PHY 359 2.0 / ASP 487 2.0
Telecommunication

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Modulation and Demodulation

Introduction

- For Radio Transmission, necessary to send an audio signal (Ex. music, speech etc.) from a broadcasting station over great distances to a receiver. And audio signals employ wireless communication.
- The audio signal cannot be sent directly over the air for appreciable distance. Even if the audio signal is turned into an electrical signal, it cannot be transmitted very far without using a significant amount of power.
- The energy of a wave is directly proportional to its frequency. At audio frequencies (20 Hz to 20 kHz), the signal power is small, and radiation level is not practicable.
- The radiation of electrical energy is practicable only at high frequencies (above 20 kHz). The high frequency signals can be sent thousands of km distance even with comparatively small power.

Introduction

- So, if the audio signal is to be transmitted properly, A method has to be developed that will allow for high-frequency transmission while still enabling the audio signal to be carried. Electrical audio signals can be superimposed over high frequency electrical carriers to achieve this task.

- The above resultant waves are known as modulated waves or radio waves and the process is called modulation.

- At the radio receiver, the audio signal is extracted from the modulated wave by the process called demodulation.

- Then the signal is then amplified and reproduced into sound by the loudspeaker.

Radio Broadcasting, Transmission and Reception

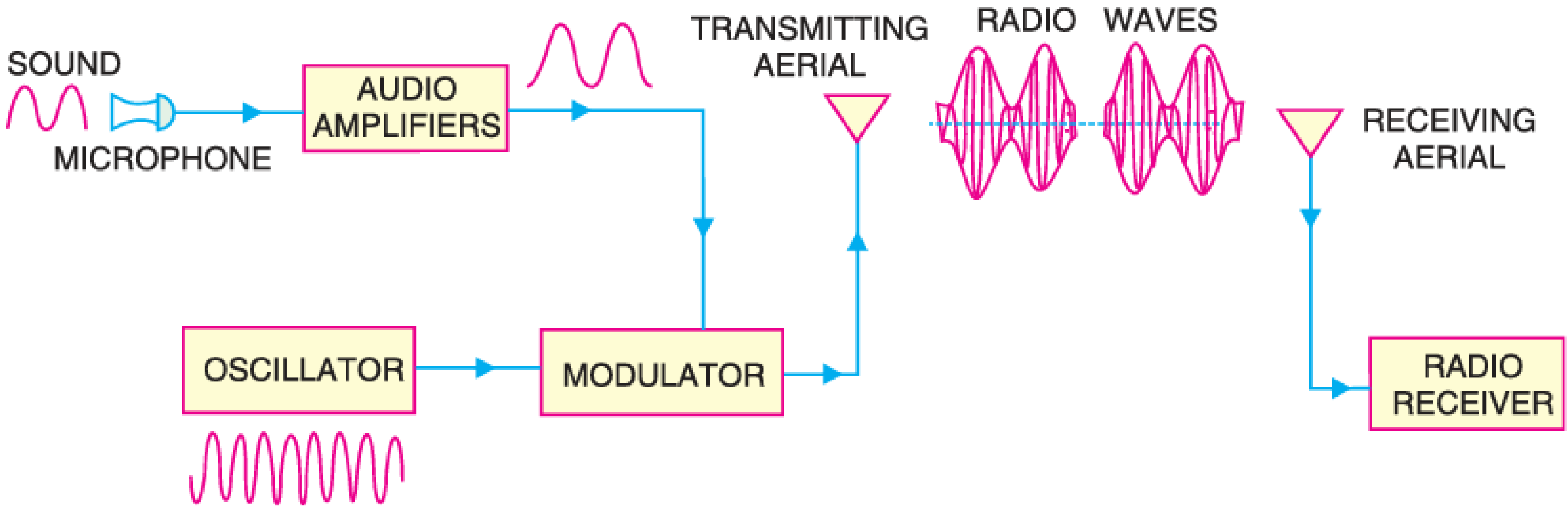


Figure: 01 Block diagram of a modern full-duplex communication system

Radio Broadcasting, Transmission and Reception

Transmitter

The transmitter’s purpose is to produce radio waves for transmission into space. The important components: **A microphone, audio amplifiers, oscillator, modulator, and transmitting antenna.**

Microphone

A microphone is a device which converts sound waves into electrical waves. The output of microphone is fed to a multistage audio amplifier for raising the strength of a weak signal.

Audio amplifier

Since the microphone's audio signal is so weak, it needs to be amplified. Audio amplifiers that are cascaded do this function. The modulator receives the amplified output from the final audio amplifier in order to perform the modulation process.

Radio Broadcasting, Transmission and Reception

Oscillator

- A carrier wave, which is a high frequency signal, is produced by an oscillator. For this, a crystal oscillator is typically employed.
- Radio frequency amplifier stages increase the carrier wave's power level to a suitable level. The majority of broadcasting stations have several kW (kilowatts) of carrier wave power. To send the signal over the required distances, such great power is required.

Modulator

- The modulator receives both the carrier wave and the amplified audio signal. In this case, the audio signal is superimposed on the carrier wave properly. The process is known as modulation, and the final waves are referred to as radio waves or modulated waves.
- The audio signal can be sent at the carrier frequency through the modulation procedure. The audio signal may travel great distances because the carrier frequency is so high.
- The transmitting antenna or aerial receives the radio waves from the transmitter and radiates them into space.

Radio Broadcasting, Transmission and Reception

radio waves Transmission

- The radio waves are sent into space in all directions by the transmitting antenna. The speed of these radio waves is 3×10^8 m/s, which is the speed of light.
- Electromagnetic waves and radio waves have many general characteristics.
- It is readily demonstrated that electrical energy may be emitted into space at high frequencies.

Radio receiver

- The radio waves cause a small e.m.f. to be induced in the receiving antenna upon reaching it.
- The radio receiver provides this small voltage. Here, the radio waves are amplified initially, and the signal is then extracted by the **Demodulation process**.
- Audio amplifiers amplify the signal before feeding it to the speaker so that sound waves can be produced.

modulation schemes – by Signals

- ❖ Modulation by Analog signals
- ❖ Modulation by Digital signals.

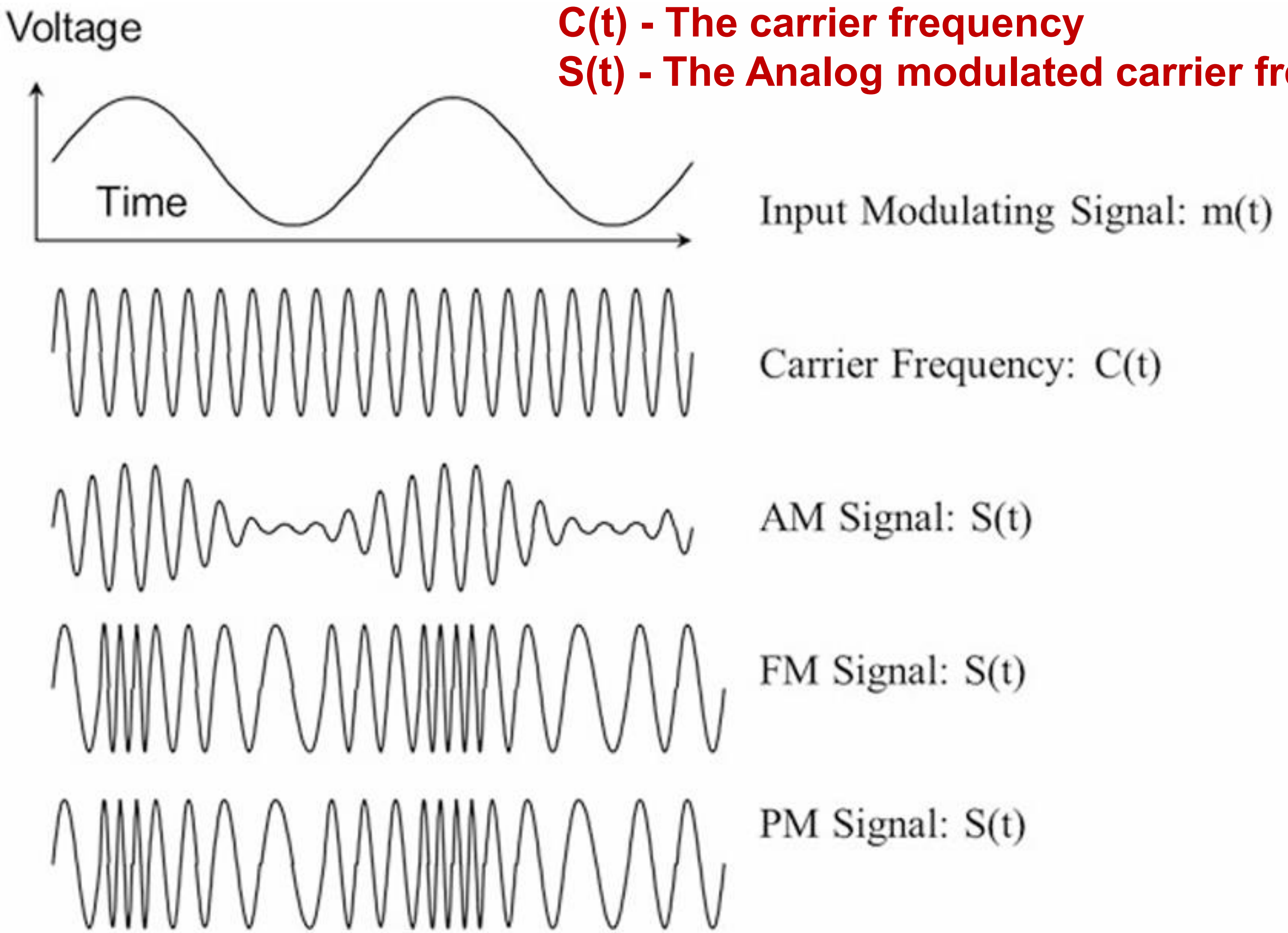
Modulation by Analog Signals

For analog signals, there are three well-known modulation techniques AM, FM, and PM.

- Amplitude Modulation (AM)
- Frequency Modulation (FM)
- Phase Modulation (PM)

Modulation by Analog Signals

m(t) - The input modulating audio signal
C(t) - The carrier frequency
S(t) - The Analog modulated carrier frequency



Modulation by Analog Signals

Amplitude Modulation (AM)
The amplitude of the carrier changes in accordance with the input analog signal, while the frequency of the carrier remains the same.

Frequency Modulation (FM)
The frequency of the carrier changes in accordance with the input modulation signal. In FM, only the frequency changes while the amplitude remains the same.

Phase Modulation (PM)
- The phase of the carrier changes in accordance with the phase of the carrier, while the amplitude of the carrier does not change. PM is closely related to FM.
- FM is derived from the rate of change of phase of the carrier frequency. Both FM and PM belong to the same mathematical Method.

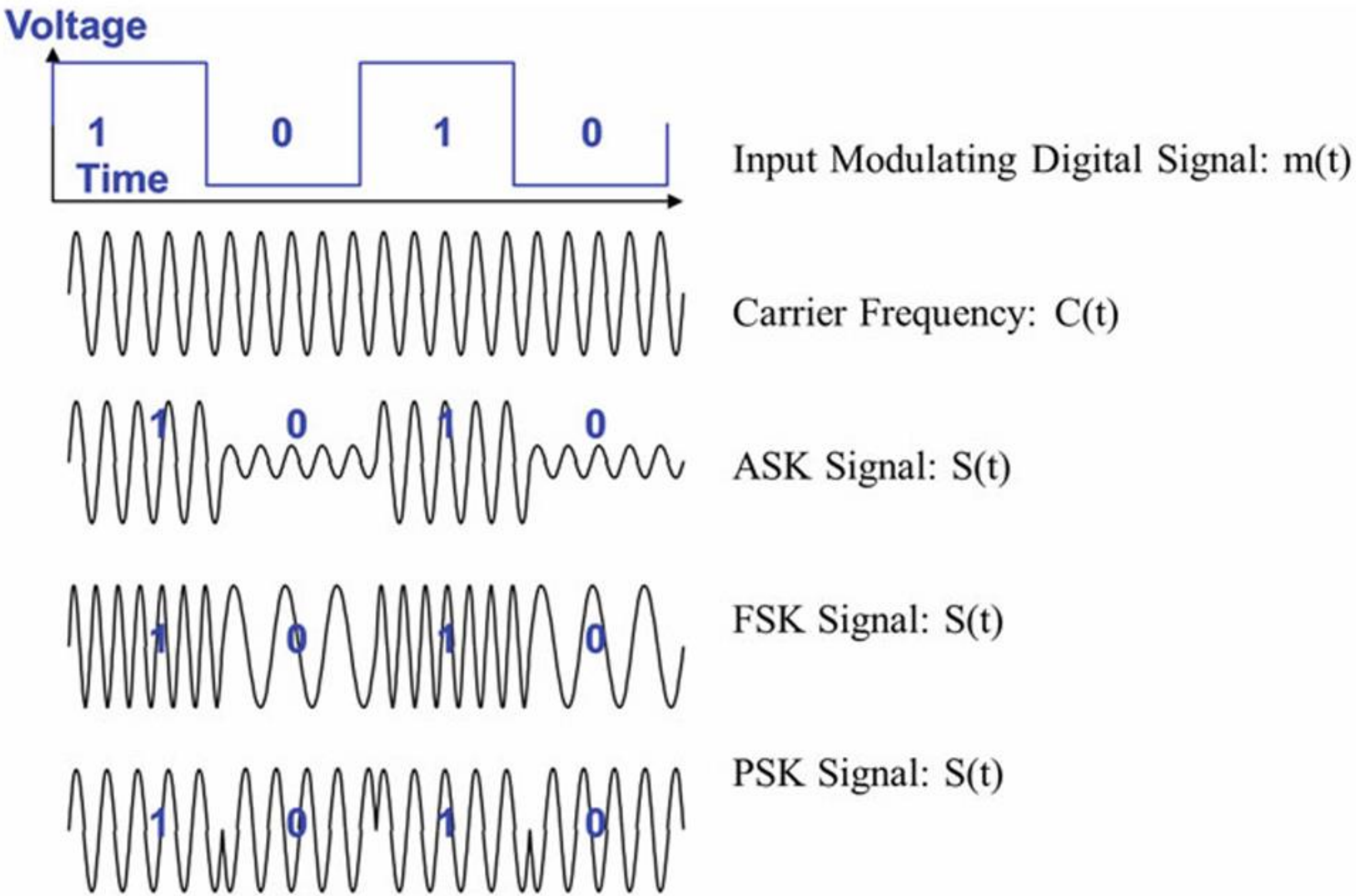
Modulation by Digital Signals

Modulation by Digital Signals

For digital signals, there are several modulation techniques available. The three main digital modulation techniques are:

- Amplitude shift keying (ASK)
- Frequency shift keying (FSK)
- Phase shift keying (PSK)

Modulation by Digital Signals



Modulation by Digital Signals

Amplitude shift keying (ASK)

- known as On–Off Keying (OOK), is a method of digital modulation that utilizes amplitude shifting of the relative amplitude of the career frequency.
- The signal to be modulated and transmitted is binary; this is referred to as ASK, where the amplitude of the carrier changes in discrete levels,
- In accordance with the input signal

Binary 0 (bit 0): Amplitude = Low
Binary 1 (bit 1): Amplitude = High

- Output of the ASK-modulated carrier, For binary signal 1, the carrier is ON. For the binary signal 0, the carrier is OFF. However, a small residual signal may remain due to noise, interference, etc.

Modulation by Digital Signals

Frequency shift keying (FSK)

- FSK is a method of digital modulation that utilizes frequency shifting of the relative frequency content of the signal. The signal is to be modulated and transmitted in binary; this is referred to as binary FSK (BFSK).
- Where the carrier frequency changes in discrete levels, in accordance with the input signal:

Binary 0 (bit 0): Frequency = $f + \Delta f$
Binary 1 (bit 1): Frequency = $f - \Delta f$

- Output is the FSK-modulated carrier, which has two frequencies f_1 and f_2, corresponding to the binary input signal

- These frequencies correspond to the messages binary 0 and 1, respectively.

Modulation by Digital Signals

Phase shift keying (PSK)

- PSK is a method of digital modulation that utilizes the phase of the carrier to represent the digital signal. The signal to be modulated and transmitted is binary; this is referred to as binary PSK (BPSK).

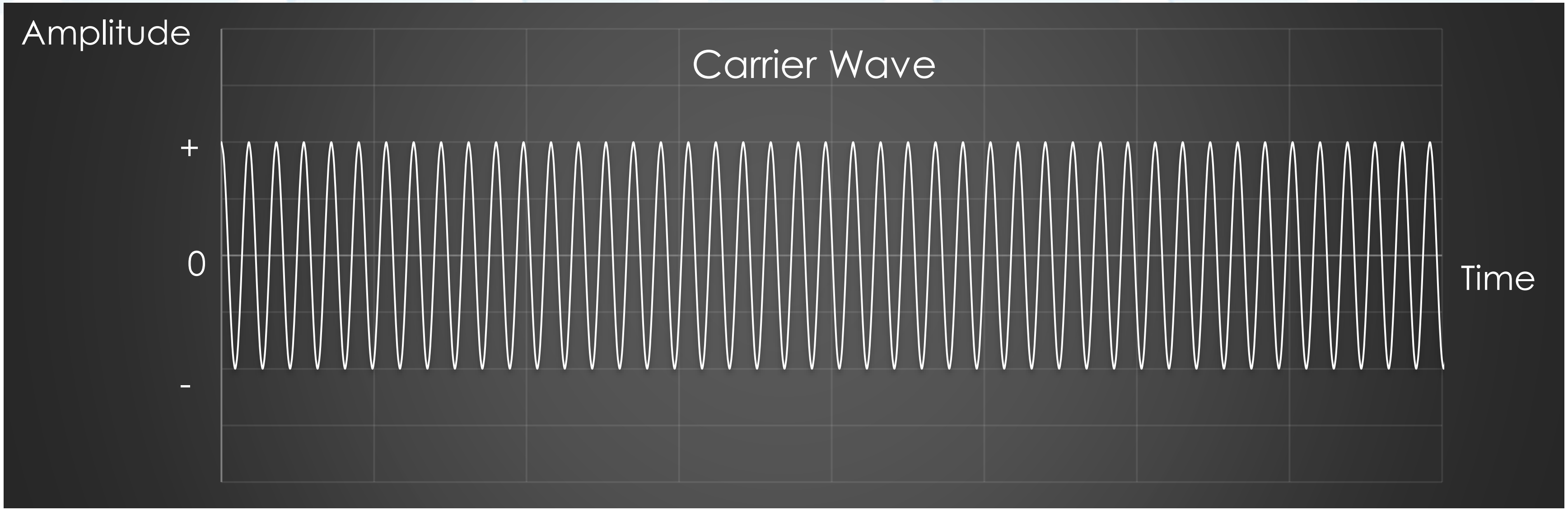
- Where the phase of the carrier changes in discrete levels, in accordance with the input signal:

Binary 0 (bit 0): Phase1 = 0°
Binary 1 (bit 1): Phase2 = 180°

- Output is the BPSK-modulated carrier, which has two phases ϕ_1 and ϕ_2 corresponding to the two information bits.

Amplitude Modulation and Demodulation

Carrier Wave



$$c(t) = A_c \cos(\omega_c t + \Phi_c)$$

$c(t)$= instantaneous carrier amplitude (volts)
A_c = carrier amplitude (peak volts)
ω_c = angular frequency in radians and $\omega_c = 2\pi f_c$
f_c = carrier frequency (hertz)
Φ_c = carrier phase delay (radians)

Amplitude Modulation

- Amplitude Modulation (AM) is used in short and medium wave radio transmission
- AM is varying the amplitude of a carrier wave, c(t), about a mean value, linearly with the baseband (message) signal, m(t)
- Carrier wave is given by:

$$c(t) = A_c \cos(\omega_c t + \Phi_c)$$

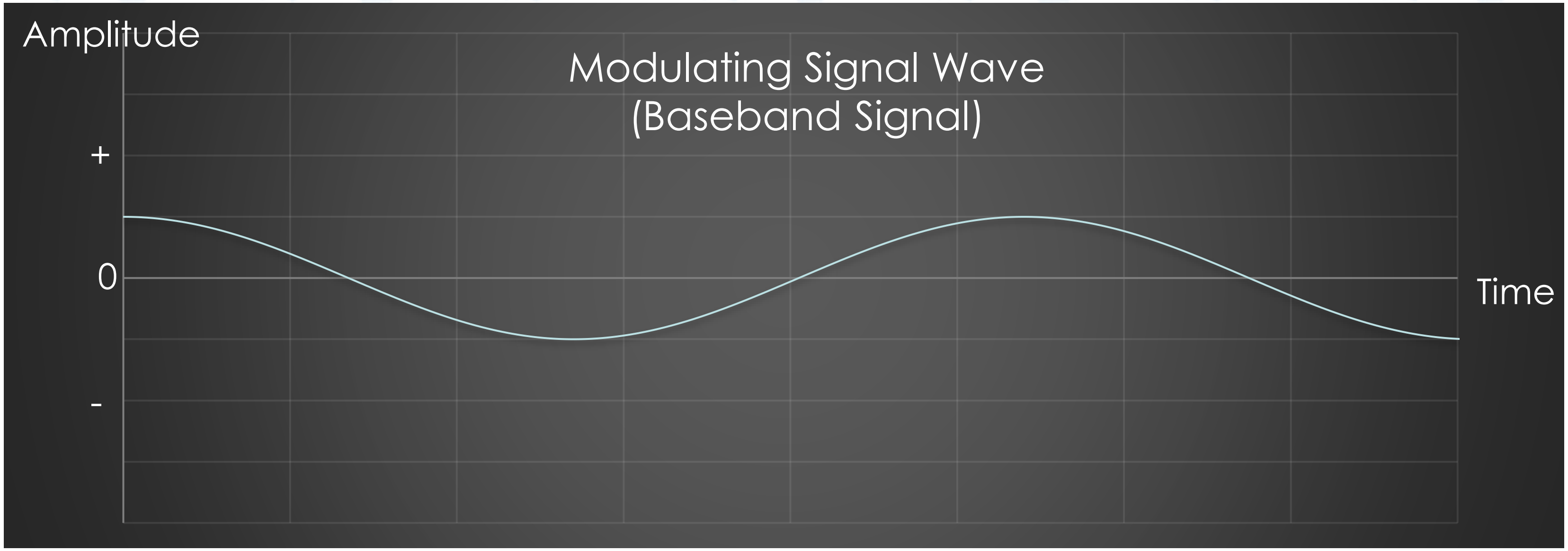
- AM modulated wave is given by:

$$s(t) = A_c[1+k_a m(t)] \cos(\omega_c t + \Phi_c)$$

- k_a is the amplitude sensitivity of the modulator
- For simplicity:

$$s(t) = A_c[1+m(t)] \cos(\omega_c t)$$

A Simple Baseband Signal



$$m(t) = A_m \cos(\omega_m t)$$

$m(t)$ = instantaneous modulating amplitude (volts)
A_m = modulating amplitude (peak volts)
ω_m = angular frequency in radians and $\omega_m = 2\pi f_m$
f_m = modulating frequency (hertz)

Amplitude Modulation..

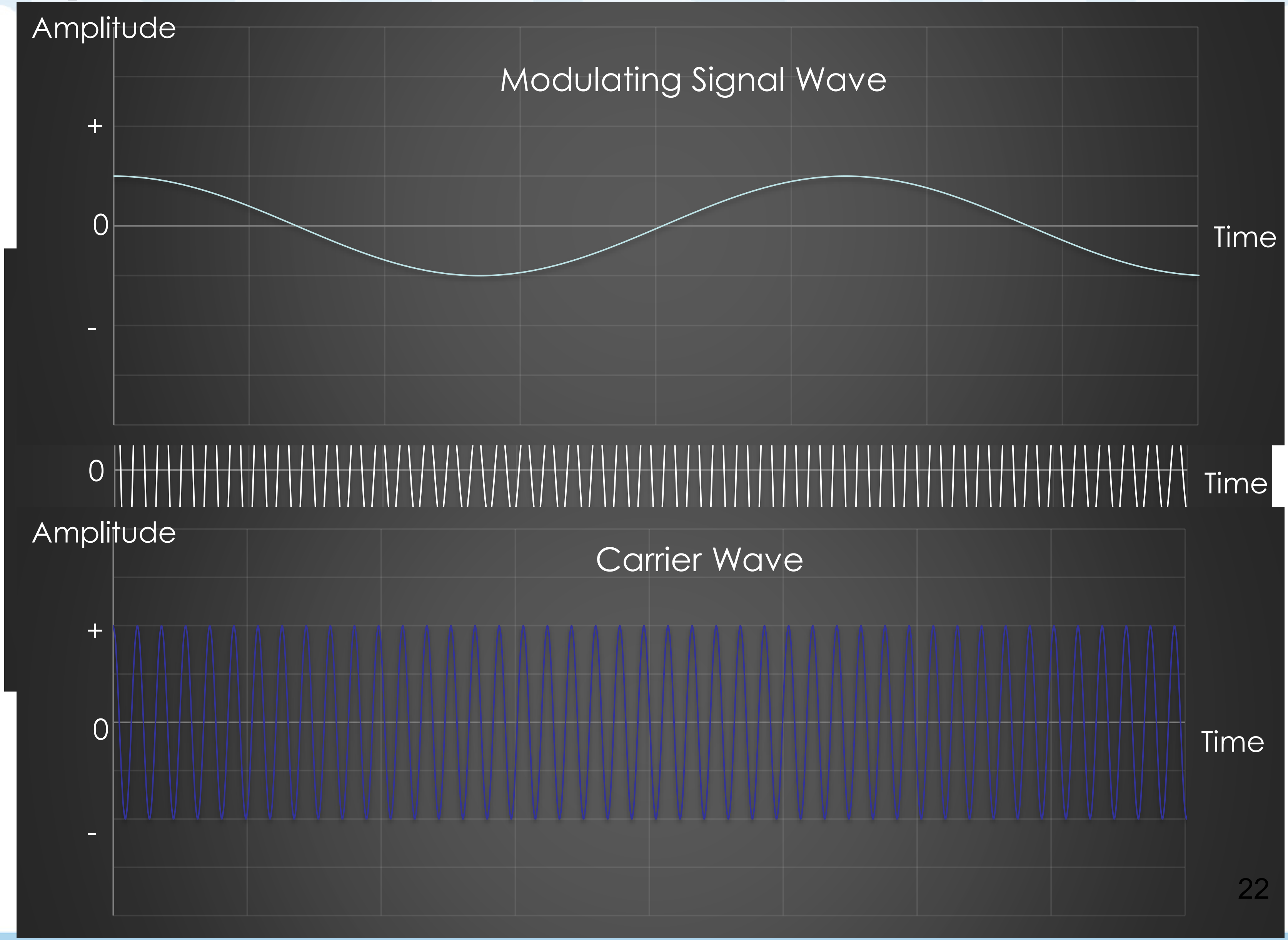
- Amplitude of carrier is made to vary about A_c by the message signal m(t)

$$m(t) = A_m \cos(\omega_m t)$$

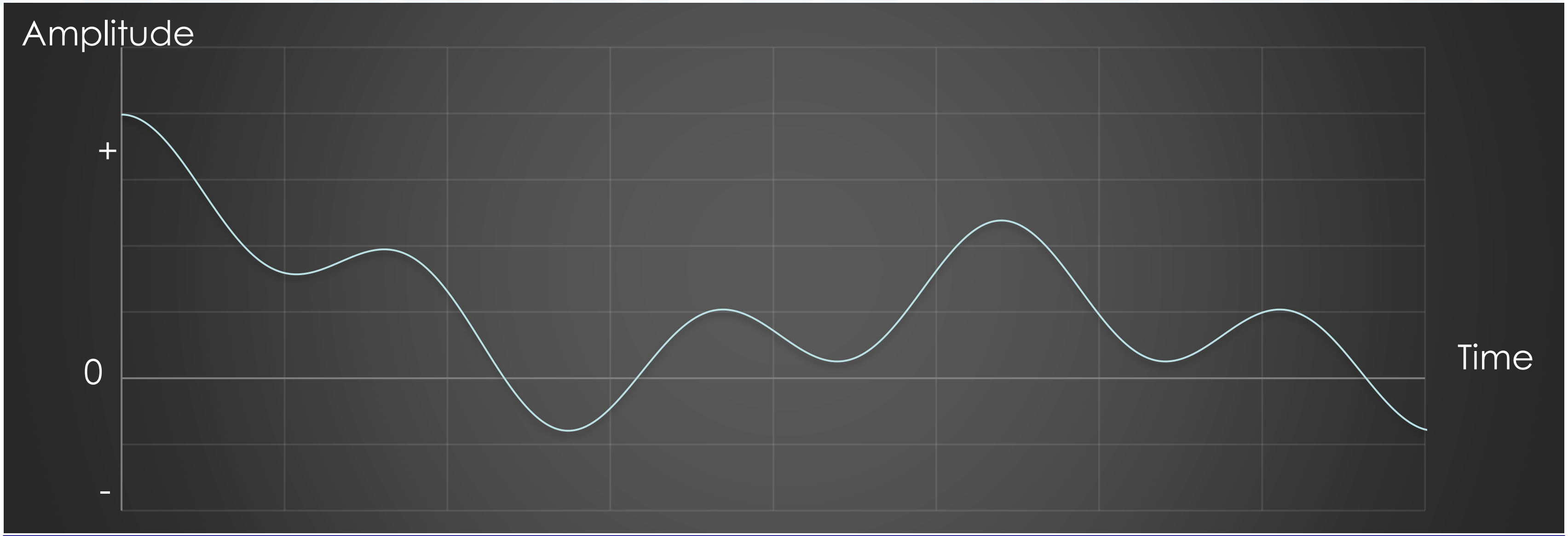
- Modulated signal becomes:

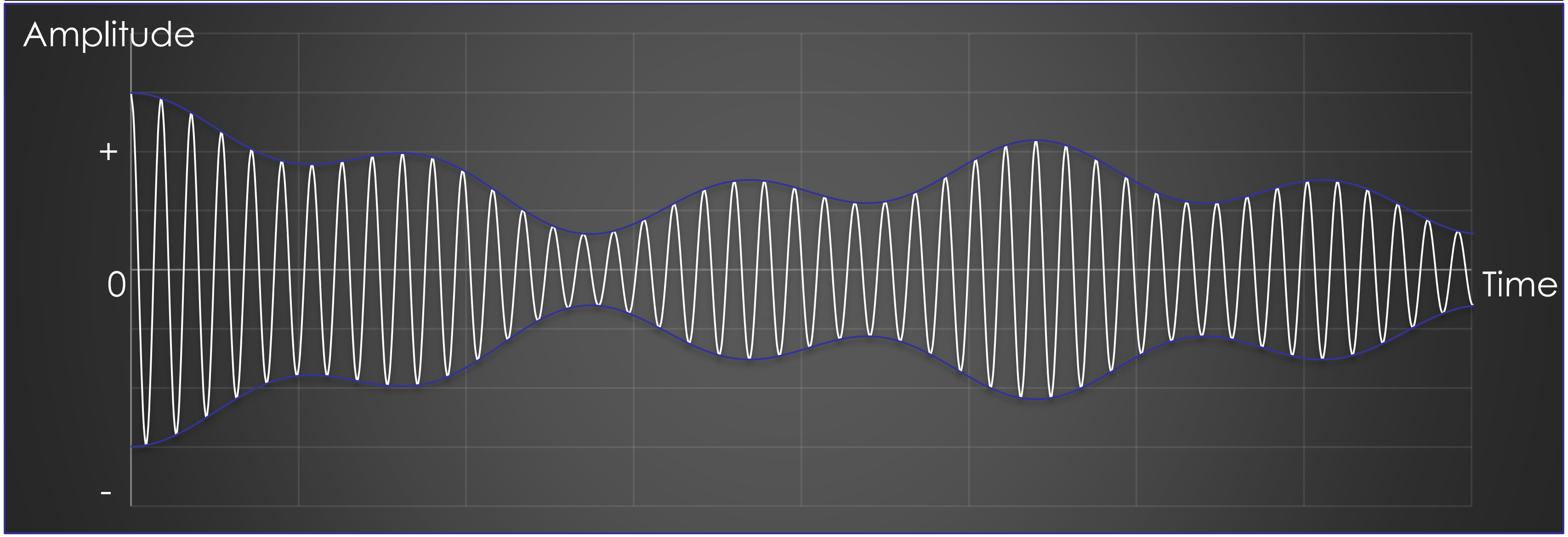
$$s(t) = A_c[1+m(t)] \cos(\omega_c t)$$
$$s(t) = A_c[1+A_m \cos(\omega_m t)] \cos(\omega_c t)$$

Amplitude Modulation..



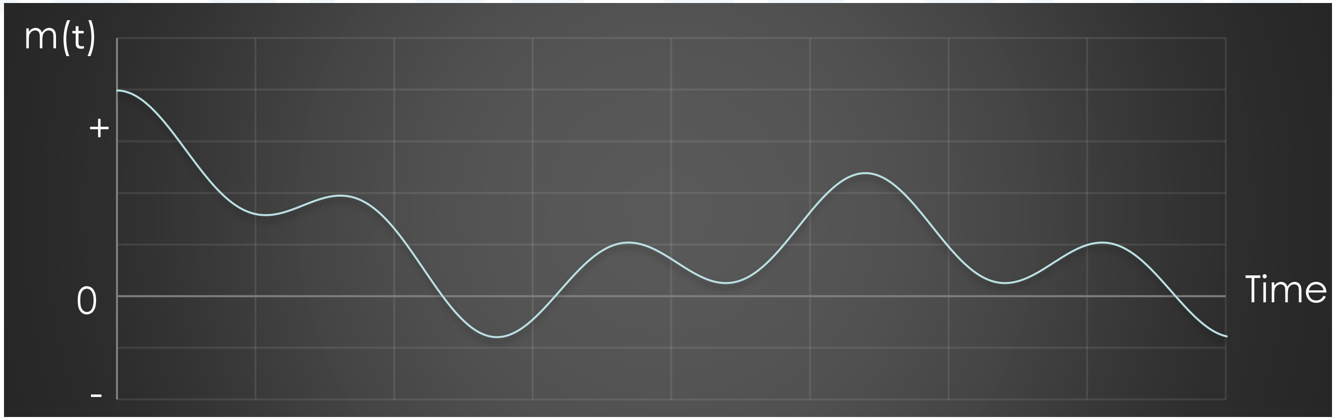
A Realistic Baseband Signal





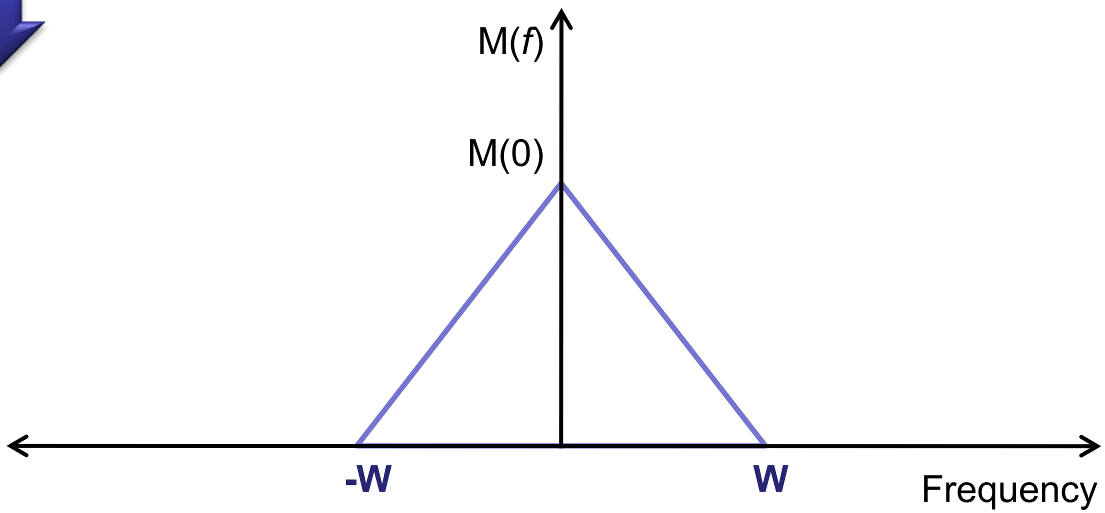
Frequency Domain Representation

Time Domain



Fourier Transform

Frequency Domain



Frequency Domain Representation

- AM signal:

$$s(t) = A_c[1+m(t)] \cos(\omega_c t)$$

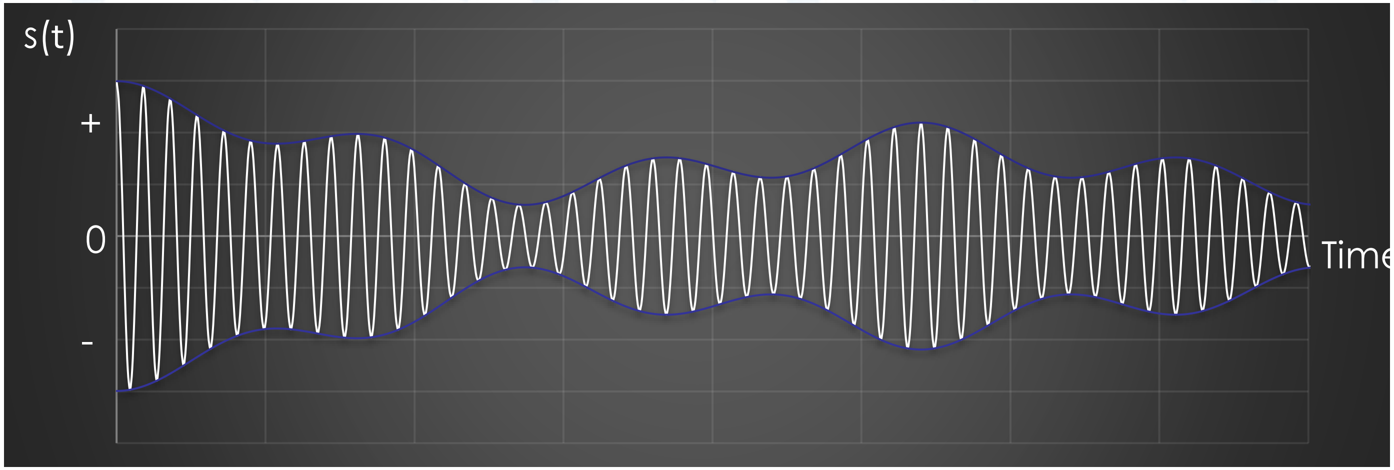
$$s(t) = A_c\cos(\omega_c t) + A_c m(t)\cos(\omega_c t)$$

- Fourier transform S(f) of AM signal s(t):

$$S(f) = \tfrac{1}{2} A_c [\delta(f-f_c) + \delta(f+f_c)] + \tfrac{1}{2} A_c [M(f-f_c) + M(f+f_c)]$$

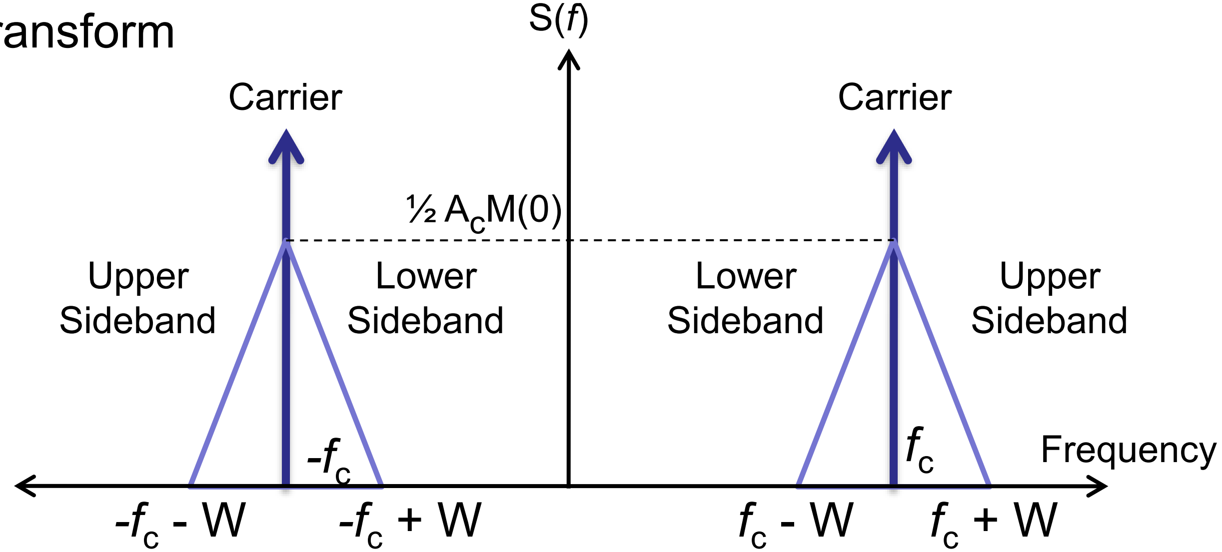
Frequency Domain Representation

Time Domain



Fourier Transform

Frequency Domain



Results of Amplitude Modulation

- Spectrum consists of:
  - two delta functions weighted by $A_c/2$ (occur at $\pm f_c$)
  - Two versions of the baseband spectrum transformed by $\pm f_c$, scaled in amplitude by $A_c/2$

- As a result of modulation, negative frequencies of m(t), from –W to 0, become visible as positive (i.e. measurable) frequencies

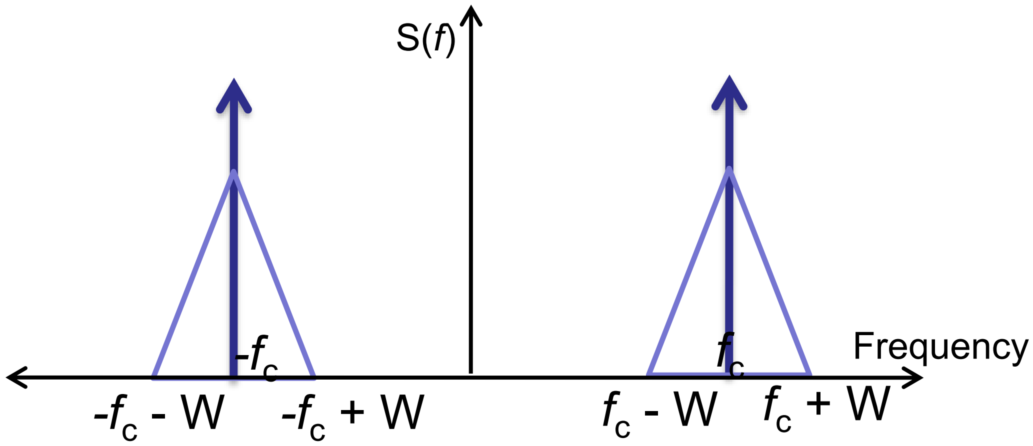
- Transmission Bandwidth

= Highest frequency – Lowest frequency

$$B_T = f_c + W - (f_c - W)$$

$$B_T = 2W$$

Carrier Frequency Selection



- Carrier frequency, f_c, should be much higher than the highest frequency component, W, of the message signal
- $f_c >> W$ is not satisfied an envelop cannot be detected satisfactorily

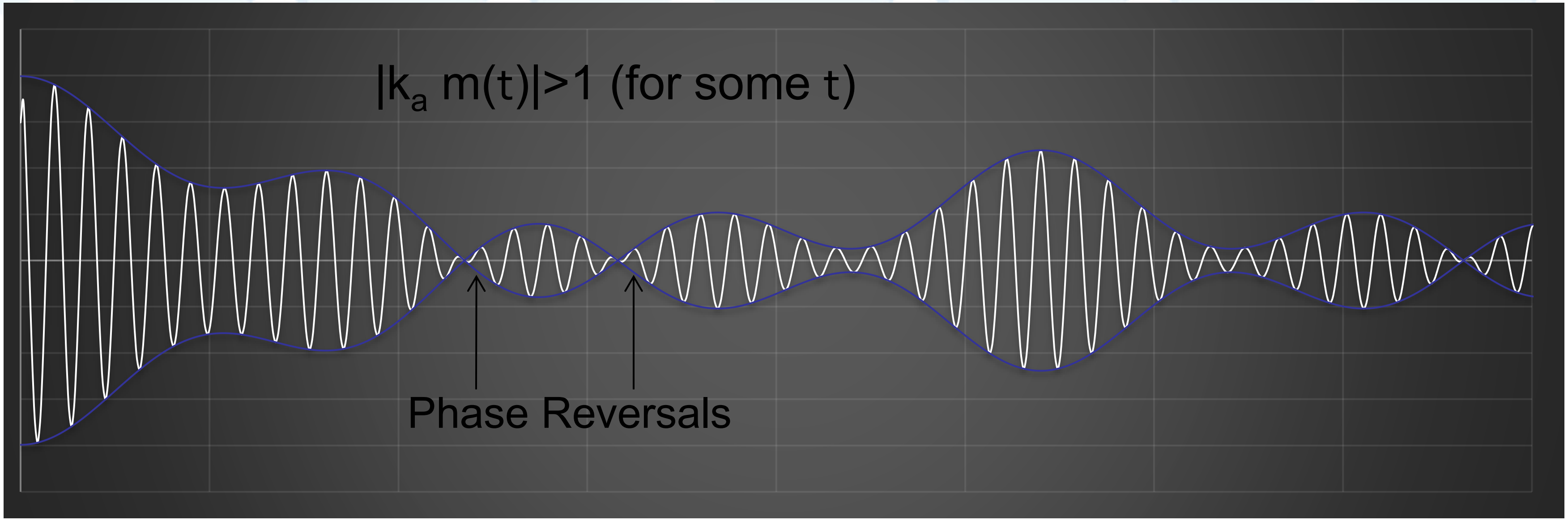
Amplitude Sensitivity of Modulator

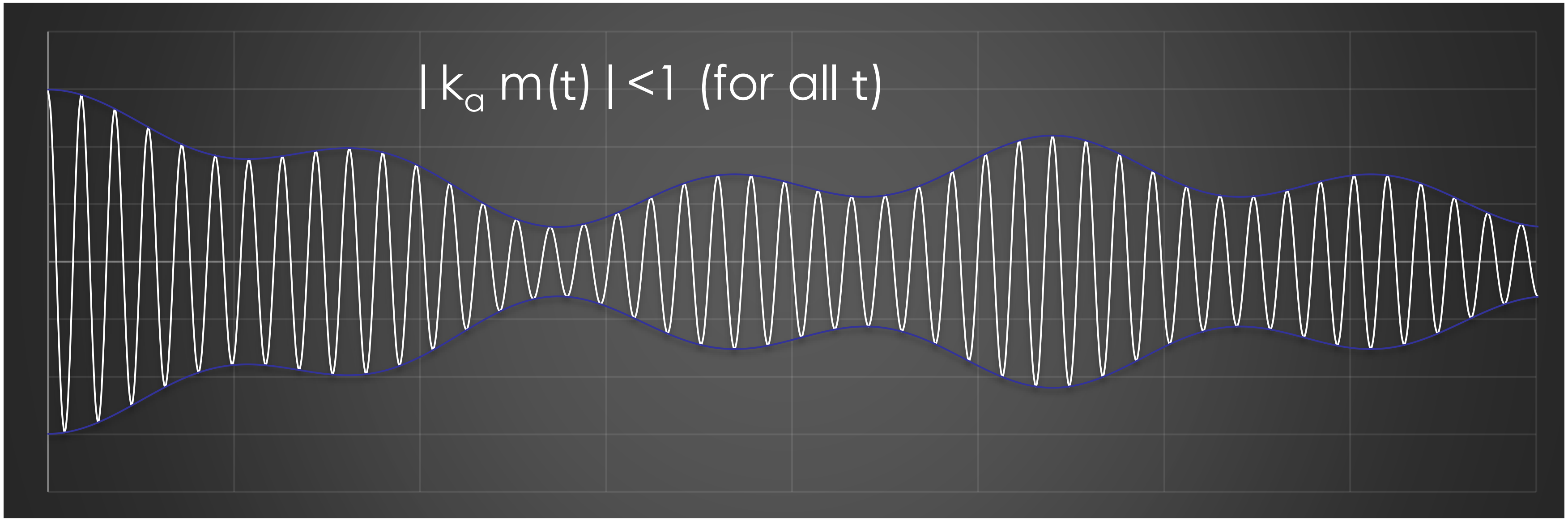
- AM waveform is given by:

  $$s(t) = A_c[1+k_a m(t)] \cos(\omega_c t)$$

- For all t, $|k_a\, m(t)|<1$ to ensure $[1+k_a m(t)]$ is always positive
- If k_a of the modulator is large enough to make $|k_a m(t)|>1$ for any t, the carrier wave becomes over modulated, resulting in carried phase reversals whenever the factor $|k_a m(t)|$crosses 0
- Modulated wave shows envelope distortion

Modulation Sensitivity

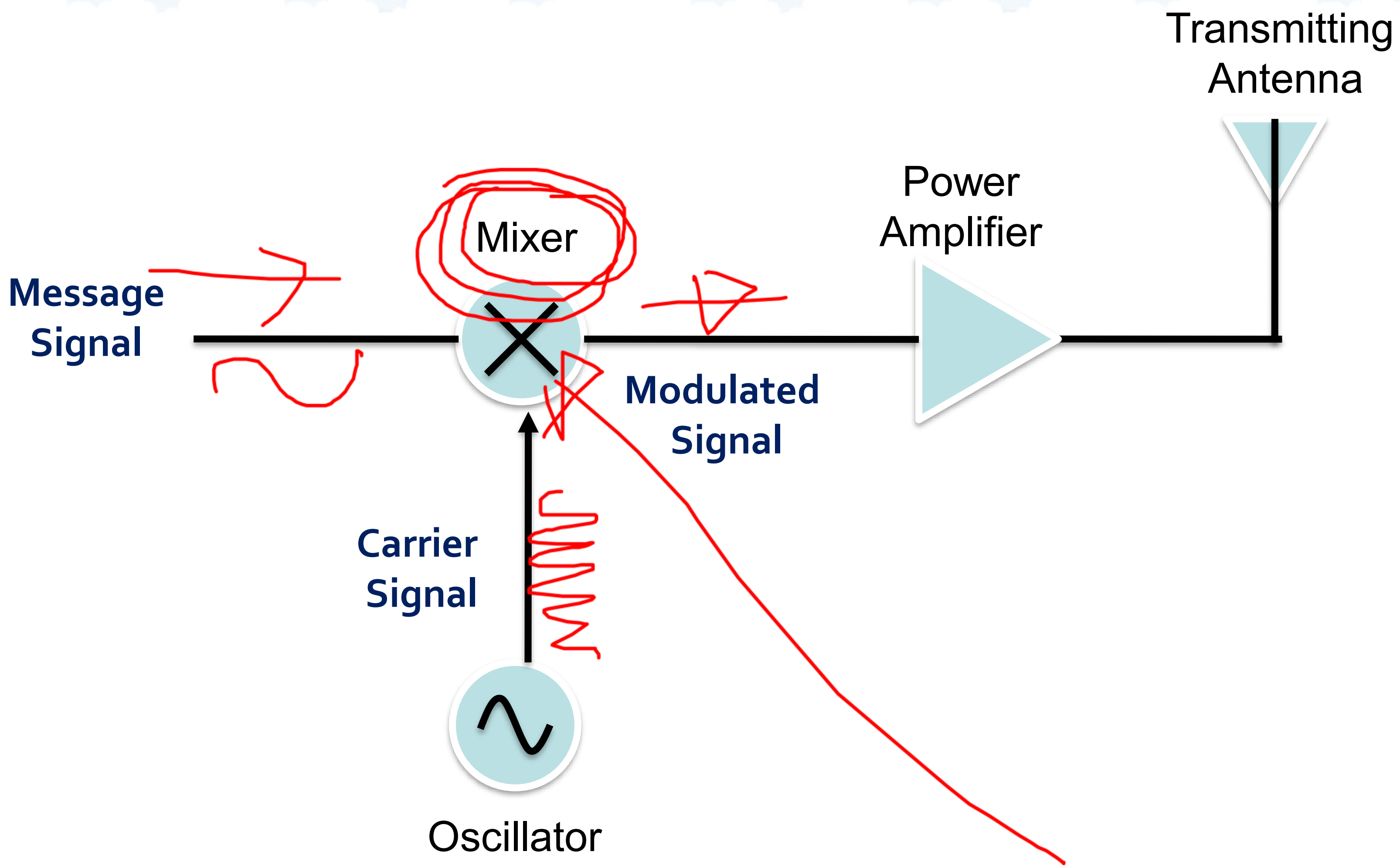




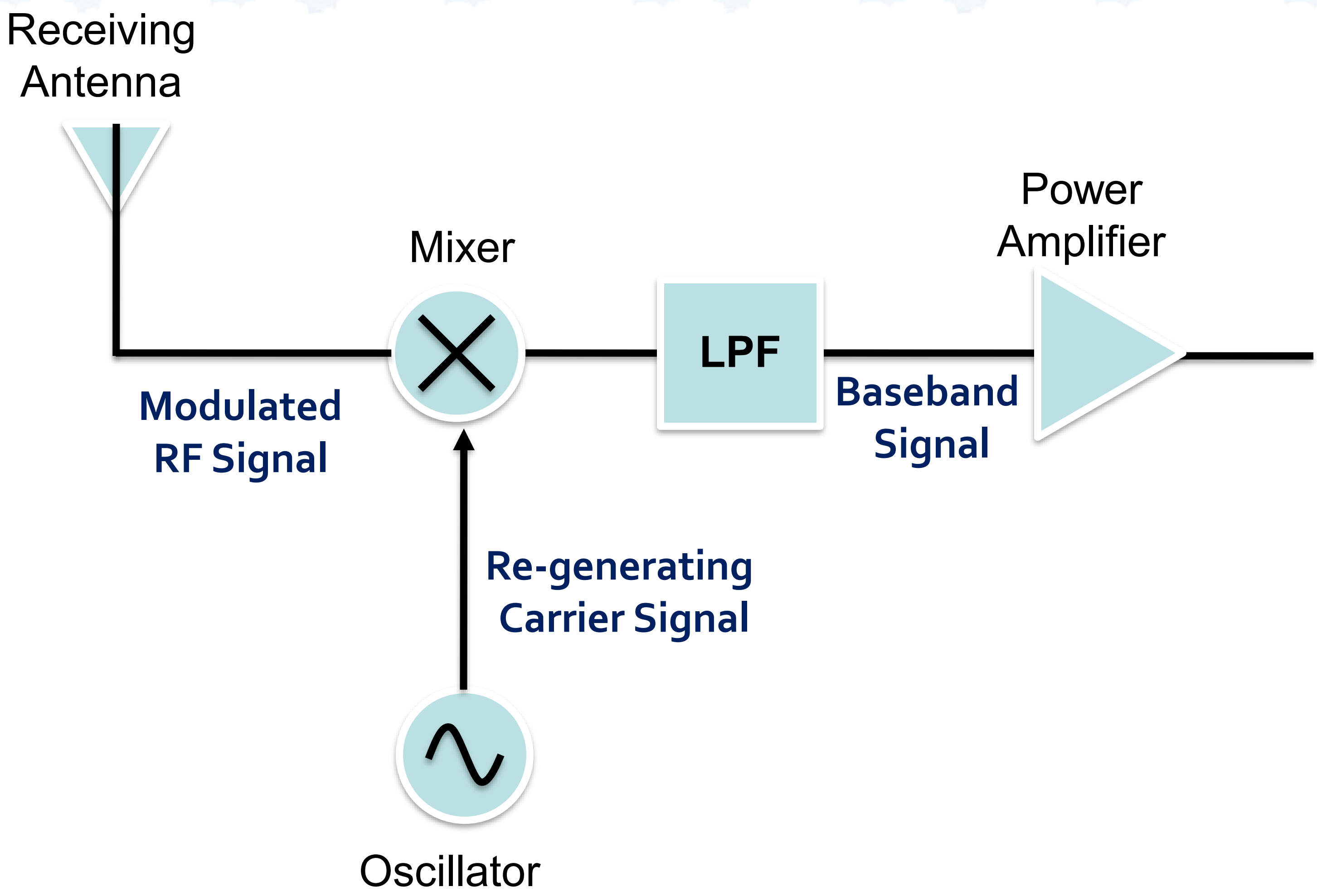
Limitations of AM & Remedies

- Transmitted power and channel bandwidth are primary communication resources
- AM has two major limitations:
  - Wasteful of power – only a fraction of power carries m(t)
  - Wasteful of bandwidth – only one sideband is necessary
- Suppressing the carrier and modifying sidebands overcomes these inefficiencies
- Double-sideband suppressed-carrier(DSBSC), single-sideband(SSB), double-sideband reduced-carrier (DSBRC), vestigial sideband(VSB) are some such technologies
- Removing carrier signal increases transmitter efficiency by three times
- Carrier must be regenerated, using a beat frequency oscillator, to use conventional demodulating techniques for DSBSC and DSBRC

AM Transmitter



AM Receiver


Receiving
Antenna
Mixer
LPF
Power
Amplifier
Modulated
RF Signal
Baseband
Signal
Re-generating
Carrier Signal
Oscillator

Modulation Factor

The ratio of the change of amplitude of the carrier wave to the amplitude of the normal carrier wave is called the modulation factor “**m**”

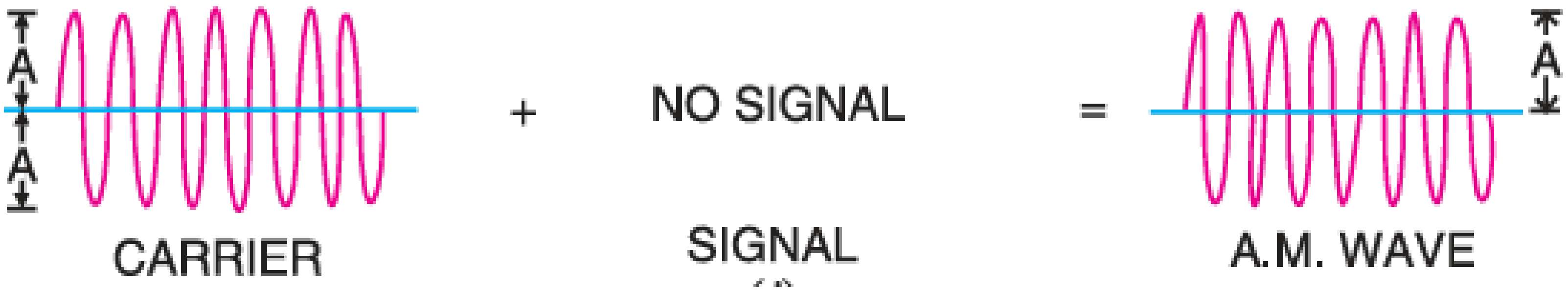
$$\textbf{Modulation factor}(m) = \frac{\textbf{Amplitude change of carrier wave}}{\textbf{Normal carrier amplitude (unmodulated)}}$$

The value of the modulation factor depends upon the amplitudes of the carrier and signal.

Modulation Factor

- When the **signal amplitude is zero**, the carrier wave is not modulated. The amplitude of the carrier wave **remains unchanged**.

Amplitude change of carrier = 0
Amplitude of normal carrier = A
Modulation factor, m = 0/A = 0 or 0%

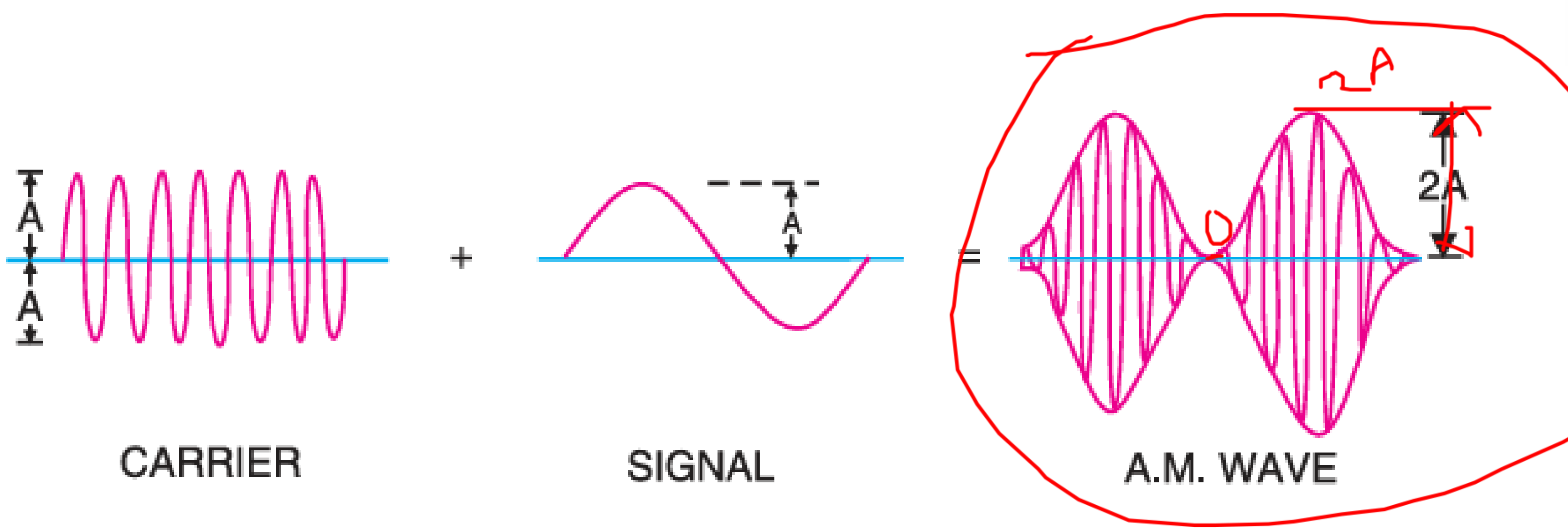


Modulation Factor

- When the signal amplitude is equal to the carrier amplitude, the amplitude of carrier varies between 2A and zero. Amplitude change of carrier = 2 A − A = A.

∴ Modulation factor, m = A/A = 1 or 100 %

In this case, the carrier is said to be 100% modulated.

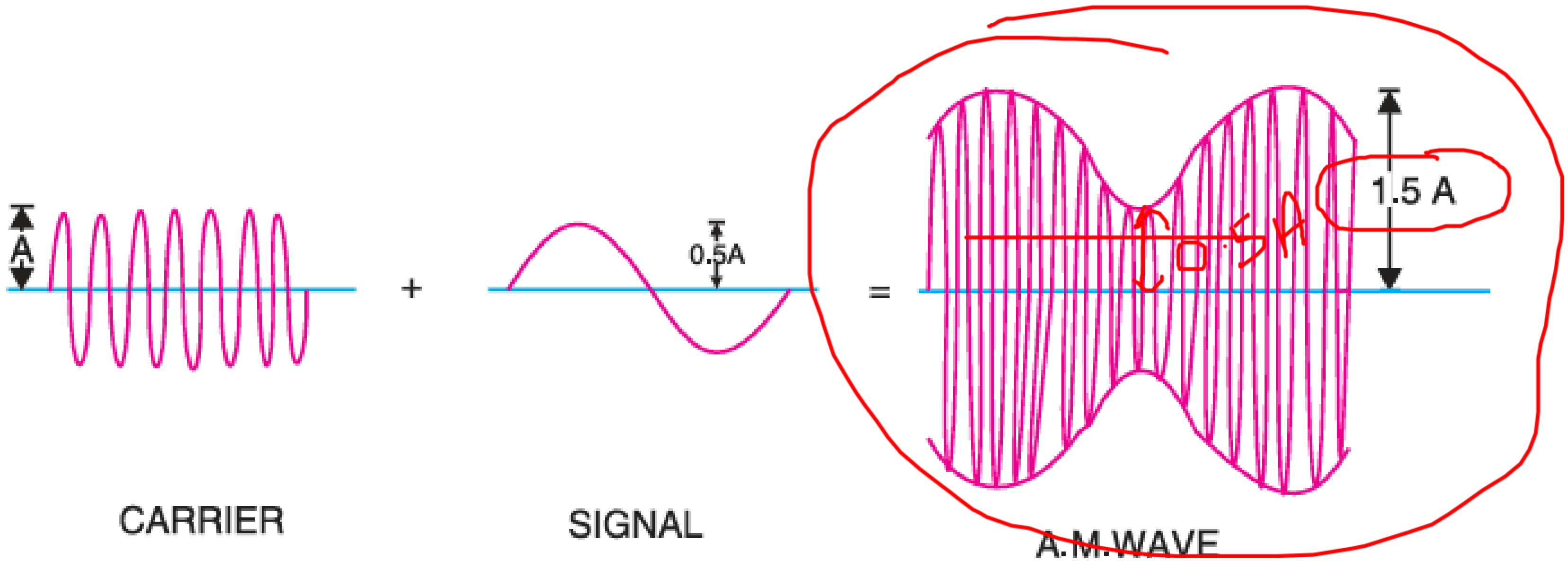


Modulation Factor

- When the signal amplitude is one-half the carrier amplitude, the amplitude of the carrier wave varies between 1.5 A and 0.5 A. Amplitude change of carrier = 1.5 A − A = 0.5 A.

∴ Modulation factor, m = 0.5 A/A = 0.5 or 50 %

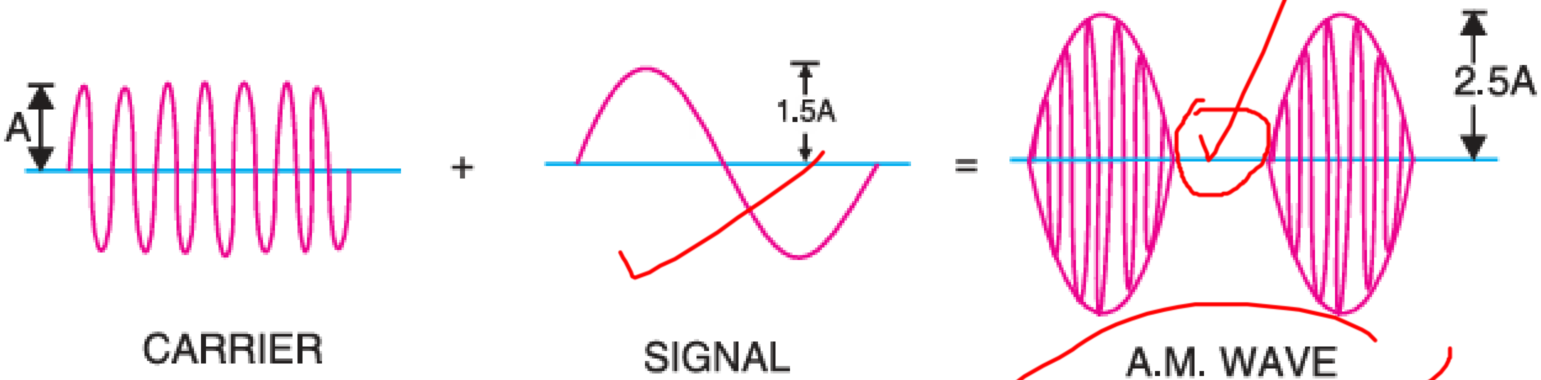
In this case, the carrier is said to be **50% modulated.**



Modulation Factor

- When the signal amplitude is 1.5 times the carrier amplitude, the maximum value of the carrier wave becomes 2.5 A.

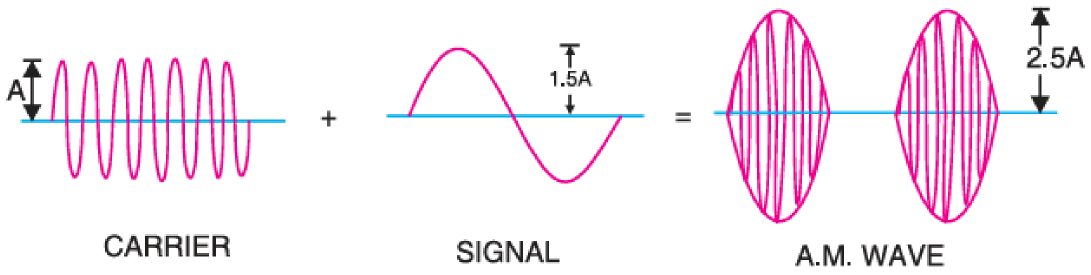
∴ Amplitude change of carrier wave = 2.5 A − A = 1.5 A
Modulation factor, m = 1.5 A/A = 1.5 or 150 %
In this case, the carrier is said to be **150% modulated (Called - over-modulated)**



Modulation Factor

Importance of modulation factor:

- It determines the strength and quality of the transmitted signal.
- When the carrier is modulated to a small degree (for small m), the amount of carrier amplitude variation is small.
- Consequently, the audio signal being transmitted will not be very strong. The greater the degree of modulation (m), the stronger and clearer will be the audio signal.
- If the carrier is overmodulated (i.e. $m > 1$), distortion will occur during reception. The AM waveform is clipped and the envelope is discontinuous. Therefore, the degree of modulation should never exceed 100%.



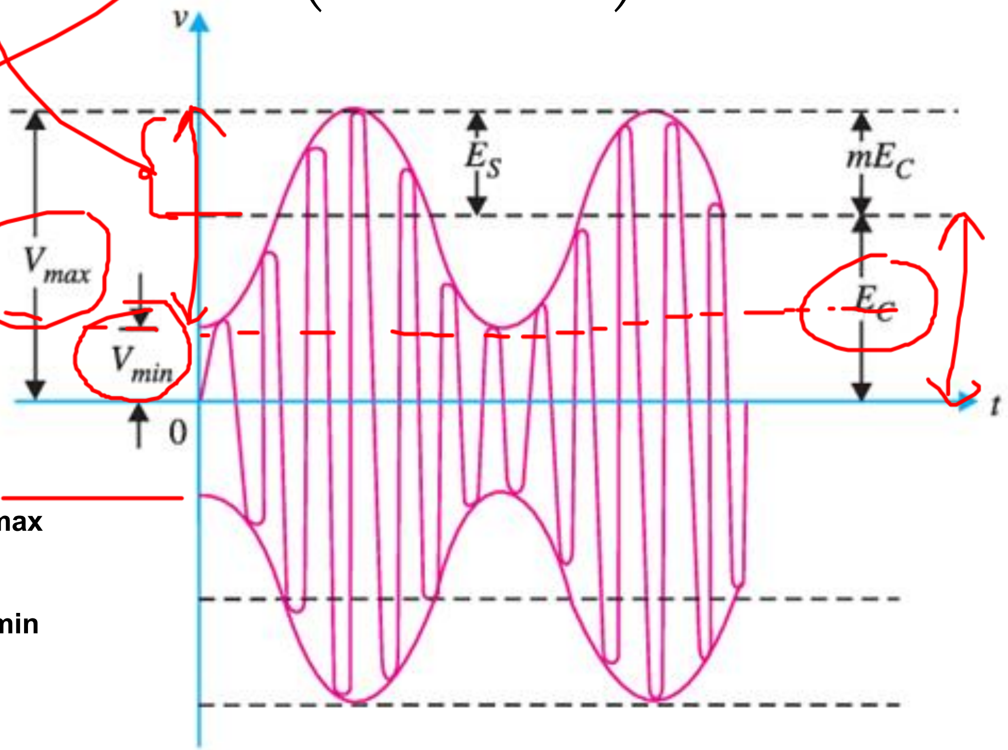
Modulation Factor

Let the amplitude of the normal carrier wave by E_C: $E_C = \frac{V_{max} + V_{min}}{2}$

If the signal amplitude E_S, $E_s = \frac{V_{max} - V_{min}}{2}$

$E_s = m.E_C$ ∴ $\frac{V_{max} - V_{min}}{2} = m.\left(\frac{V_{max} + V_{min}}{2}\right)$

$$m = \left(\frac{V_{max} - V_{min}}{V_{max} + V_{min}}\right)$$



Maximum voltage of an AM wave = V_{max}

Minimum voltage of an AM wave = V_{min}

Modulation Factor

Examples:

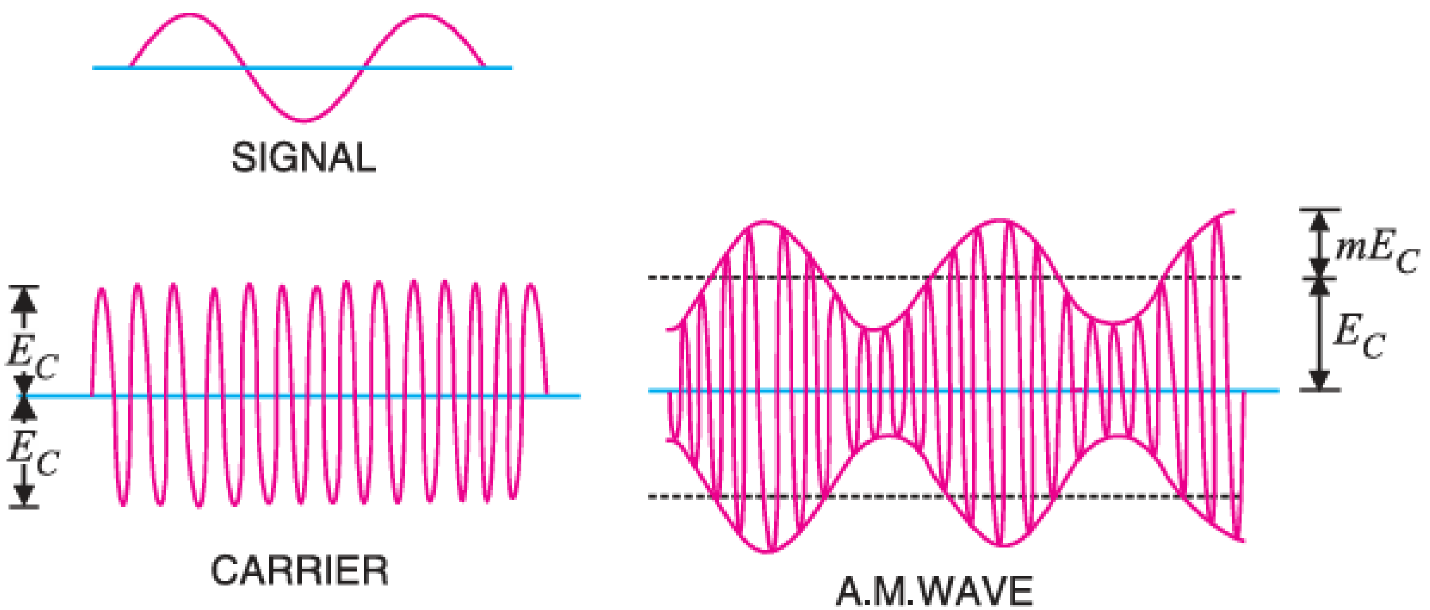
1. The maximum peak-to-peak voltage of an AM wave is 12 mV and the minimum peak-to-peak voltage is 3 mV. Calculate the modulation factor.

2. A carrier of 120V and 1600 kHz is modulated by a 60 V, 3000 Hz sine wave signal. Find the modulation factor.

Analysis of Amplitude Modulation Wave

$e_c = E_c \cos(\omega_c t)$ – Carrier Wave
e_c = Instantaneous voltage of carrier
E_c = amplitude of carrier
$\omega_c = 2\pi f_c$ (Angular velocity at carrier frequency f_c)

$e_s = m E_c \cos(\omega_s t)$ – Modulating Signal
e_s = Instantaneous voltage of the signal
$m E_c$ = Amplitude of the signal
$\omega_s = 2\pi f_s$ =(Angular velocity at signal frequency f_s)



Analysis of Amplitude Modulation Wave

The instantaneous voltage of AM wave is = s(t)

$$s(t) = [1+m\cos(\omega_s t)]\, E_c\cos(\omega_c t)$$

$$s(t) = E_c\cos(\omega_c t) + m\, E_c \cos(\omega_s t)\cos(\omega_c t)$$

$$s(t) = E_c\cos(\omega_c t) + \frac{m\,Ec}{2}[2\cos(\omega_s t)\cos(\omega_c t)]$$

[2 cos A cos B = Cos(A + B) + cos(A - B)]

$$\mathbf{s(t) = E_c\cos(\omega_c t) + \frac{m\,E_c}{2}\cos(\omega_c+\omega_s)t + \frac{m\,E_c}{2}\cos(\omega_c - \omega_s)t]}$$

- The AM wave is equivalent to the summation of three sinusoidal waves; one having amplitude E_c and frequency f_c, the second having amplitude $\frac{m\,E_c}{2}$ and frequency $(f_c + f_s)$ and the third having amplitude $\frac{m\,E_c}{2}$ and frequency $(f_c - f_s)$.

Analysis of Amplitude Modulation Wave

- The AM wave is equivalent to the summation of three sinusoidal waves; one having amplitude E_c and frequency f_c, the second having amplitude $\frac{m E_C}{2}$ and frequency $(f_c + f_s)$ and the third having amplitude $\frac{m E_C}{2}$ and frequency $(f_c - f_s)$.

- The AM wave contains three frequencies: f_c, $(f_c + f_s)$, and $(f_c - f_s)$. The first frequency is the carrier frequency. Thus, the process of modulation does not change the original carrier frequency but produces two new frequencies $(f_c + f_s)$ and $(f_c - f_s)$ which are called sideband frequencies.

- The sum of carrier frequency and signal frequency $(f_c + f_s)$ is called upper sideband frequency. The lower sideband frequency is $(f_c - f_s)$ that is the difference between carrier and signal frequencies.

$$s(t) = E_c \cos(\omega_c t) + \frac{m E_C}{2} \cos(\omega_c+\omega_s)t + \frac{m E_C}{2} \cos(\omega_c- \omega_s)t]$$

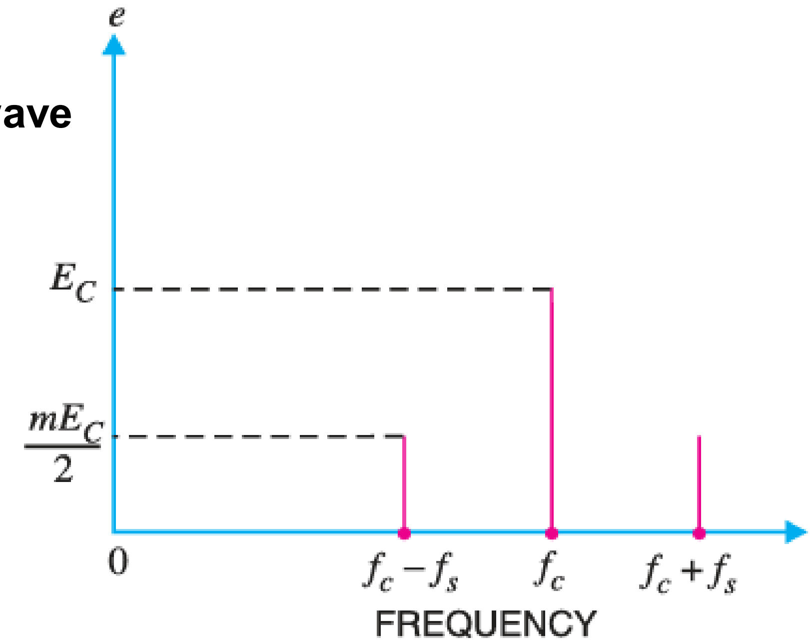
Analysis of Amplitude Modulation Wave

Frequency spectrum of an amplitude modulated wave

$$f_c = \frac{\omega_c}{2\pi}$$

$$f_c + f_c = \frac{\omega_c + \omega_s}{2\pi}$$

$$f_c - f_c = \frac{\omega_c - \omega_s}{2\pi}$$



Bandwidth

The bandwidth is from (f_c - f_s) to (f_c + f_s). Therefore, the Band with of the AM signal is 2 f_c. A very important conclusion that in amplitude modulation, bandwidth is **twice the signal frequency.**

- The tuned amplifier which is called upon to amplify the modulated wave must have the required bandwidth to include the sideband frequencies. If the tuned amplifier has insufficient bandwidth, the upper sideband frequencies may not be reproduced by the radio receiver.

Example:

1. A 3000 kHz carrier wave is modulated by an audio signal with a frequency span of 100 Hz − 15 kHz.
   (a) What are the frequencies of lower and upper sidebands?
   (b) What bandwidth of the RF amplifier is required to handle the output?

2. An AM wave is represented by the expression:
   $v(t) = 10 [1 + 0.65 \cos (7200t)] \sin (320×104t)$ volts.
   (i) What are the minimum and maximum amplitudes of the AM wave?
   (ii) What frequency components are contained in the modulated wave and what is the amplitude of each component?

3. A sinusoidal carrier voltage of frequency 3 MHz and amplitude 120 volts is amplitude modulated by the sinusoidal voltage of frequency 2 kHz producing 50% modulation. Calculate the frequency and amplitude of lower and upper sideband terms.

4. A carrier wave of frequency 8 MHz and peak value 6V is amplitude-modulated by a 4 kHz sine wave of amplitude 4V. Determine:
   (i) Modulation Factor. (ii) Sideband frequencies.
   (iii) Amplitude of sideband components.
   (iv)Draw the frequency spectrum.

Power in Amplitude Modulation Wave

The equation of AM wave reveals that it has three components of amplitude E_C, m E_C /2, and m E_C /2. The power output must be distributed among these components.

Carrier power: $$P_c = \frac{(\frac{E_c}{\sqrt{2}})^2}{R} = \frac{E_c^2}{2R}$$ (r.m.s. values)

Total Power of Sidebands: $$P_s = \frac{(\frac{mE_c}{2\sqrt{2}})^2}{R} + \frac{(\frac{mE_c}{2\sqrt{2}})^2}{R} = \frac{m^2 E_c^2}{4R}$$

Total Power of AM wave: $$P_T = P_s + P_c$$

$$P_T = \frac{E_c^2}{2R} + \frac{m^2 E_c^2}{4R} = \frac{E_c^2}{2R}\left(\frac{2 + m^2}{2}\right)$$

Power in Amplitude Modulation Wave

The Fraction of total power carried by sidebands: $\frac{P_S}{P_T} = \left(\frac{m^2}{2+m^2}\right)$

The Fraction of total power carried by Carrier: $\frac{P_c}{P_T} = \left(\frac{2}{2+m^2}\right)$

Power depends upon the modulation factor m

(i) When m = 0 , power carried by sidebands = 0 %
(ii) When m = 0.5, power carried by sidebands = 11 %
(iii) When m = 1, power carried by sidebands = 33 %

Ex: A 50 kW carrier is to be modulated to a level of 70%.
(i) What is the carrier power after modulation?
(ii) How much the power of the modulating signal (audio power) is required if the efficiency of the modulated RF amplifier is 75%?

Limitations and Drawbacks in AM Wave

- **Noisy reception**
  The signal is in the amplitude variations of the carrier. Practically all the natural and man-made noises consist of electrical amplitude disturbances. As a radio receiver cannot distinguish between amplitude variations representing noise and those containing the desired signal, reception is generally noisy.
- **Low efficiency**
  Useful power is in the sidebands as they contain the signal. An AM wave has low sideband power. For example, if modulation is 100%, the sideband power is only one-third of the total power of the AM wave. Hence the efficiency of this type of modulation is low.
- **Small operating range**
  Due to the low efficiency of amplitude modulation, transmitters employing this method have a small operating range, and messages cannot be transmitted over larger distances.
- **Lack of audio quality**
  All audio frequencies up to 15 kHz must be reproduced to attain high-fidelity reception. This necessitates a bandwidth of 30 kHz since both sidebands must be reproduced. However, AM broadcasting stations are assigned a bandwidth of only 10 kHz to minimize interference from adjacent broadcasting stations. This means that the highest modulating frequency can be 5 kHz which is hardly sufficient to reproduce the music properly.

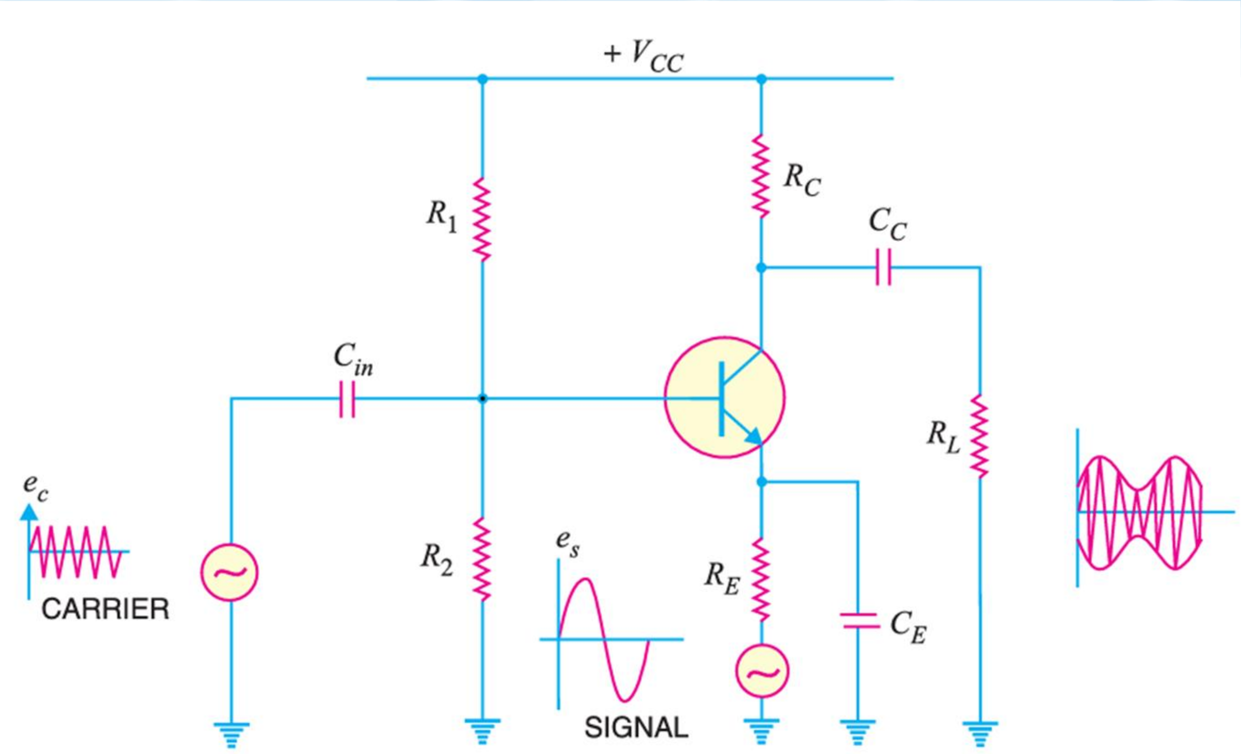
Limitations and Drawbacks in AM Wave

Drawbacks

- The modulated signal contains the carrier. So, the carrier takes power, and it does not have the information.
- Therefore, AM is inefficient in power usage.
- Moreover, there are two sidebands, containing the same information.
- It is bandwidth inefficient.
- AM is also susceptible to interference since it affects the amplitude of the carrier.

Therefore, a solution is needed to improve bandwidth and power efficiency.

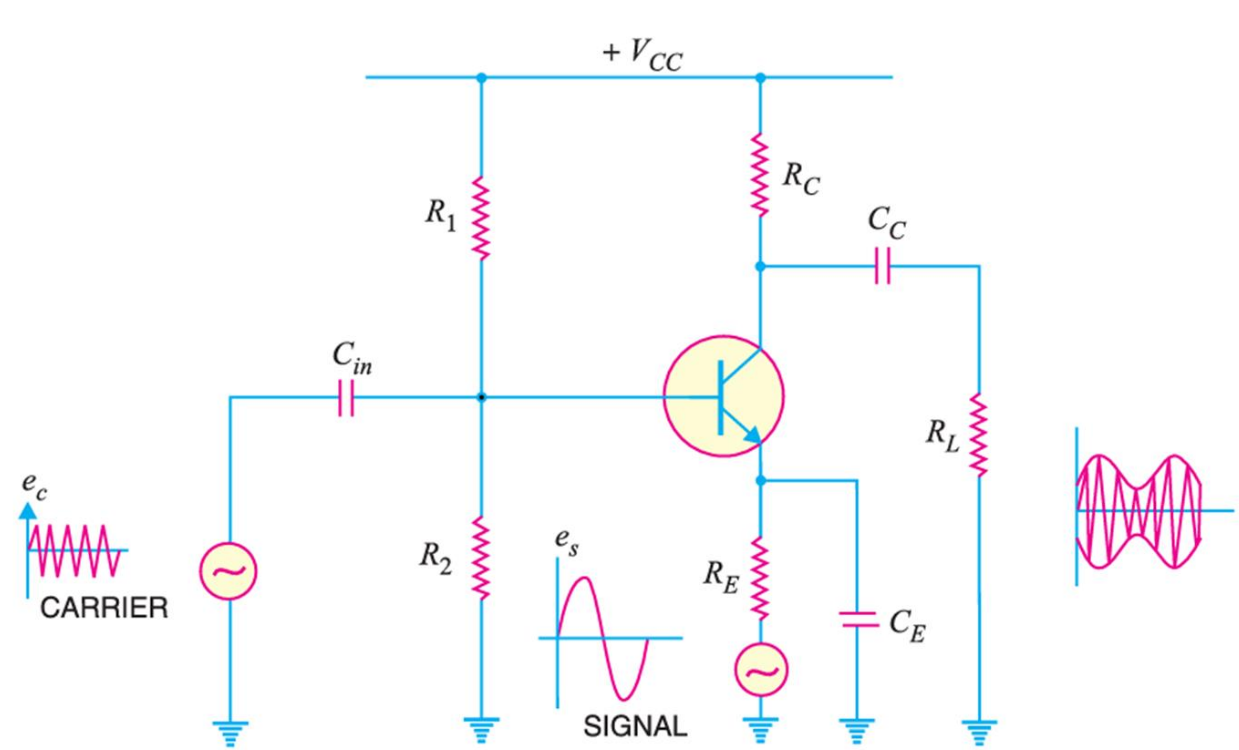
Simple circuit of the Transistor AM Modulator



CE amplifier

- The carrier wave is applied at the input of the amplifier and the modulating signal is applied in the emitter resistance circuit.
- The amplifier circuit amplifies the carrier by a factor “A” so that the output is Ax(Carrier wave amplitude).
- Since the modulating signal is a part of the biasing circuit, it produces low-frequency variations in the emitter circuit.

Simple circuit of the Transistor AM Modulator



CE amplifier

- The result is that amplitude of the carrier varies in accordance with the strength of the signal. Consequently, the amplitude-modulated output is obtained across RL.
- It may be noted that the carrier should not influence the voltage gain A; only the modulating signal should do this. To achieve this objective, the carrier should have a small magnitude and the signal should have a large magnitude.

Double Sideband-Suppressed Carrier (DSBSC)

DSBSC Modulation

known as a product modulator, is an AM signal that has a suppressed carrier. The original AM signal as given below:

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

- The first term is the carrier only, which does not have any information. The second and third terms contain information.
- In DSBSC, we suppress the carrier, which is the first term that does not have any information. Therefore, by suppressing the first term we obtain the following:

$$S(t) = (1/2)A_cA_m\cos[2\pi(f_c + f_m)t] + (1/2)A_cA_m\cos[2\pi(f_c - f_m)t]$$

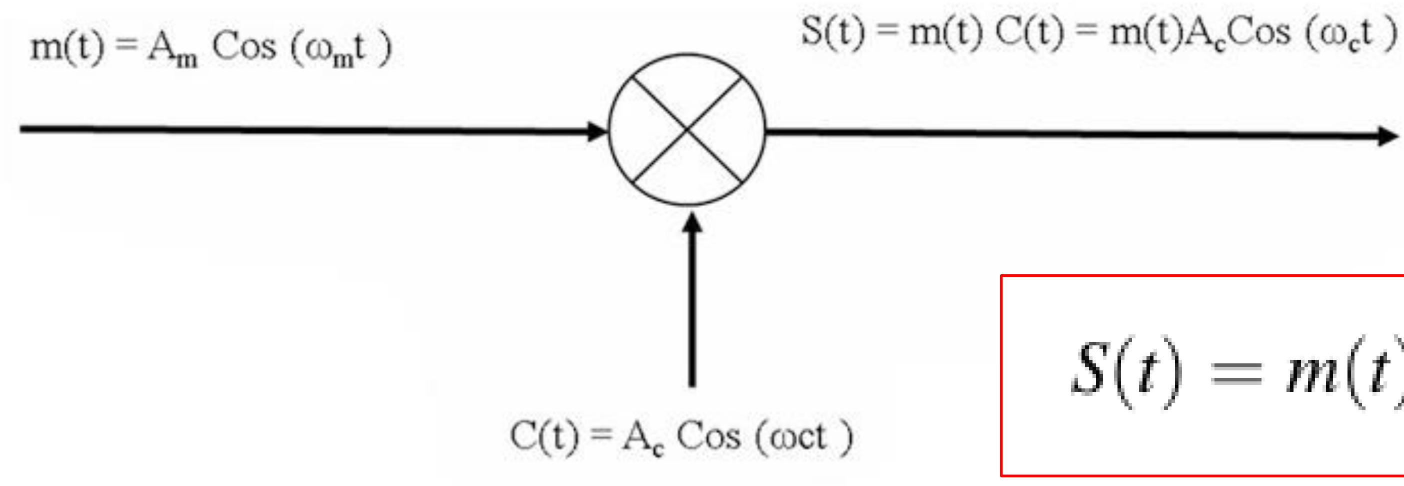
$$S(t) = A_cA_m\cos(\omega_m t)\ \cos(\omega_c t)$$

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

Double Sideband-Suppressed Carrier (DSBSC)

Now, define

$$m(t) = A_m \cos(\omega_m t)$$
$$C(t) = A_c \cos(\omega_c t)$$



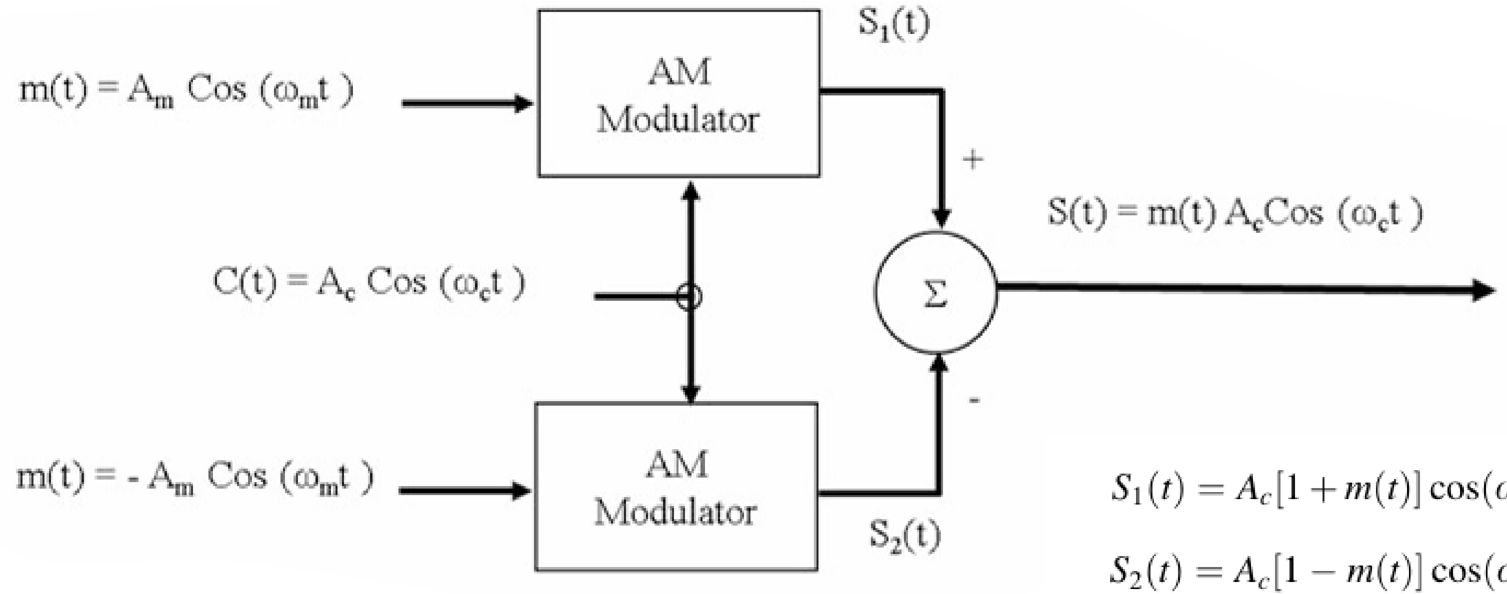
$$S(t) = m(t)\, C(t)$$

- **This is the DSBSC waveform. Since the output is the product of two signals, it is also known as a product modulator. The symbolic representation is given in the above, where m(t) is the input modulating signal and C(t) is the carrier frequency.**

Double Sideband-Suppressed Carrier (DSBSC)

Generation of DSBSC Signal

- A DSBSC signal can be generated using two AM modulators arranged in a balanced configuration.
- The outcome is a cancellation of the discrete carrier.
- Also, the output is the product of two inputs: S(t)=m(t) C(t). This is why it is called a "product modulator."



$$S_1(t) = A_c[1 + m(t)]\cos(\omega_c t)$$

$$S_2(t) = A_c[1 - m(t)]\cos(\omega_c t)$$

Double Sideband-Suppressed Carrier (DSBSC)

Generation of DSBSC Signal

$$S_1(t) = A_c[1 + m(t)]\cos(\omega_c t)$$

$$S_2(t) = A_c[1 - m(t)]\cos(\omega_c t)$$

Subtracting $S_2(t)$ from $S_1(t)$, we essentially cancel the carrier to obtain;

$$\begin{aligned} S(t) &= S_1(t) - S_2(t) \\ &= 2\,m(t)\,A_c\,\cos(\omega_c t) \end{aligned}$$

Therefore, except for the scaling factor 2, the above equation is exactly the same as the desired DSBSC waveform shown earlier, which does not have the carrier. In other words, the carrier has been suppressed, hence the name **double sideband suppressed carrier (DSBSC).**