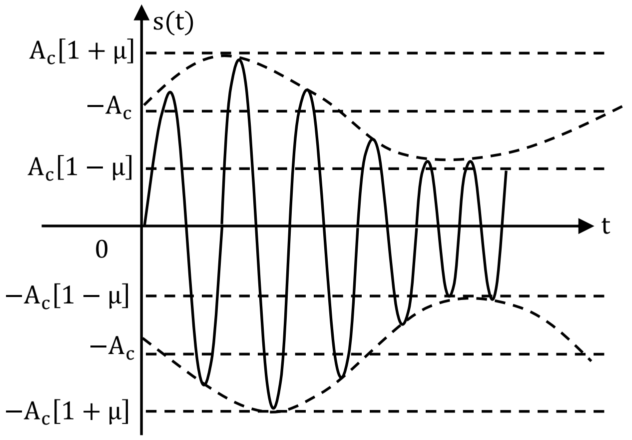
Amplitude Modulation (AM)

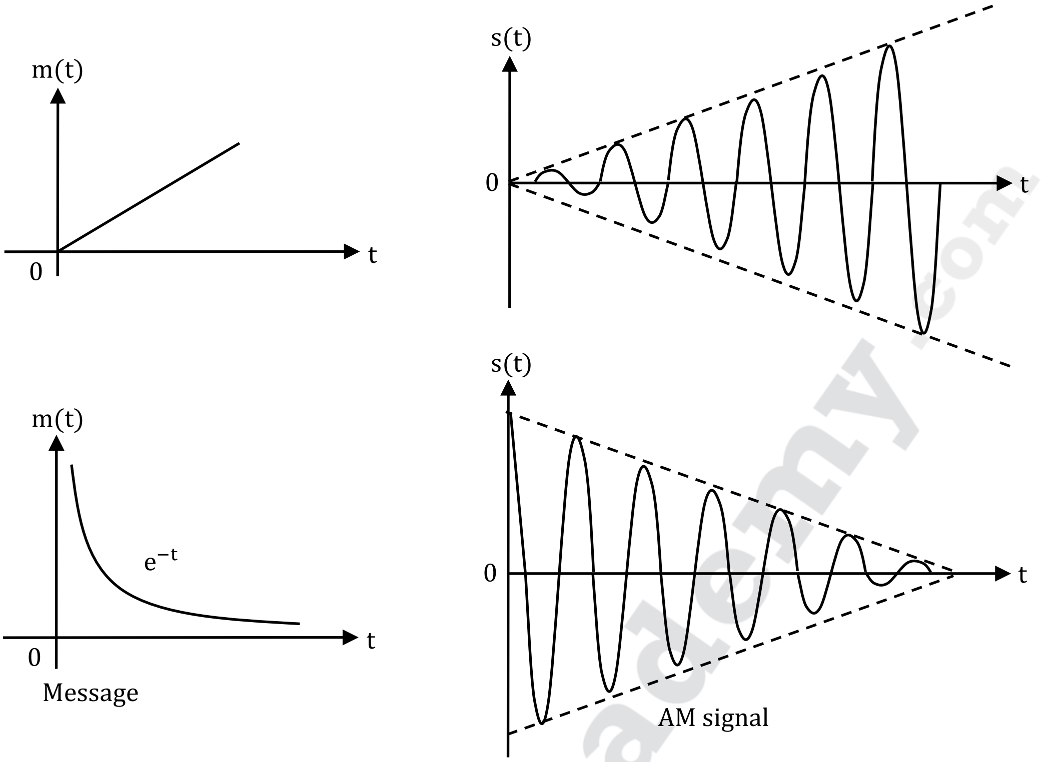
In AM the amplitude of carrier wave $c(t) = A_c \cos 2\pi f_c t$ is varied linearly with the amplitude of message signal.



$\mu = K_a m(t)$

$0 < \mu \leq 1$





Amplitude Modulation

Time Domain Equation of AM

The standard form of AM wave is defined by,

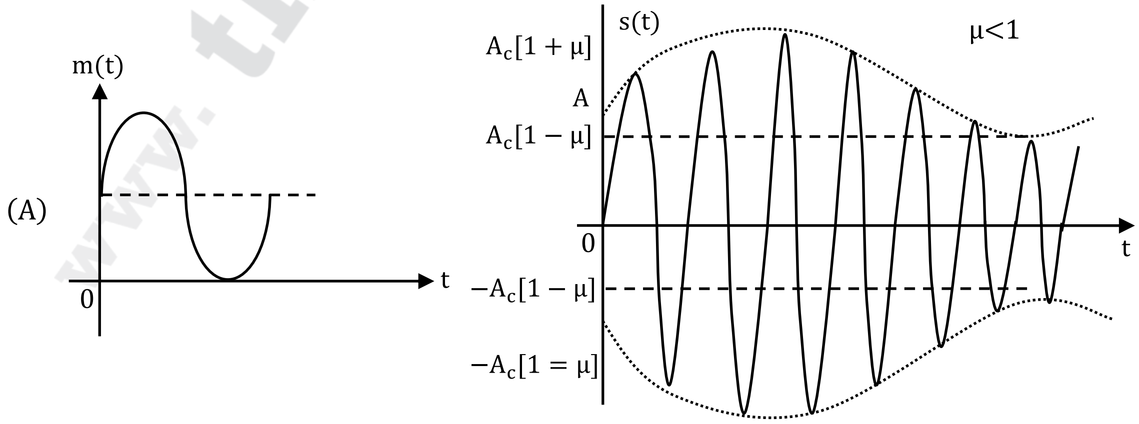
$S(t) = A_c \cos 2\pi f_c t + A_c K_a m(t) \cos 2\pi f_c t = A_c[1 + K_a m(t)]\cos 2\pi f_c t$ ……. (1.1)

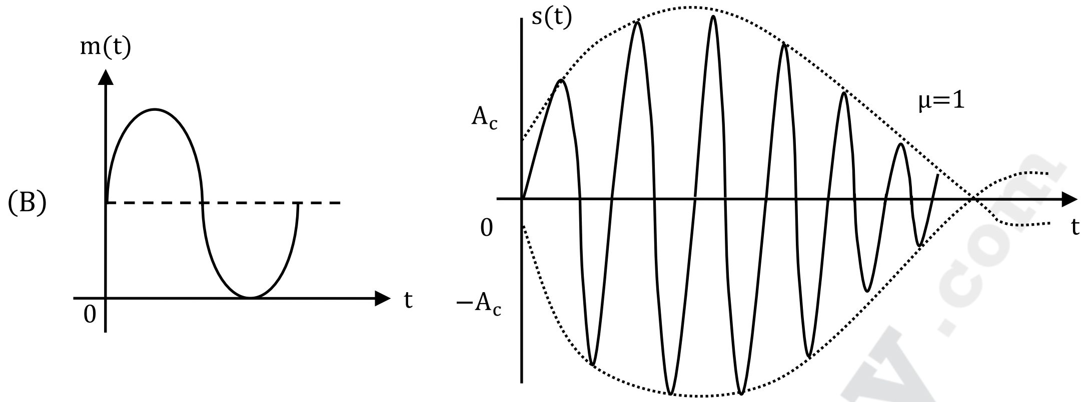
The amplitude of the carrier before modulation is A_c and the amplitude of the carrier after modulation is $A_c[1+K_a m(t)]$ (After modulation the carrier amplitude depends on the message signal),K_a= Amplitude sensitivity of the modulator.

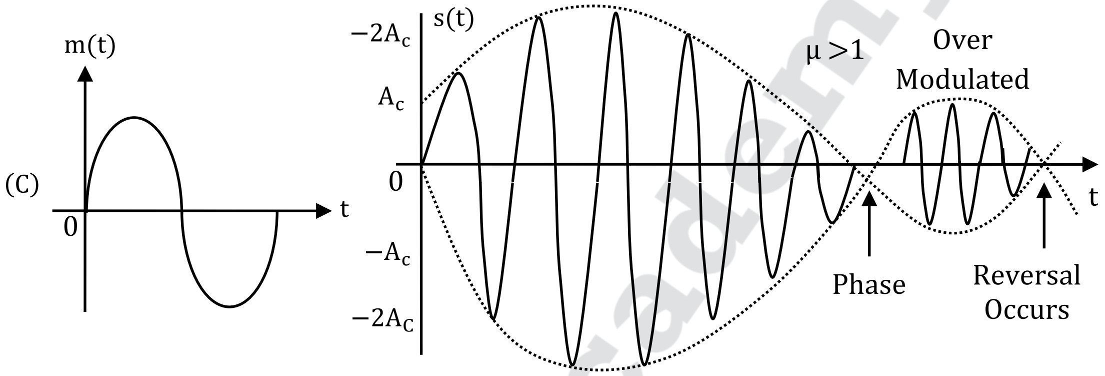
Envelope of AM wave S (t) is given by,

$a(t) = A_c|1 + K_a m(t)|$ ……..(1.2)

The maximum absolute value of K_a m (t) multiplied by 100 is referred as percentage modulation. When $|K_a m(t)| \le 1$ for all t, the term $[1 + K_a m(t)]$ is always non-negative, on the other hand when $|K_a m(t)| > 1$ for all t, the term $[1 + K_a m(t)]$ will not be always non- negative and the AM wave is said to be over modulated and it is said that wave suffer from envelope distortion.

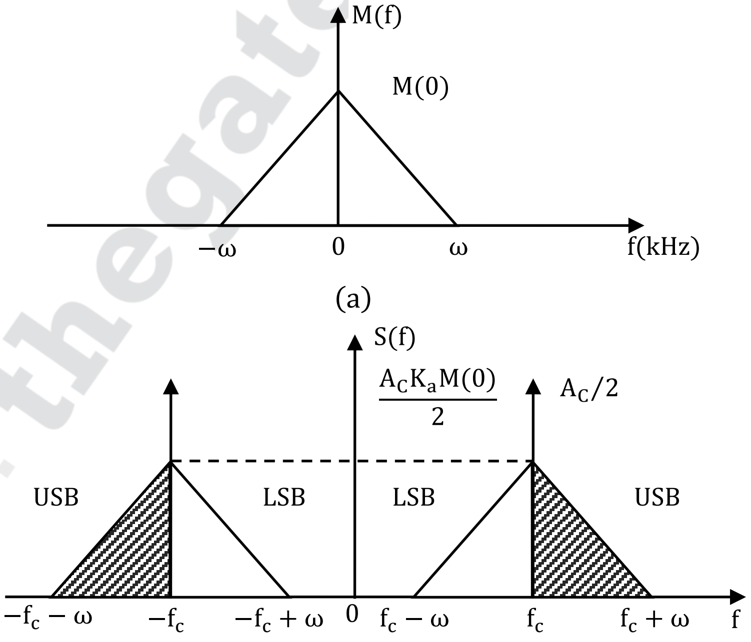






By taking Fourier transform of both side of equation (1.1) the AM wave in frequency domain is,

$$s(f) \ = \frac{A_c}{2}[\delta(f-f_c)+\delta(f+f_c)\,] \ +\frac{A_c}{2}\ k_a[M(f-f_c)+M(f+f_c)]$$



(a)

(b)

(a) Spectrum of Message Signal (b) Spectrum of AM Wave

The condition $f_c > \omega$ ensures that the side bands do not overlap otherwise, the modulated wave exhibits spectral overlap and therefore, frequency distortion.

Bandwidth of the A.M signal $= 2\ \omega$

$= 2 \times$ Message Bandwidth,

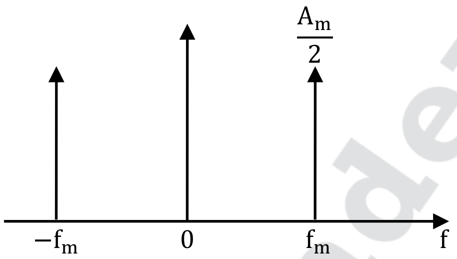
Bandwidth of USB $= \omega$

Bandwidth of LSB $= \omega$

Single Tone Modulation of AM

When the message contains single frequency or single tone, the modulation is called single tone modulation. Message signal, $M(t) = A_m \cos(2\pi f_m t)$

Spectrum of message is given by, $M(f) = \frac{A_m}{2}\,[\delta(f - f_m) + \delta(f + f_m)]$



Spectrum of Message Signal

The time domain equation of AM for single tone modulation is,

$s(t) = A_c \cos(2\pi f_c t) + A_c K_a A_m \cos(2\pi f_m t)\cos(2\pi f_c t)$

$s(t) = A_c[1 + \mu\cos(2\pi f_m t)]\cos(2\pi f_c t)$

Where $K_a A_m = \mu$= modulation index

The amplitude of the carrier after modulation is $A_c\ [1 + \mu\cos(2\pi f_m t)]$

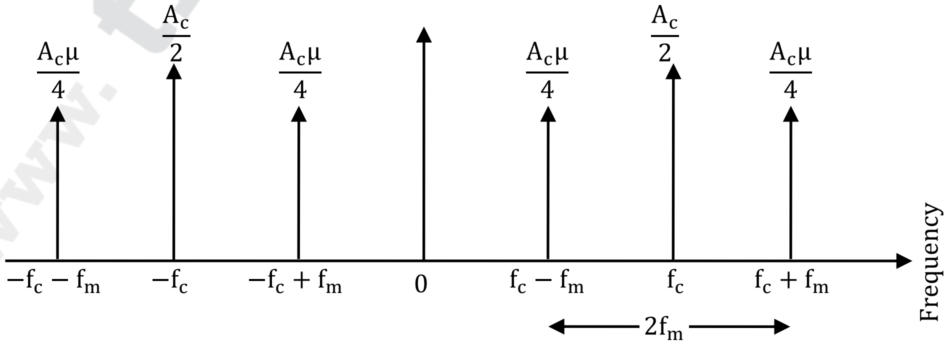
The maximum value of the positive envelope is $A_c\ [1+\mu]$

The minimum value of the positive envelope is $A_c[1-\mu]$

$$\frac{A_{max}}{A_{min}} = \frac{A_c\ (1+\mu)}{A_c\ (1-\mu)}$$

$$\therefore \mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

$$S(t) = \underset{\substack{\downarrow \\ \text{Carrier}}}{A_c \cos 2\pi f_c t} + \frac{A_c\mu}{2}\underset{\substack{\downarrow \\ \text{USB}}}{\cos 2\pi(f_c + f_m)t} + \frac{A_c\mu}{2}\underset{\substack{\downarrow \\ \text{LSB}}}{\cos 2\pi(f_c - f_m)t}$$



Spectrum of AM wave for Single Tone Modulation

Transmission B.W. $=2f_m$ =2×Highest frequency of message signal