Communication Theory I

ET 2213

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The modules to be covered

1. **Amplitude Modulation** (10 hrs)

   Introduction to Communication, AM modulation and its limitations, AM Receiver, DSB-SC Modulation, SSB-SC Modulation, Vestigial Sideband modulation, Baseband representation of modulated waves and band pass filter

2. **Angle Modulation** (9 hrs)

   Properties of Angle Modulated Signal, Relationship between PM and FM, Narrow Band FM, Wideband FM, Transmission , Generation and Demodulation of FM waves

3. **Pulse Modulation** (9 hrs)

   Sampling Process, PAM, PPM, Quantization, PCM, Delta Modulation, Differential PCM, Line codes

4. **Random Signals and Noises** (6 hrs)

   Probability and random variables, Expectation, Gaussian Random Variables,

   The central limit theorem, Random processes, Correlation of Random Processes, spectra of Random Signals, Gaussian Processes, White Noise, Narrow Band Noise

5. **Noise in Analog Communication** (10hrs)

   Noise in communication systems, Signal to Noise Ratio, Band pass receiver structures, Noise in Linear receivers using Coherent detection, Noise in AM Receivers using envelop detection, Noise in SSB Receivers, Detection of Frequency Modulation(FM), FM pre-emphasis and De-Emphasis

Method of Assessment

1. Continuous Assessment : 30%
2. End Semester Examination : 70%

Important Points

- Total Credits : 3
- Total Number of Hours : 45
- Number of hrs to cover the Modules : 42
- Continues Assessments/Tutorials/Practicals: 6 hrs

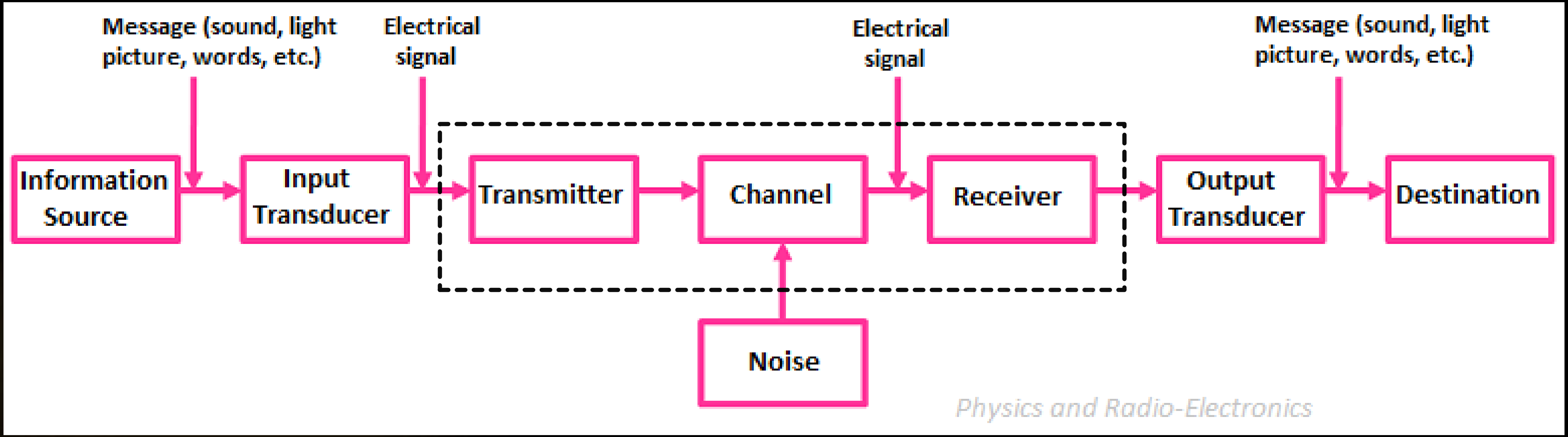
References

1. Bruce Carlson and Paul Crilly,(2009).Communication Systems, McGraw-Hill Education.
2. Simon Haykin, Michael Moher. Communication Systems

What is communication?

- Communication is the mechanism of sending, processing and receiving data or information by electrical means (In **Engineering point of view**).

Block Diagram of Communication system



Information Source

- It generates the data message to be transferred. The message can be audio, Video, image Signal. For Ex- **Human Voice in an audio signal**.

Input Transducer

- The input transducer **converts the non-electrical signal into electrical form**. Ex- **microphone converts** human voice into an Electrical Voltage or Current signal.

Transmitter

- Transmitter is a combination of **modulator, amplifier and antenna**. The modulator-amplifier strengths or enhances signal characteristics such as amplitude, frequency and phase for long distance transmission. The antenna converts electrical signals into electromagnetic waves(in **Wireless communication**).

Channel

- The Channel is the medium of propagation of the electrical data/massage signal. It is a transmission medium. Ex, air, copper cables, Co-axial cables, optical fiber cables.

Receiver

- Basically a combination of Antenna, Demodulator , Amp. The Demodulator extracts the original message signal from the modulated carrier.

Output Transducer

- The Output transducer convers electrical signal into original non-electrical form. Ex- Loudspeaker convers electrical signal into voice signal.

Module 1: Amplitude Modulation

What is Modulation?

- Modulation is the **process of changing the parameters of the carrier signal**, in accordance with the **instantaneous values of the modulating signal.**

Need for Modulation

- **Baseband signals are incompatible** for direct transmission (there are some possible uses are exists)
- For such a signal, to travel longer distances, its strength has to be increased by modulating with a **high frequency carrier wave**, which doesn't affect the parameters of the modulating signal
- A high frequency signal can travel up to a longer distance, without getting affected by external disturbances , We take the help of such **high frequency signal which is called as a carrier signal** to transmit our message signal

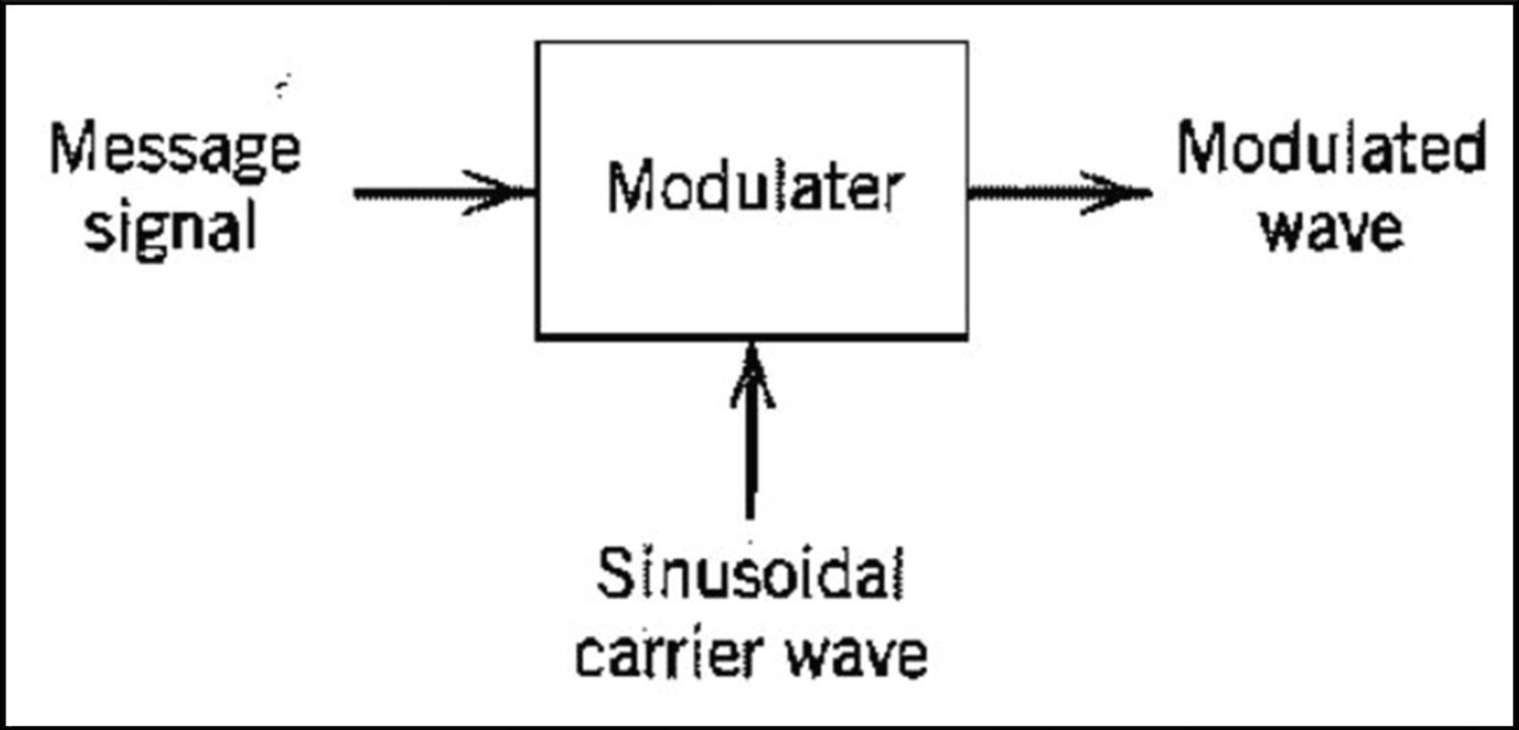
Advantages of Modulation

- Reduction of antenna size
- No signal mixing
- Increased communication range
- Multiplexing of signals
- Possibility of bandwidth adjustments
- Improved reception quality

The antenna used for transmission, had to be very large, if modulation was not introduced. The range of communication gets limited as the wave cannot travel to a considerable distance without getting distorted.

Signals in the Modulation Process

- Following are the three types of signals in the modulation process

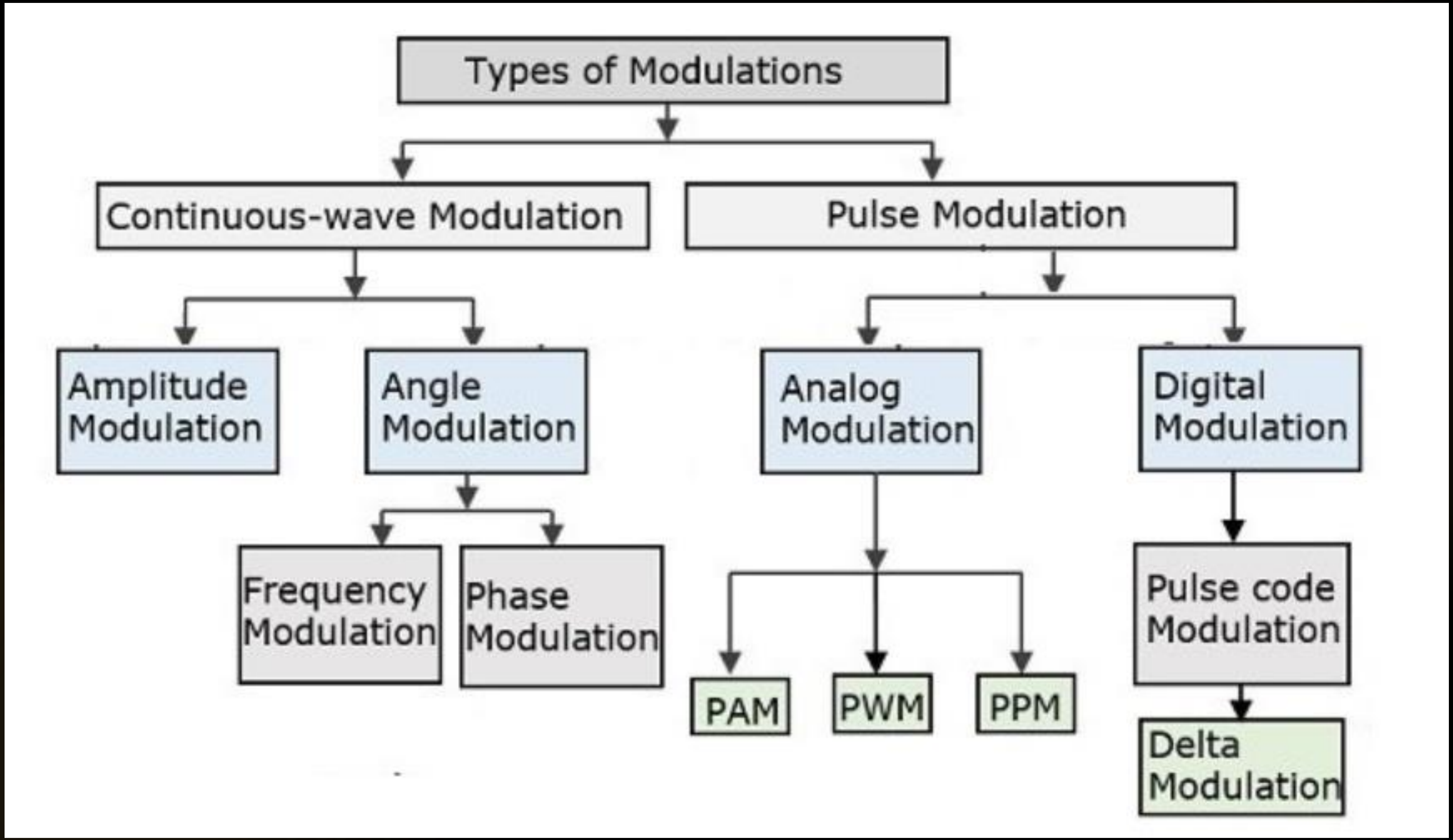


- **Message or Modulating Signal** The signal which contains a message to be transmitted, is called as a message signal. It is a baseband signal, which has to undergo the process of modulation, to get transmitted. Hence, it is also **called as the modulating signal**.

- **Carrier Signal** The high frequency signal, which has a certain amplitude, frequency and phase **but contains no information** is called as a carrier signal. It is **an empty signal** and is used to carry the signal to the receiver after modulation.

- **Modulated Signal** The resultant signal after the process of modulation is called as a modulated signal. This signal is a **combination of modulating signal and carrier signal**.

Types of Modulation



In **continuous-wave modulation**, a high frequency sinusoidal wave is used as a carrier wave. This is further divided into amplitude and angle modulation.

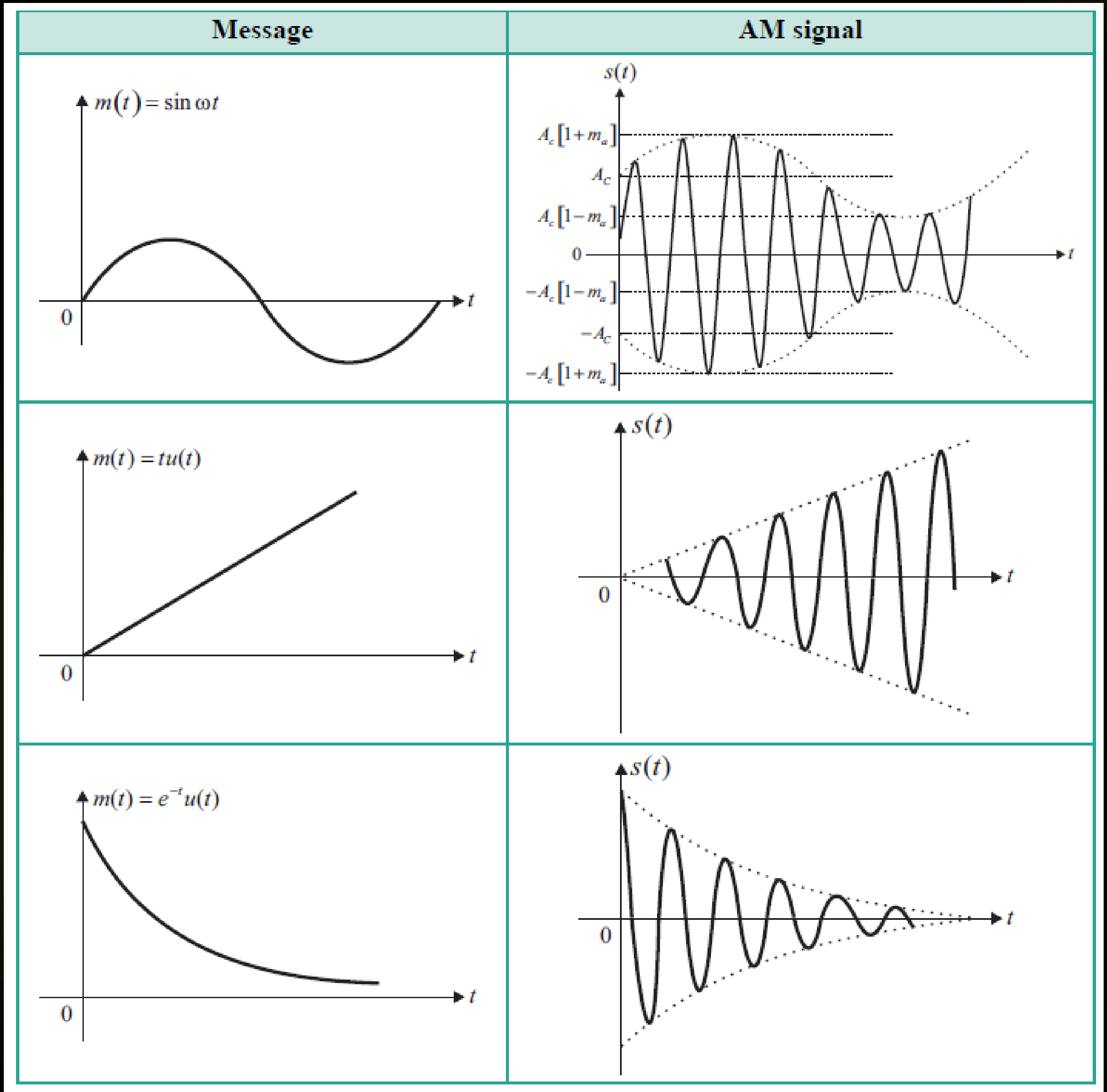
In **Pulse modulation**, a periodic sequence of rectangular pulses, is used as a carrier wave. This is further divided into analog and digital modulation.

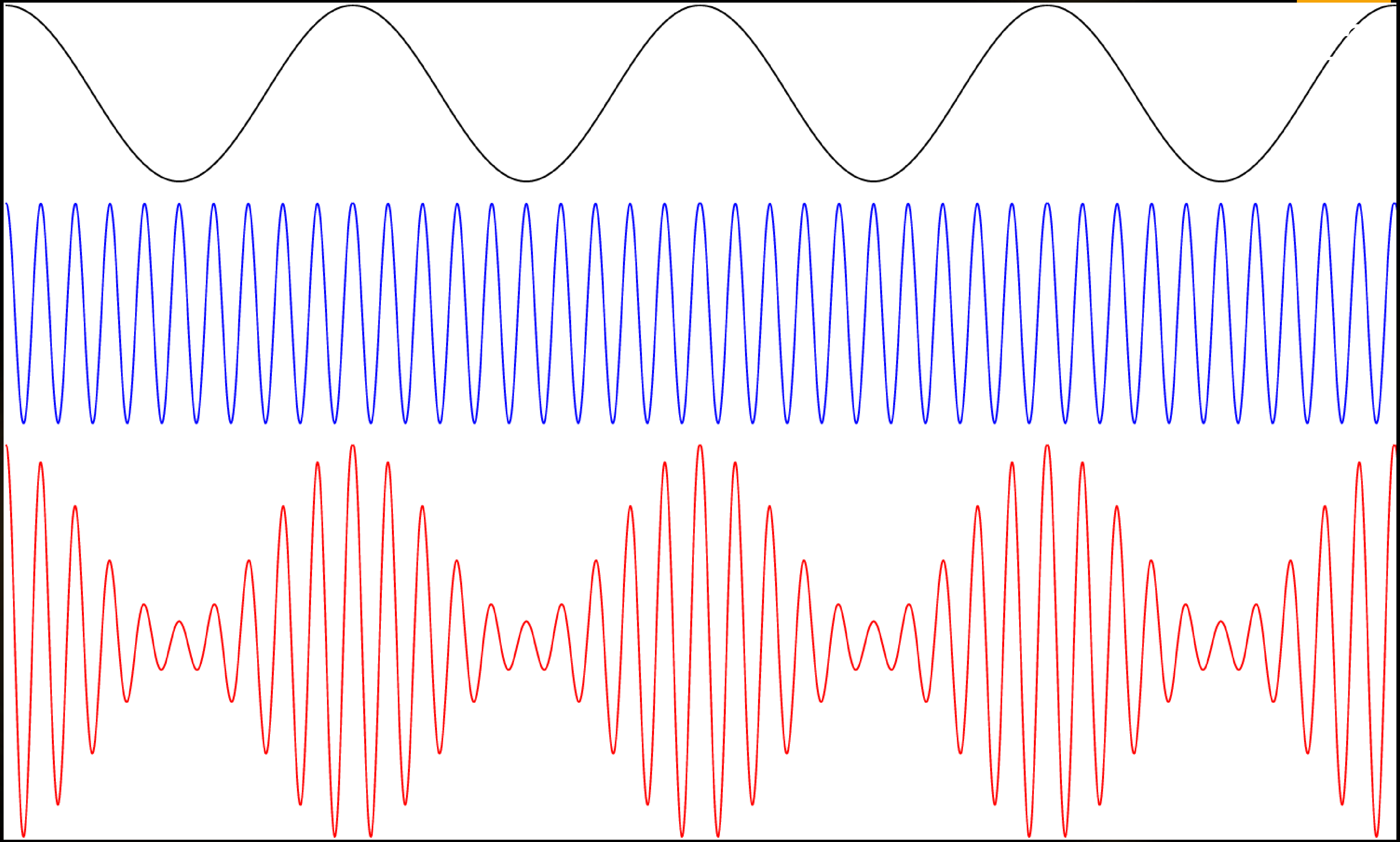
AMPLITUDE MODULATION – AM (DSB -FC)

AMPLITUDE MODULATION – Definition

- The **amplitude of the carrier signal varies** in accordance with the **instantaneous amplitude** of the modulating signal.

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



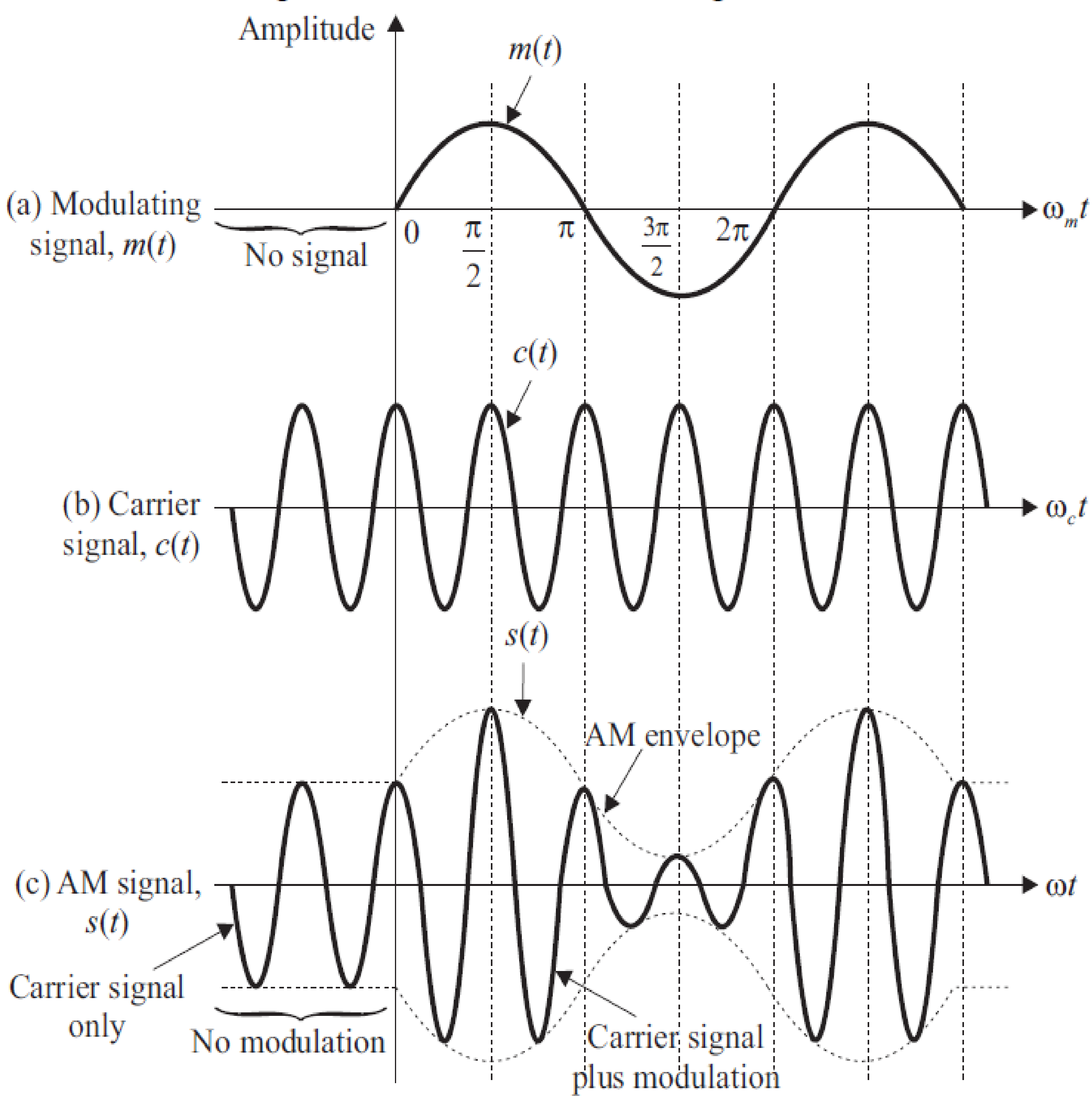


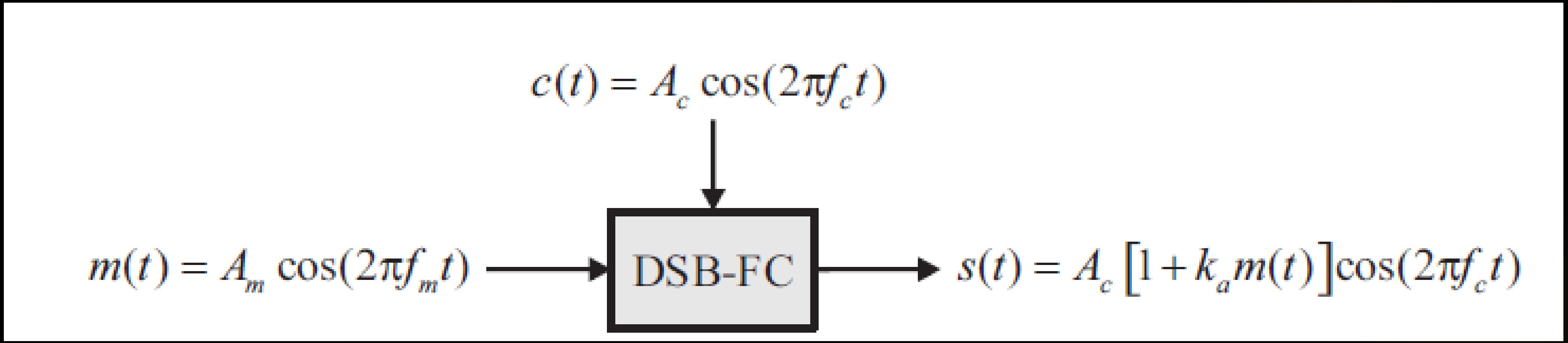
From the amplitude-modulated signal waveform, it is observed that:

➢When **no modulating signal** is applied, the modulated AM signal waveform is simply the **unmodulated carrier signal** C(t).

➢ **When a modulating signal - m(t) is applied**, the amplitude of modulated signal waveform varies in accordance with the amplitude of the modulating signal.

➢ The **frequency of the carrier signal** in the **amplitude modulated signal waveform remains the same** as that of the original unmodulated carrier signal.





- Figure illustrates the **relationship among the modulating signal m(t) , the carrier signal c(t)** ,
- and the **amplitude modulated signal s(t) for amplitude modulated (AM) signal**, will be described later.

Mathematical Expressions

Time-domain Representation of the Waves

For a **single-tone modulating signal**, the modulating signal be,
$m(t)=A_m\cos(2\pi f_m t)$

and the carrier signal be, **$c(t)=A_c\cos(2\pi f_c t)$ – we have assumed that the phase is equal to zero when t=0**

Where,

Am and **Ac** are the Amplitude of the Modulating Signal and the Carrier Signal respectively.(Typically measured in volts- v)

fm and **fc** are the frequency of the modulating signal and the carrier signal respectively.(fc >> fm)

Then, the Time domain equation of **standard Amplitude Modulated** wave can be written as;

$S(t)=A_c[1+K_a m(t)]\cos(2\pi f_c t)$: Where **K_a** is the amplitude Sensitivity

We can get : $S(t)=[A_c+m(t)]\cos(2\pi f_c t)$

$S(t)=[A_c+Am\cos(2\pi f_m t)]\cos(2\pi f_c t)$

We can see that:

$S(t)=A_c\cos(2\pi fct) +m(t)\cos(2\pi f_m t)$

(Carrier Wave + Side Bands)

Mathematical Expressions

Amplitude Sensitivity of the Modulator

$$S(t)=[A_c+m(t)]\cos(2\pi f_c t)$$

$$S(t)=A_c[1+(1/A_c)m(t)]\cos(2\pi f_c t)$$

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

- **K_a** is a constant and is called **Amplitude Sensitivity** of the Modulator.
- If the message signal is a voltage signal : **K_a** is Measured in (1/Vots)
- Responsible for **generating of the modulated Signal**.
- Use the Equation Ka=**$1/A_c$**, **[Use, if Ka is not given** at the question**]**

Envelop of the modulated Wave

- The **time-varying shape of the amplitude-modulated waveform** is called the envelope of the AM signal or simply the **AM envelope**.

From amplitude-modulated waveform as shown in above figure, the following is observed :

- When the peaks of the individual waveforms of the carrier signal in amplitude-modulated wave in positive half and negative half are joined together separately (as shown by dotted lines), the resulting envelopes resemble the original modulating signal.
- The exterior shape of the each half (positive or negative) of the **AM envelope is identical to the shape of the modulating signal.**

- The **modulated AM wave contains the information signal** in the amplitude variations of the carrier signal.
- The AM envelope contains all the frequency components **(the carrier signal, sum and difference of carrier frequency and modulating frequency)** that make up the AM signal.

- **E(t) = Ac(1 + kam(t))** is called the **Envelope** of the AM signal.
- This is very much important, **because at the receiver, we need to recover the massage signal** from the Modulated wave.

Modulation Index- (Depth of Modulation)

- A carrier wave, after being modulated, **if the modulated level is calculated**, then such an attempt is called as **Modulation Index or Modulation Depth**. It states the **level of modulation that a carrier wave undergoes**.
- The amplitude modulation index is also known as **depth of modulation, coefficient of modulation, degree of modulation, modulation factor**.
- Generally Modulation index is defined as :

$$\mu = K_a.\mathrm{Max}\ [m(t)] = K_a A_m$$

- Where as: $\mu = A_m/A_c$: [Use **if, Ka is not given** at the question]

- We know that:
- **$S(t)=A_c[1+K_a m(t)]\cos(2\pi f_c t)$**

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

- we can write the modulation index as: **$\mu=A_m/A_c$**

- Let **Emax** and **Emin** be the **Maximum** and **Minimum** amplitudes of the modulated wave and these values are the **maximum and Minimum values of the Envelope**.$\{E= A_c[1+\mu\cos(2\pi f_m t)]\}$

- We will get the **The maximum value of the positive envelope** when $\cos(2\pi f_m t)$ is 1:

$\Rightarrow \mathbf{E_{max}}= A_c.[1+\mu] = A_c+A_m$

We will get the **The minimum value of the positive envelope**, when $\cos(2\pi f_m t)$ is -1.

$\Rightarrow \mathbf{E_{min}} = A_c.[1-\mu] = A_c - A_m$

We can get ; $E_{max} + E_{min} = A_c + A_m + A_c - A_m = 2A_c$

$\Rightarrow A_c = (E_{max} + E_{min})/2$

We can get ; $E_{max} - E_{min} = A_c + A_m - (A_c - A_m) = 2A_m$

$\Rightarrow A_m = (E_{max} - E_{min})/2$

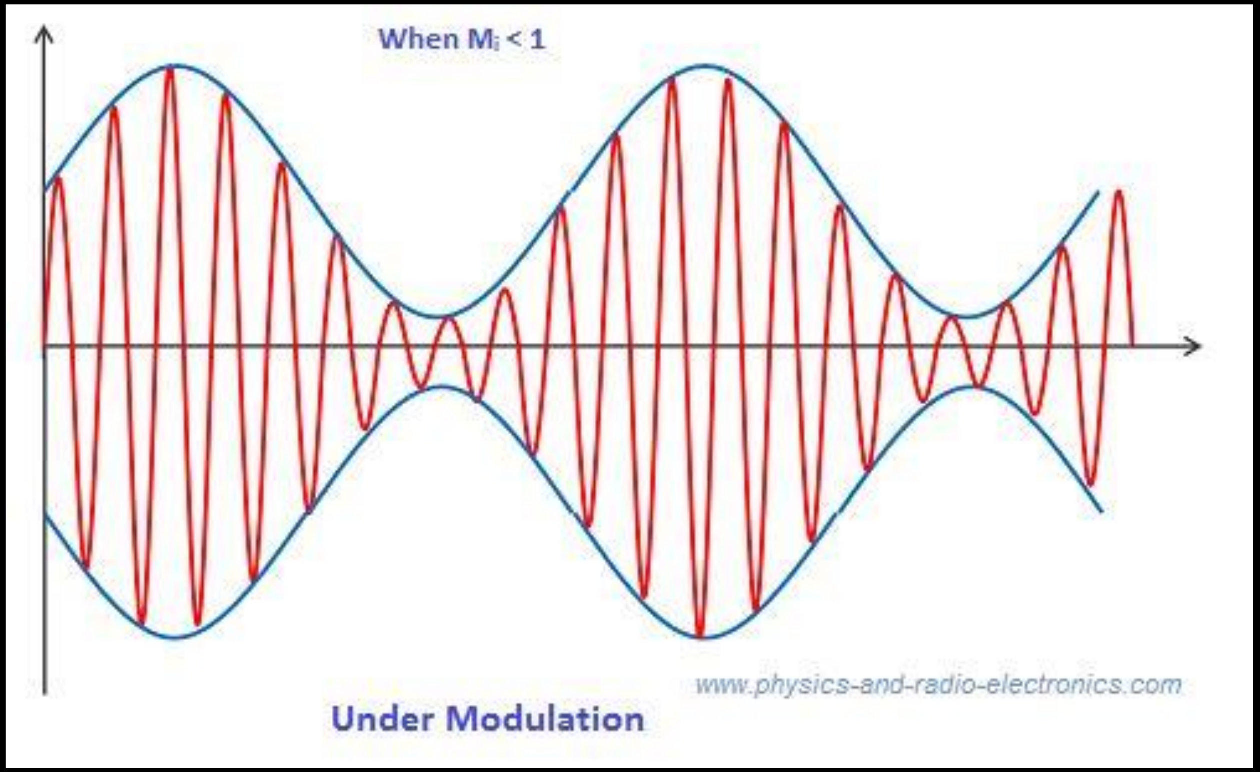
$A_m/A_c = (E_{max} - E_{min})/2/(E_{max} + E_{min})/2$

$\mu = (E_{max} - E_{min})/(E_{max} + E_{min})$: Another equation for the Modulation Index

<u>Based on Modulation Index</u>, there are **three types of modulation**

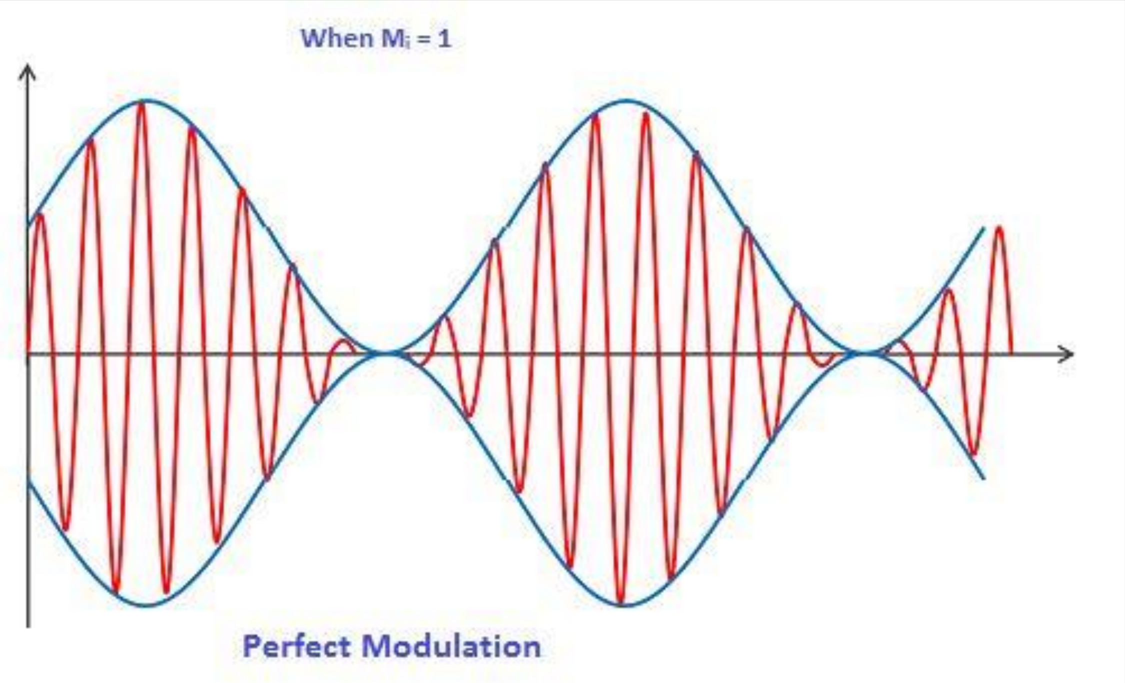
Under Modulation : (μ<1)

- Occurs when the maximum amplitude of the message signal or modulating signal is less than the maximum amplitude of the carrier signal (**A_m < A_c**).
- Under-modulation **causes no distortion**



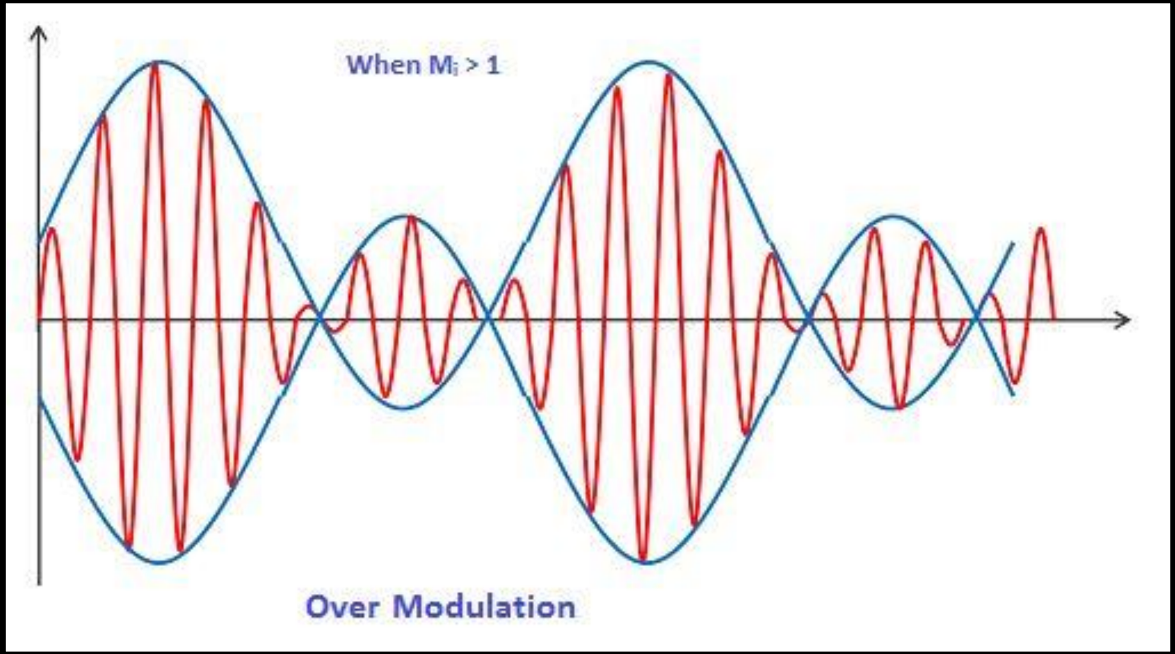
Perfect modulation (μ=1)

- Occurs when the maximum amplitude of the message signal or modulating signal is **exactly equal** to the maximum amplitude of the carrier signal ($A_m = A_c$).
- Perfect-modulation **causes no distortion**



Over Modulation (μ>1)

- Occurs when the maximum amplitude of the message signal or modulating signal is greater than the maximum amplitude of the carrier signal ($A_m > A_c$).
- **causes severe distortion** of the waveform of the message signal **which results in data loss**



In over-modulation, the carrier wave experiences 180° phase reversals where, the carrier level falls below the zero point.