ECE 321 TELECOMMUNICATION I (2 Credits)

INTRODUCTION

Communication can be defined as the process whereby information is transferred from one point in space and time called the source to another point called the destination or user.

OR

Communication is simply the basic process of exchanging information.

OR

It is the process of establishing connection or link between two points for information exchange.

Communication equipments are the electronic equipments which are used for communication ~~process~~ purpose. A communication system is formed when different communication equipments are assembled together.

The ability to share information is one of the characteristics of the human race which has played a major role in its development. Down through the ages man has striven to increase his range of communication by different methods.

~~Today~~, Electrical communication systems are found wherever information is to be conveyed from one point to another. Telephony, radio and television have become integral parts of our everyday life. ~~The~~ Communication has become more widespread with use of satellites and fiber optics. Today, there has been an increasing emphasis on the use of computer in communication.

MODEL OF A COMMUNICATION SYSTEM

A communication system is the totality of mechanisms that provide the link for information to be transferred from one point to another. The primary objective of all communication systems is to provide acceptable replica of the information at the destination. Irrespective of the nature of information transmitted or the actual method of transmission used, we can use a general

Model to describe any communication system. We will consider a typical model of a communication system and see how the various elements play their role in achieving successful communication. Any communication system can be symbolically represented by the block diagram of fig 1.1

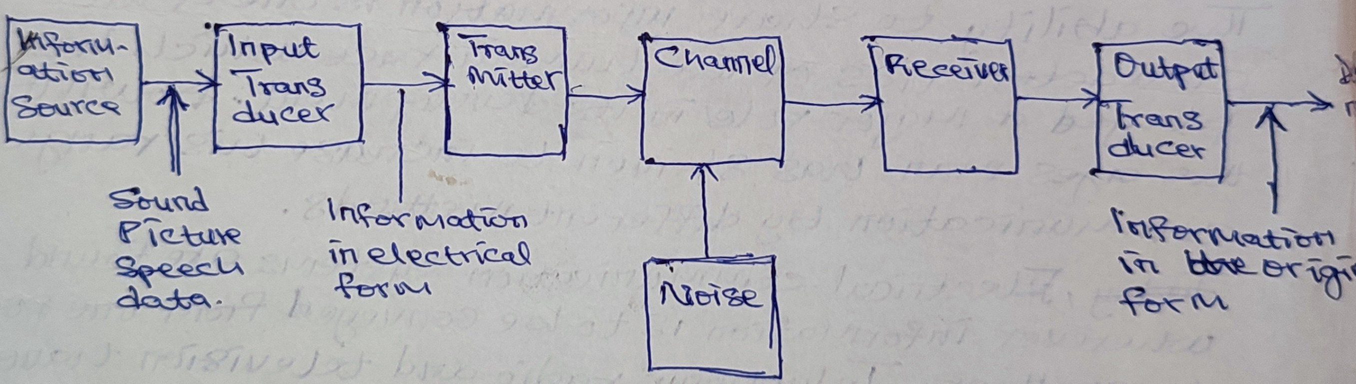


Fig 1.1 Block diagram of a communication system

Information Source: its function is to produce required message which has to be transmitted. There can be various messages in form of words, code, symbols, sound signal etc.

Input Transducer: It is a device which converts one form of energy into another form. The message from the information source may or may not be electrical in nature. When the message produced by the information source is not electrical in nature, an input transducer is used to convert into a time varying electrical signal. Eg. A microphone converts the message or information which is in the form of sound waves into corresponding electrical signal, in case of radio-broadcas

Transmitter: ~~It is to~~ Its function is to process the electrical signal from different aspects. ~~A simple example arises in~~ The signal from input transducer is not generally suitable for transmission over long distances. A simple example arises in radio transmission. Here, the output signal from the microphone contains audio frequencies which in most cases are less than 16 KHz whereas the effective radio wave propagation requires the use of much higher frequencies. Part of the function of the transmitter is therefore to modify the frequencies from the input transducer to those which can be used for transmission by the channel. To achieve this, the transmitter performs several signal processing operations, including amplification, filtering and modulation.

The Channel and the Noise:

The central section of the communication system is known as the channel. It covers the path or medium by which communication is established between two points. ~~It is~~ Its function is to ~~provide~~ physical connection between the transmitter and the receiver.

There are two types of channels, namely point-to-point channels and broadcast channels. Examples of point-to-point channels are wire lines, microwave links and optical fibres. Wire lines operate by guided electromagnetic wave and they are used for local telephone transmission. In microwave links, the transmitted signal is radiated as an electromagnetic wave in free space. They are used in long distance telephone transmission. An optical fiber is a lowloss, well controlled, guided optical medium.

On the other hand, the broadcast channels provide a capability where several receiving stations can be reached simultaneously from a single transmitter. An example of a broadcast channel is a satellite in geostationary orbit which covers about one third of the earth's surface.

Noise is an unwanted signal which tend to interfer with the required signal. It may interfer with signal at any point in a communication system. However, the noise has its greatest effect on the signal in the channel.

Receiver: its main function is to reproduce the message signal in electrical form from the distorted received signal. This reproduction of the original signal is accomplished by a process known as the demodulation. Demodulation is the reverse process of modulation carried out in the transmitter.

Output transducer and the Destination:
The received signal is passed to the output transducer which converts the electrical signal to audio signal. A good example of an output transducer is the telephone ear-piece which converts the electrical waveform impinging on its diaphragm to audible speech.
From the output transducer the signal is then sent to the last stage of its journey which is the destination or user.

FUNDAMENTAL LIMITATIONS IN ELECTRICAL COMMUNICATIONS

When designing a communication system, the designer faces several constraints or limitations. These are noise limitation, bandwidth limitation and equipment limitation.

Noise Limitation: The noise may be defined as an unwanted form of energy which tend to interfer with the transmission and reception of the desired signals in a communication system. It cannot be eliminated completely. However, its effect on desired signals can be minimized with the help of several techniques. Noise can be classified into two broad categories depending upon the source: external noise and internal noise. Internal noise is that type of noise whose sources are internal to communication system and is inevitable in every communication system. It forms a basic limitation on transmission and reception of signals. eg thermal noise and shot noise.
Meanwhile, external noise is that type of noise whose sources are external to communication system. Eg. atmospheric noise, galactic noise and industrial noise. Typical noise ~~variations are~~ variations are measured in microvolts.

Bandwidth Limitation: the band of frequency or frequency range needed for a particular given transmission is known as bandwidth. It is also called channel. This band of frequencies or bandwidth for a particular transmission is always allocated by some International regulatory agencies. This type of regulation is essential to avoid interference among signals having same frequency. But, for a given the transmission, this allocated bandwidth may not be sufficient to convey the entire information.

Equipment Limitation: Bandwidth and noise limitations dictate what can be achieved in terms of performance. However, this theoretical limit may not be reached in a practical system due to equipment limitation. This limitation include such things as cost, environmental consideration and equipment complexity.

~~AMPLITUDE~~ MODULATION:

INTRODUCTION: Modulation is the systematic transformation of a carrier wave in accordance with the message signal. Two signals are used in modulating process, they are: modulating signal and the carrier. The modulating signal is the baseband signal or information signal while carrier is the high frequency sinusoidal ~~frequency~~ signal. In modulation process, some parameter of the carrier wave such as amplitude, frequency or phase is varied in accordance with the modulating signal. The ~~wave~~ carrier wave acts as a carrier which carries the information signal (modulating signal) from the transmitter to receiver. The carrier wave is generally a radio frequency signal.

The success of a communication system in any given mission, to a large extent, depends on the modulation, so much so that the type of modulation is a pivotal decision to system design. Various modulating techniques may be grouped into two basic types according to their kind of carrier wave; analogue and digital modulation. Analogue modulation uses sinusoidal waveform as the carrier signal while digital modulation uses a discrete or pulse train as the carrier signal. *

The two most important methods of analogue modulation are amplitude modulation and angle modulation. * Angle modulation (frequency modulation & phase modulation). However, regardless of the type of modulation used, whether analogue or digital, it must be appreciated that modulation is a fairly complicated process and would obviously not be used without some very sound and compelling reasons.

REASONS FOR MODULATION

1) Modulation for ease of Radiation: If the communication channel consist of free space, then antennas will be required to radiate and receive the signal. Several difficulties are involved in the propagation of electromagnetic waves at frequency corresponding to the audio spectrum i.e below 20KHz. The greatest of these is that for efficient radiation and reception, the transmitting and receiving antennas would have physical dimensions comparable to at least one-tenth of the wavelength and the frequency being used. Now many signals, especially audio signals have frequency components down to 100 Hz or lower. For these signals we require antennas which are 300km long if the signals are to be radiated directly. A vertical antenna of this size is unthinkable. However, utilizing the frequency-translation property of modulation, these signals can be impressed ~~over~~ on a high frequency carrier, thereby permitting reduction of antenna size. For example, to transmit our audio signal of frequency 10KHz over the channel requires an antenna of length:—

$$\text{Minimum height} = \frac{\lambda}{4} = \frac{c}{4f} = \frac{3 \times 10^8}{4 \times 10 \times 10^3} = 7{,}500\text{m i.e } 7.5\text{km}$$

whereas, the use of carrier frequency of 1MHz requires an antenna size of 75meter only

Minimum height $= \frac{\lambda}{4} = \frac{c}{4f} = \frac{3\times10^8}{4\times1\times10^6} = 75$ meter.

Note: λ is wavelength and $\lambda = \frac{c}{f}$ where C is the speed of light $= 3\times10^8$ and f is the frequency. In the above example, we considered antenna height multiple of $\left(\frac{\lambda}{4}\right)$.

(2) Frequency assignment: It is true ~~that~~ all sounds are within 20Hz to 20KHz, and they are all available in space: There is need for sounds to be seperated. For example, Sounds from radio, TV, walkie talkie, telephone, etc. need to be seperated from each other. We need to seperate ABS from NTA and Unizik radio from ABS radio. This is achieved by assigning different frequencies (carrier frequencies) to each of the operators. GLO and MTN ~~opera~~ operate different assigned frequencies as given by the Nigeria Communication Commission, NCC.

(3) Multiplexing is ~~made~~ possible: It is a process in which two or more signals can be transmitted over the same communication channel simultaneously. This is possible with modulation: The multiplexing allows the same channel to be used by many signals. Hence many TV channels can use the same frequency range without getting mixed with each other.

(4) Modulation to reduce noise and interference/ ~~imp~~ improve quality of reception: the effect of noise and interference cannot be completely eliminated in a communication system but with frequency modulation (FM) and the digital communication techniques ~~like PCM~~, the effect of noise is reduced to a great extent. This improves quality of reception.

(5) Increases the range of communication: the frequency of baseband signals is low, and the low frequency signals can not travel a long distance when they are transmitted. They get heavily attenuated (suppressed). The attenuation reduces with increase in frequency of the transmitted signals, and they travel longer distance. The modulation process increases the frequency of the signal to be transmitted. Therefore, it increases the range of communication.

AMPLITUDE MODULATION: It may be defined as a system in which the maximum amplitude of the carrier wave is made proportional to the instantaneous value (amplitude) of the modulating or baseband signal. It is the oldest and simplest form of modulation.

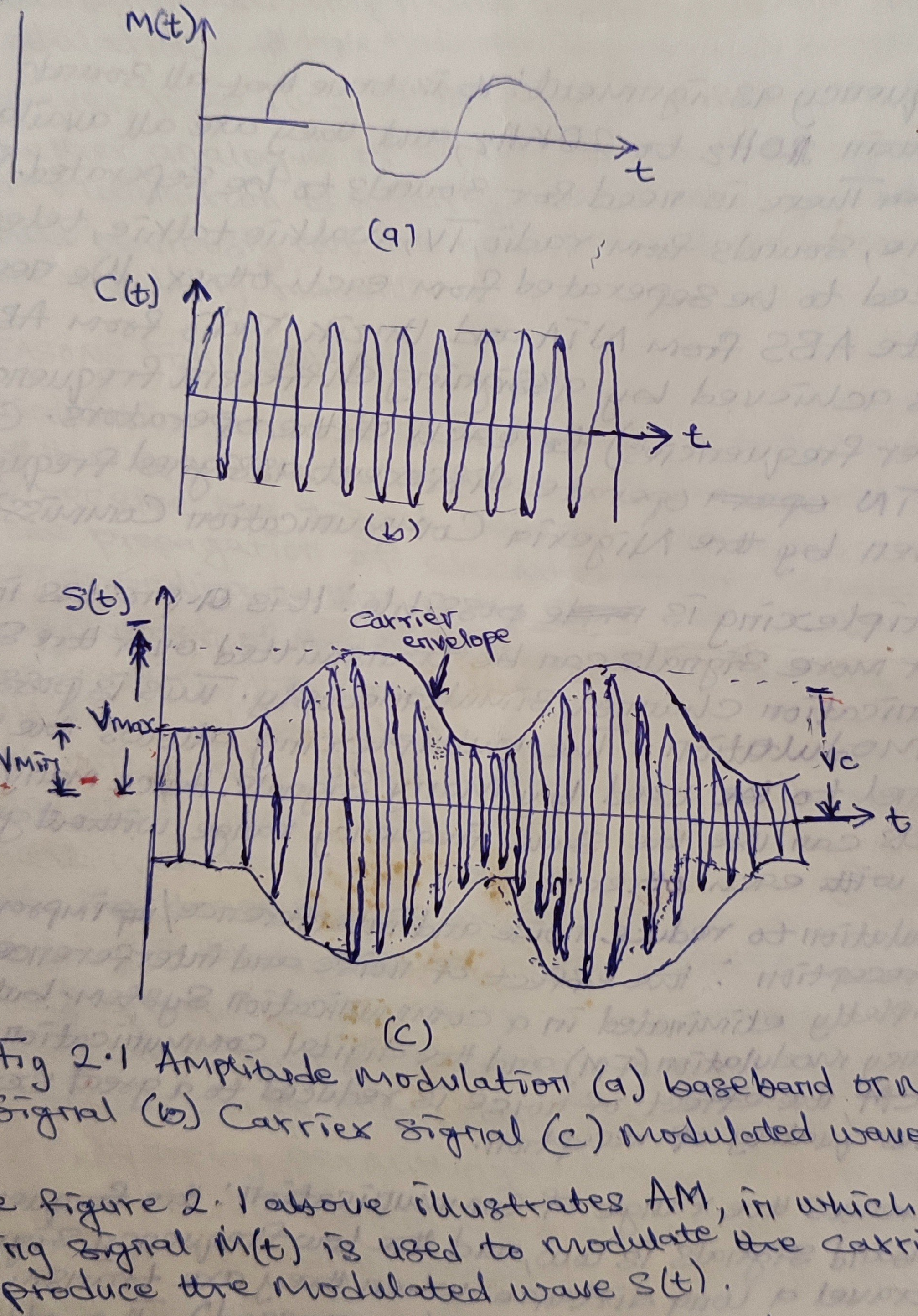


Fig 2.1 Amplitude modulation (a) baseband or modulating signal (b) Carrier signal (c) Modulated wave

The figure 2.1 above illustrates AM, in which the modulating signal M(t) is used to modulate the carrier C(t) to produce the modulated wave S(t).

$$V_{max} = V_c + V_m \text{ and } V_{min} = V_c - V_m$$

The base band fig 2.1 (a) is given by

$$M(t) = V_m \cos \omega_m t \quad \text{------ eqn. 2.2}$$

The full AM wave is given by

$$S(t) = C(t) + c(t)\,M(t) \quad \text{------ eqn 2.3}$$

ϕ_c (phase angle) is neglected since we are not dealing with the phase angle.

Therefore, $S(t) = V_c \cos W_c t + V_M \cos W_c t \cos W_M t$ --- eqn 2.4
with the carrier amplitude following that of the modulating signal,

Let m (Modulation depth or index) $= \frac{V_M}{V_c}$ $\therefore V_M = mV_c$ --- eqn 2.5

Therefore, $S(t) = V_c \cos W_c t + mV_c \cos W_c t + \cos W_m t$ ---- eqn 2.6

From trigonometry,

$$2\cos A \cos B = \cos(A+B) + \cos(A-B)$$

$$\cos A \cos B = \tfrac{1}{2}\left[\cos(A+B) + \cos(A-B)\right]$$

From equation 2.6

$$S(t) = V_c \cos W_c t + \frac{mV_c}{2}\left[\cos(W_c + W_M)t + \cos(W_c - W_M)t\right] \quad \text{--- eqn 2.7}$$

This is the equation of a full AM wave comprising three component parts as follows:

(a) $V_c \cos W_c t$ ~~which~~ the unmodulated carrier signal which bears no information.

(b) $\frac{mV_c}{2}\cos(W_c + W_M)t$ – is the Upper side band (USB).

(c) $\frac{mV_c}{2}\cos(W_c - W_M)t$ – is the lower sideband (LSB).

The two sidebands bear the information being transmitted. The carrier frequency is given by W_c while the USB and LSB are given by $W_c + W_M$ and $W_c - W_M$ respectively. The frequency spectrum for AM is shown in fig. 2.2.

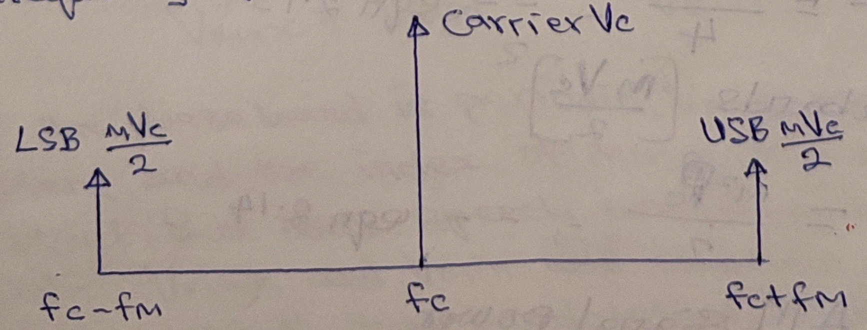


Fig 2.2: AM frequency spectrum for sinusoidal $m(t)$

In this brief analysis, we have only assumed that the modulating signal $m(t)$ is a sinusoid. If $m(t)$ has a peak positive value of +1 and a peak negative value of −1, the AM signal is said to be 100% modulated.

The percentage of positive modulation on an AM signal is

$$\%\ \text{positive modulation} = \frac{V_{max} - V_c}{V_c} \times 100 \quad \text{--- eqn 2.8}$$

and the percentage of negative modulation is

$$\%\ \text{negative modulation} = \frac{V_c - V_{min}}{V_c} \times 100 \quad \text{--- eqn 2.9}$$

The overall modulation percentage is

$$\%\ \text{modulation} = \frac{V_{max} - V_{min}}{2V_c} \times 100 \quad \text{--- eqn 2.10}$$

where V_{max} is the maximum value of $V_c[1 + m(t)]$ the modulating carrier, and V_{min} is the minimum value and V_c is the level of the AM envelop under the condition of no modulation, i.e $m(t) = 0$

POWER IN AM SIGNAL

The voltage amplitude of AM signal is

$$V = V_c + \frac{mV_c}{2} + \frac{mV_c}{2} \quad \text{---- eqn 2.11}$$

For a 1Ω resistive load

$$P_c = \frac{V_c^2}{R_L} = V_c^2 \quad \text{---- eqn 2.12}$$

Where P_c is carrier power

Power in one sideband

$$P_s = \frac{m^2 V_c^2}{4} = \frac{m^2 P_c}{4} \quad \text{--- eqn 2.13}$$

For two sidebands $\left[\frac{mV_c}{2}\right]^2$

$$P_s = \frac{m^2 V_c^2}{2} = \frac{m^2 P_c}{2} \quad \text{--- eqn 2.14}$$

Hence, total AM signal power

$$P_T = P_c + P_s = \frac{P_c}{} + \frac{m^2 P_c}{2} = P_c\left[1 + \frac{m^2}{2}\right] \quad \text{--- eqn 2.15}$$

The following power ratio are very useful

$$\frac{P_T}{P_c} = 1 + \frac{M^2}{2} \quad \text{-----} \quad \text{eqn } 2{\cdot}16$$

$$\frac{P_S}{P_T} = \left[\frac{M^2 P_c}{2}\right] \div P_c\left[1 + \frac{M^2}{2}\right]$$

$$\frac{P_S}{P_T} = \frac{M^2}{M^2+2} \quad \text{-------} \quad \text{eqn } 2{\cdot}17$$

and $$\frac{P_S}{P_c} = \frac{M^2}{2} \quad \text{-------} \quad \text{eqn } 2{\cdot}18$$

The modulation efficiency, δ, is the percentage of the total power of the modulated signal that conveys information. In AM, only one sideband componenents convey information, so modulation efficiency is given by

$$\delta = \frac{P_S}{P_T} = \frac{M^2}{M^2+2}$$

If one sideband is used

$$\delta = \frac{M^2}{2(M^2+2)} \quad \text{-----} \quad \text{eqn } 2{\cdot}19$$

~~Solved Eg (11)~~

Solved ~~Examples~~ on AM

(1) A transmitter radiates a total power of 5 KW, the waveform being Amplitude modulated to a depth of 60%. Calculate the power in the sidebands and the carrier power.

Solution

Given $P_T = 5\,KW = 5000\,W$, modulation depth, $M = 60\% = 0{\cdot}6$

Using the formula $\frac{P_S}{P_T} = \frac{M^2}{M^2+2}$, we have $\frac{P_S}{P_T} = \frac{(0{\cdot}6)^2}{(0{\cdot}6)^2+2} = \frac{0{\cdot}36}{2{\cdot}36}$

$$\frac{P_S}{P_T} = 0{\cdot}153$$

$\therefore P_S = 0.153 P_T = 0.153 \times 5000 = 762.71$ Watts.

$P_S = 762.71$ represents the power in the two sidebands. The power in each sideband is therefore $\frac{762.71}{2} = 381.4$ Watts..

Since total AM power = Carrier power − Sidebands power

$$P_C = P_T - P_S = 5000 - 762.71 = 4237.3 \text{ Watts.}$$

(2) An AM transmitter radiates 50KW of a carrier power; what would be the radiated power at 85% modulation?

Solution

Given $P_C = 50KW = 50{,}000$ and $M = 0.85$

At 85% modulation $P_T = P_C\left[1 + \frac{M^2}{2}\right]$

$$= 50{,}000\left(1 + \frac{0.85^2}{2}\right)$$

$$= 50{,}000 \times 1.3613$$

$$= 68.06 \text{ KW}$$

AMPLITUDE MODULATION INDEX

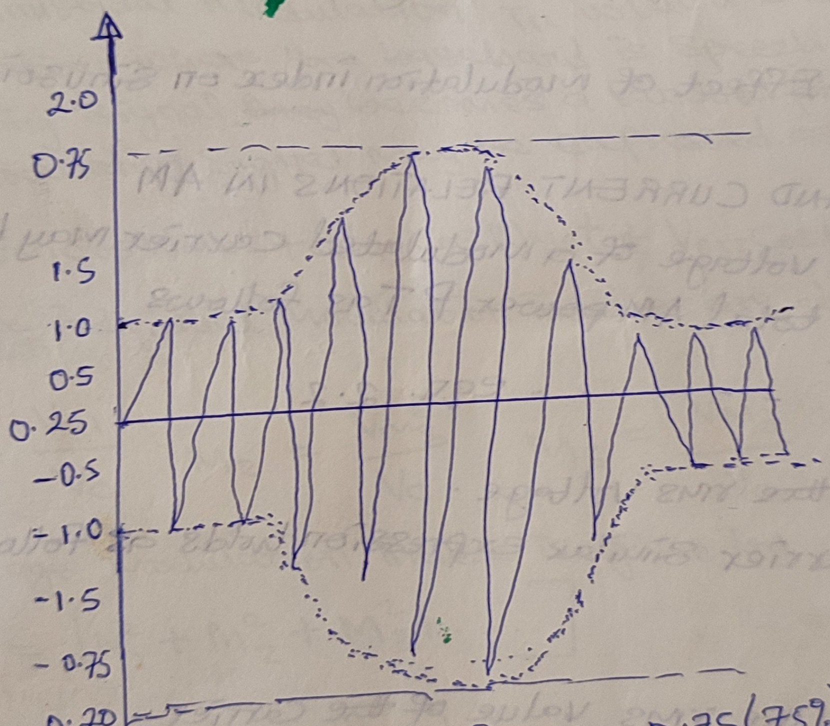
Modulation index controls the depth of modulation and is given by

$$M = \frac{\text{amplitude of the modulating of signal}}{\text{amplitude of the unmodulated carrier}}$$

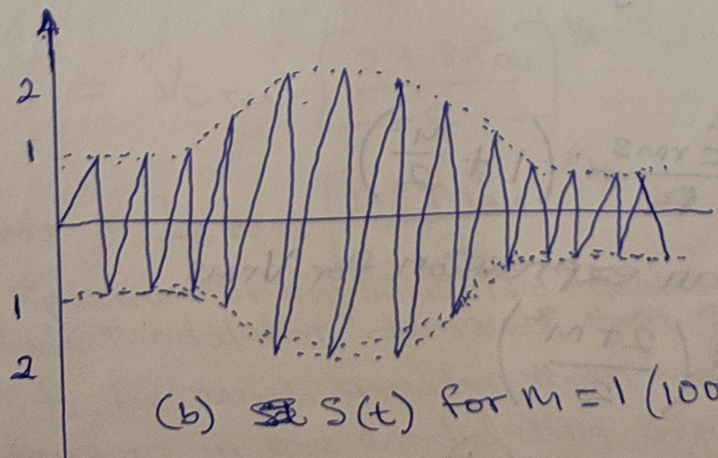
$$= \frac{V_{max} - V_{min}}{V_{max} + V_{min}} = \frac{V_M}{V_C} \quad \ldots \text{eqn. 2.20}$$

If the baseband is periodic, V_{max} and V_{min} remain constant and the index of modulation 'M' will remain constant. But with speech waveform, which is not periodic V_{max} and V_{min} will continue to change, with the result that modulation index M continues to vary.

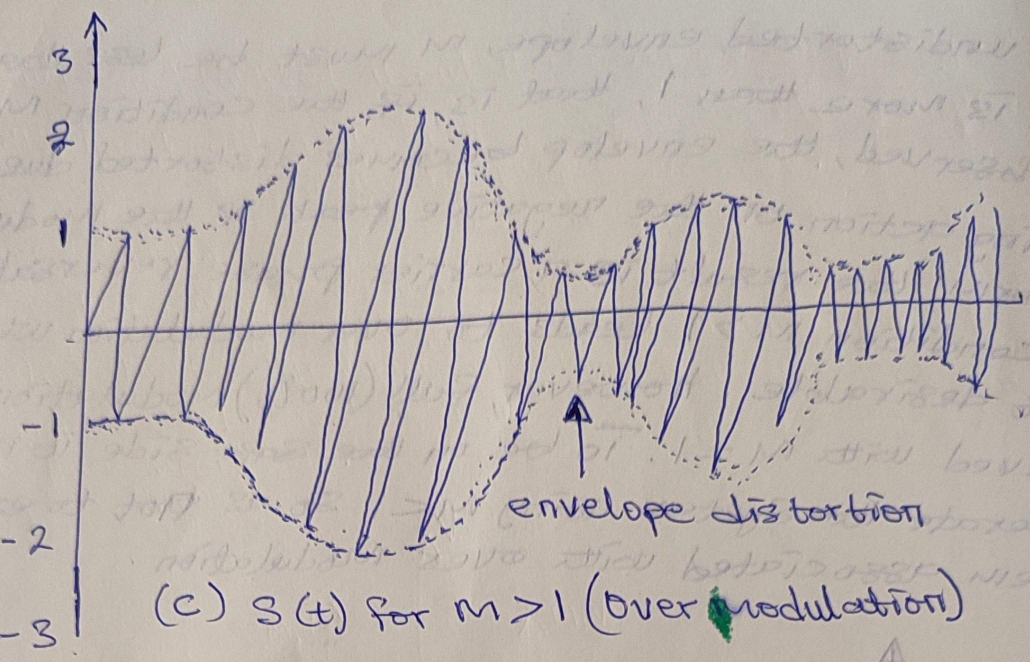
For undistorted envelope, m must be less than 1. If m is more than 1, that is, if the condition $m \leq 1$ is not observed, the envelop becomes distorted due to the clipping action on the negative peak of the modulating waveform; the result is a carrier phase reversal. The condition $m > 1$ leads to over modulation which is not desirable. However, full (100%) modulation is achieved with $m = 1$. To be on the safe side it is better to operate the system using $m < 1$ so as not to experience problem associated with over modulation.



(a) S(t) for m = 0.75 (75%)



(b) S(t) for m = 1 (100%)



(c) $s(t)$ for $m > 1$ (over modulation)

Fig 2.2 Effect of modulation index on sinusoidal AM wave

VOLTAGE AND CURRENT RELATIONS IN AM

The overall voltage of a modulated carrier may be expressed in terms of ~~total~~ AM power P_T as follows

$$P_T = \frac{V^2}{R} \quad \text{- - - - . . . eqn. 2.21}$$

Where V is the rms voltage.

For ~~the~~ carrier similar expression holds as follows:

$$P_c = \frac{V_c^2}{R}$$

where V_c is the rms value of the carrier.

From eqn 2.15 we may recall ~~that~~

$$P_T = P_c\left(1+\frac{m^2}{2}\right)$$

hence
$$\frac{V_{rms}^2}{R} = \frac{V_{crms}^2}{R}\left(1+\frac{m^2}{2}\right)$$

We need to obtain an expression for V_{rms}

$$\frac{V_{rms}^2}{R} = \frac{V_{crms}^2}{R}\left(\frac{2+m^2}{2}\right)$$

$$V_{rms}^2 = \frac{V_{crms}^2 (2+M^2)}{2R} \times R$$

$$V_{rms} = V_{crms}\left(\frac{2+M^2}{2}\right)^{1/2} \text{ . . . . eqn } 2.22$$

Similarly, it can be shown ~~that the~~ rms value of modulation current is given by

$$I_{rms} = I_{crms}\left(\frac{2+M^2}{2}\right)^{1/2} \text{ . . . . . eqn } 2.23$$

At this juncture it might be necessary to ~~state that the~~ power equation $P_T = P_c\left(\frac{1-M^2}{2}\right)$ is applicable ~~with~~ only sinusoidal modulation in which case, M is constant. For situations where ~~the~~ baseband is speech or music, the modulating signal ~~they~~ becomes a random power signal. Such modulating signal may be expressed as follows

$$M(t) = V_{m1}\cos W_{m1}t + V_{m2}\cos W_{m2}t + V_{m3}\cos W_{m3}t + \dots \quad 2.24$$

hence, the individual modulation indexes are determined as follows:

$$M_1 = \frac{V_{m1}}{V_c}, \quad M_2 = \frac{V_{m2}}{V_c}, \quad M_3 = \frac{V_{m3}}{V_c}$$

An average modulation index is given by

$$M_{av} = \left[M_1^2 + M_2^2 + M_3^2 + \dots\right] \text{ . . . . eqn } 2.25$$

hence, $P_T = P_c\left[1 + \frac{M_{av}^2}{2}\right)$ . . . . eqn 2.26

$$V_{rms} = V_{crms}\left[\frac{2+M_{av}^2}{2}\right]^{1/2} \text{ . . . . . eqn } 2.27$$

and $I_{rms} = I_{crms}\left[\frac{2+M_{av}^2}{2}\right]^{1/2}$ . . . . . . eqn 2.28

The AM spectrum for non sinusoidal modulation is shown in fig 2.3.

Amplitude modulation demands that the frequency of the carrier, fc, be much greater than the highest frequency ~~of the~~ present in the modulating signal so ~~that~~ sidebands remain band limited about the carrier frequency. Usually the bandwidth of the required radio frequency is twice that of the modulating waveform.

$BW = 2f_{m\,max}$ - - - - - - - - eqn 2.29.

This will ensure that the sideband frequencies being generated do not lie outside the normal sidebands which eventually may overlap with the sidebands of adjacent channels. This is why over modulation must be avoided.

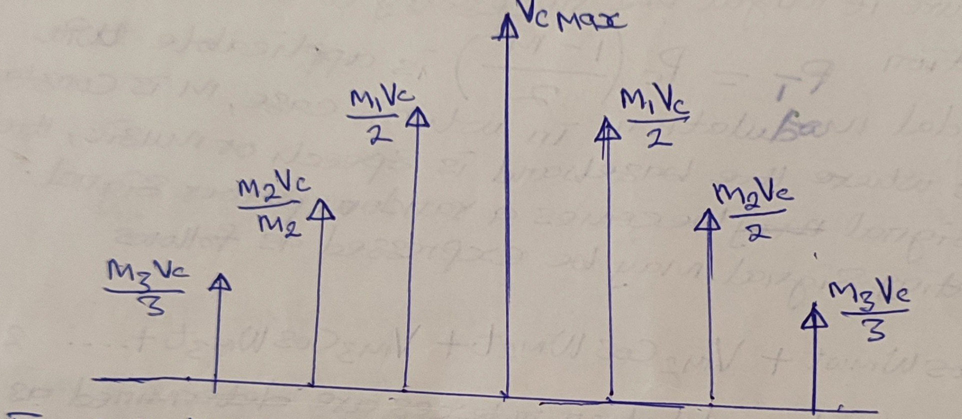


Fig. 2-3 AM Spectrum for non-sinusoidal modulation.

AMPLITUDE MODULATION SYSTEM

There are various forms of AM. They include

(a) Double Sideband (DSB) or Double Sideband full carrier system (DSB-FC)
(b) Double Sideband Suppressed Carrier DSB-SC
(c) Single Sideband ~~SSB~~ suppressed carrier system (SSB-SC)
(d) Vestigial Sideband system (VSB)
(d) Independent side band system (ISB).

DOUBLE SIDEBAND (DSB): It is the conventional envelope AM. It is also called Double Sideband full carrier system (DSB-FC) or sometimes called large carrier amplitude modulation LCAM. Here ~~both~~ the carrier and both sidebands (USB and LSB) are transmitted. Its disadvantages include power wastage, bandwidth inefficient system and its wave gets affected due to noise

Various methods of Modulation exist. Let us consider Carrier signal C(t) which is modeled as a cosine function as follows;

$$C(t) = V_c \cos\left(2\pi f_c(t) + \phi_c t\right) \quad \ldots \quad \text{eqn } 2.1$$

where V_c = amplitude of ~~the~~ carrier, (Volts). If this parameter of the carrier is varied in accordance with the amplitude of the modulating signal, we have Amplitude Modulation.

$2\pi f_c t + \phi_c t$ = angle of the cosine function. If this angle is varied in accordance with the amplitude of the modulating signal, we have angle modulation.

f_c = frequency of the carrier signal. If this parameter of the carrier is varied in accordance with the amplitude of modulating signal, we have frequency modulation.

ϕ_c = Phase angle of the carrier. If this parameter of the carrier signal is changed in accordance with the amplitude of the modulating signal, we have phase modulation.

~~Hen~~

DOUBLE SIDEBAND SUPPRESSED (DSB-SC): It is an amplitude modulated carrier that has a suppressed discrete carrier. This type of suppression of carrier does not affect the baseband signal in any way ~~thereby~~ making its signal to be infinite. Its modulation efficiency is 100% since no power is wasted in a discrete carrier. Expensive product detector is required for demodulation of its signal.

SINGLE SIDEBAND (SSB): DSB and DSB-SC are wasteful of bandwidth because both of them need a transmission bandwidth equal to twice the message signal bandwidth. ~~Meanwhile, in SSB~~ The information contained in the USB is exactly identical to ~~that~~ carried by the LSB. So, ~~the~~ SSB modulation is when the carrier and one sideband are suppressed completly and only one sideband is transmitted. It is also called Single Sideband Suppressed - Carrier (SSB-SC)

VESTIGIAL SIDEBAND (VSB)