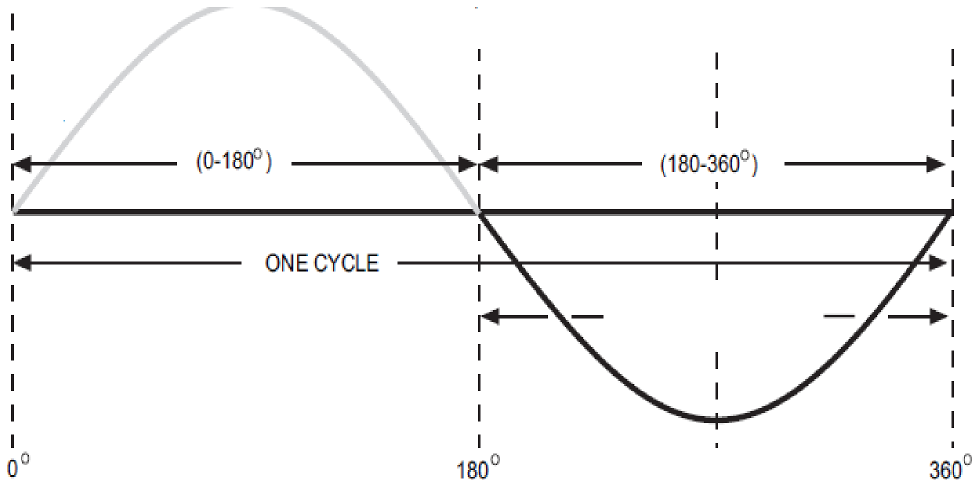
Communication System

WAVELENGTH

$$\lambda = \text{rate of travel} \times \text{period}$$

$$\lambda = \frac{\text{rate of travel}}{\text{frequency}}$$



The average range used on speech is 250 Hz to 2750 Hz

The height of the antenna should be preferably around λ/4, where λ is the wavelength of the signal to be radiated.

Rate of travel -> 300,000,000 m/sec

For 300 Hz, λ = 300,000,000 / 300 = 1,000,000 m

Table 1-1.—Radio frequency versus wavelength

FREQUENCY	WAVELENGTH	
	METRIC	U.S.
300,000 MHz	.001 m	.04 in
EHF-		
30,000 MHz	.01 m	.39 in
SHF-		
3,000 MHz	.1 m	3.94 in
UHF--		
300 MHz	1 m	39.37 in
VHF---		
30 MHz	10 m	10.93 yd
HF----		
3 MHz	100 m	109.4 yd
MF----		
300 kHz	1 km	.62 mi
LF----		
30 kHz	10 km	6.2 mi
VLF-----		
3 kHz	100 km	62 mi

Baseband and carrier communications

- The term **baseband** refers to a band of frequencies of signal generated by a information source.
- In telephony, baseband signal is 0Hz-3.4kHz
- In TV, it is 0Hz to 4.3 MHz
- In **baseband communication**, baseband signal is transmitted without modulation. It cannot be transmitted through radio link.
- In **carrier communication**, one of the basic parameters (amplitude, frequency and phase)of a sinusoidal carrier of high frequency w_c is varied in proportion to the baseband signal m(t)

Modulation

$$v_c(t) = ACos(2\pi f_c t + \phi(t))$$

A – Amplitude Modulation
f_c – Frequency Modulation
Φ(t) – Phase Modulation

- **Modulation is defined as *the process by which some characteristics of a carrier wave is varied in accordance with the message signal.***

Advantages of Modulation

- **Reduction the height of the antenna**
  - For efficient radiation, the height of the antenna should be preferably around $\lambda/4$, where λ is the wavelength of the signal to be radiated. Where $\lambda = c \backslash f$
- **Easy to Multiplex**
- **Avoids mixing of signal**
- **Increase the range of communication**
- **Allow adjustments in the bandwidth**

  For Signal to noise ratio in the receiver is the function of the signal bandwidth.
- **Improves quality of reception**

What is Modulation?

- This high frequency signal is called **CARRIER SIGNAL**

- The message signal is called **MODULATING SIGNAL or BASEBAND SIGNAL.**

- The word ***modulation*** *means the systematic alteration of one* waveform, called the *carrier, according to the characteristic of another waveform,* the *modulating signal or the message.*

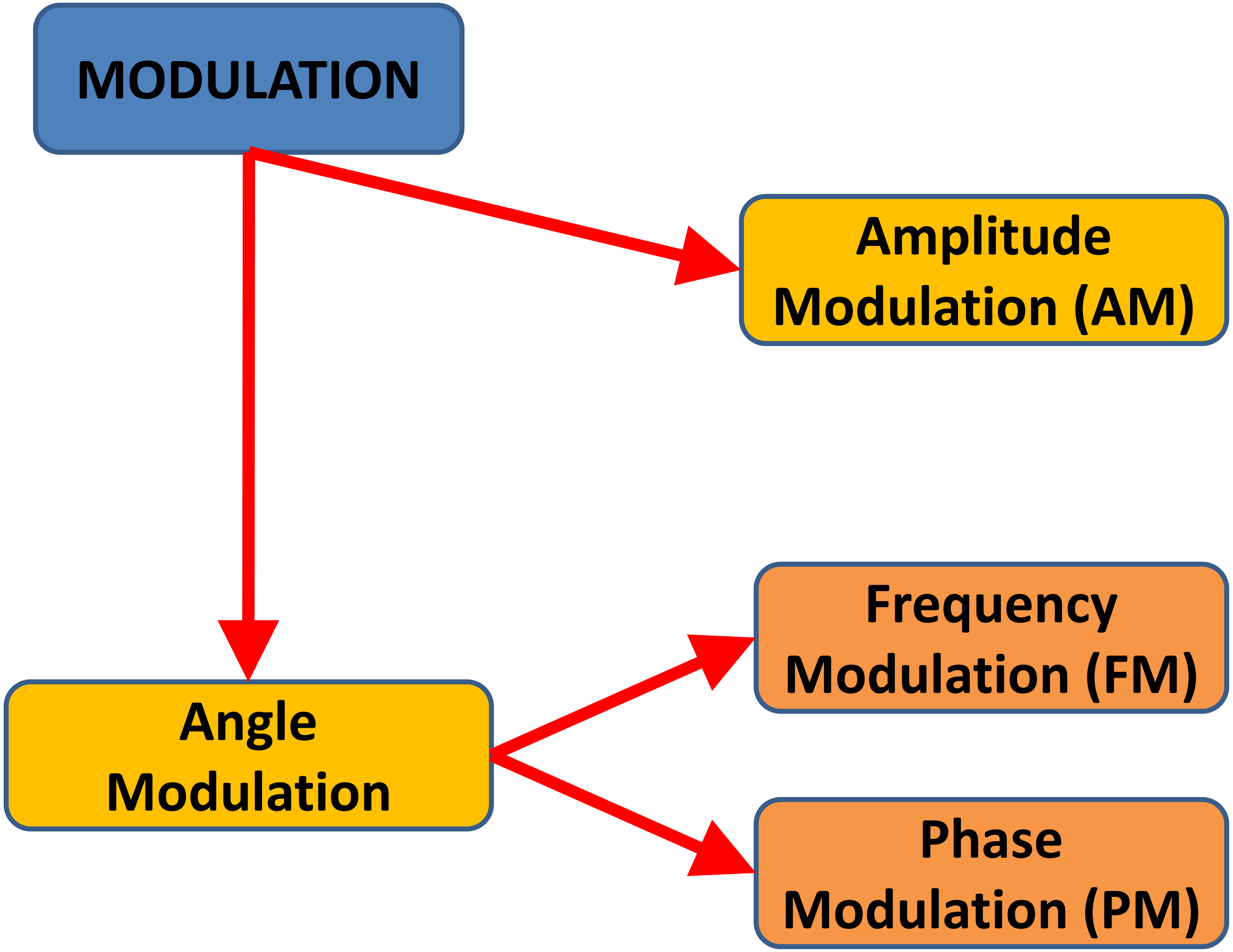
- We use ***c(t)*** *and* ***m(t)****, to denote the* ***carrier*** and the **message** waveforms respectively.

- The resultant signal after modulation is called **MODULATED SIGNAL.**

- For study purpose, the commonly used carrier and message signal is **SINUSOIDAL WAVE.**

- Transmitter Side - **Modulation**
- Receiver Side - **Demodulation**

Types of Modulation

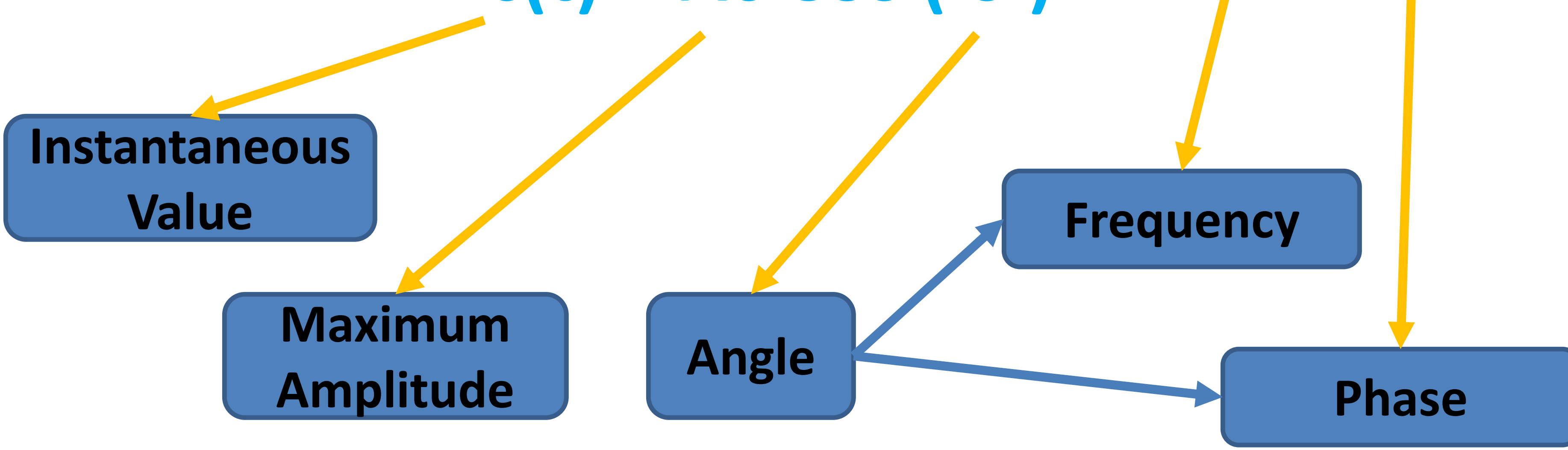


Types of Modulation

- Modulation - Characteristics of Carrier Wave is varied in accordance with the characteristics of message signal.
- Consider a Carrier wave:

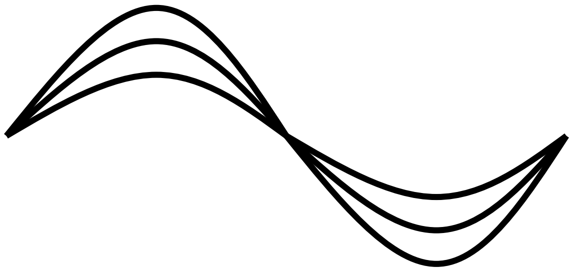
$$(2\pi \quad t + \quad)$$

$$c(t) = Ac \ Cos \ (\ \theta \ )$$



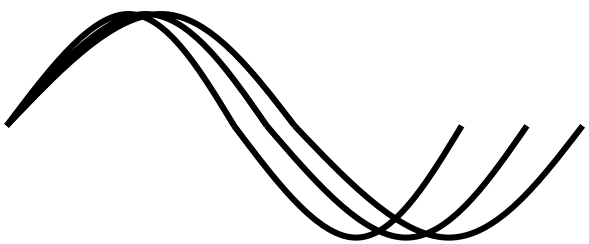
Types of Modulation

Amplitude Modulation



$$V \cdot \sin(\omega * t + \Phi)$$

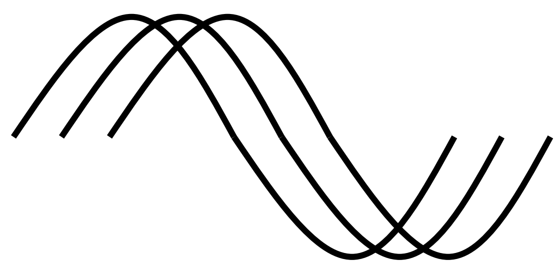
Frequency Modulation



$$V \cdot \sin(\omega * t + \Phi)$$

- **AM** – The amplitude of the carrier signal is varied in accordance with the instantaneous amplitude of the message signal.
- **FM** – The frequency of the carrier signal is varied in accordance with the instantaneous amplitude of the message signal.
- **PM** – The phase of the carrier signal is varied in accordance with the instantaneous amplitude of the message signal.

Phase Modulation



$$V \cdot \sin(\omega * t + \Phi)$$

AM & FM Waveforms

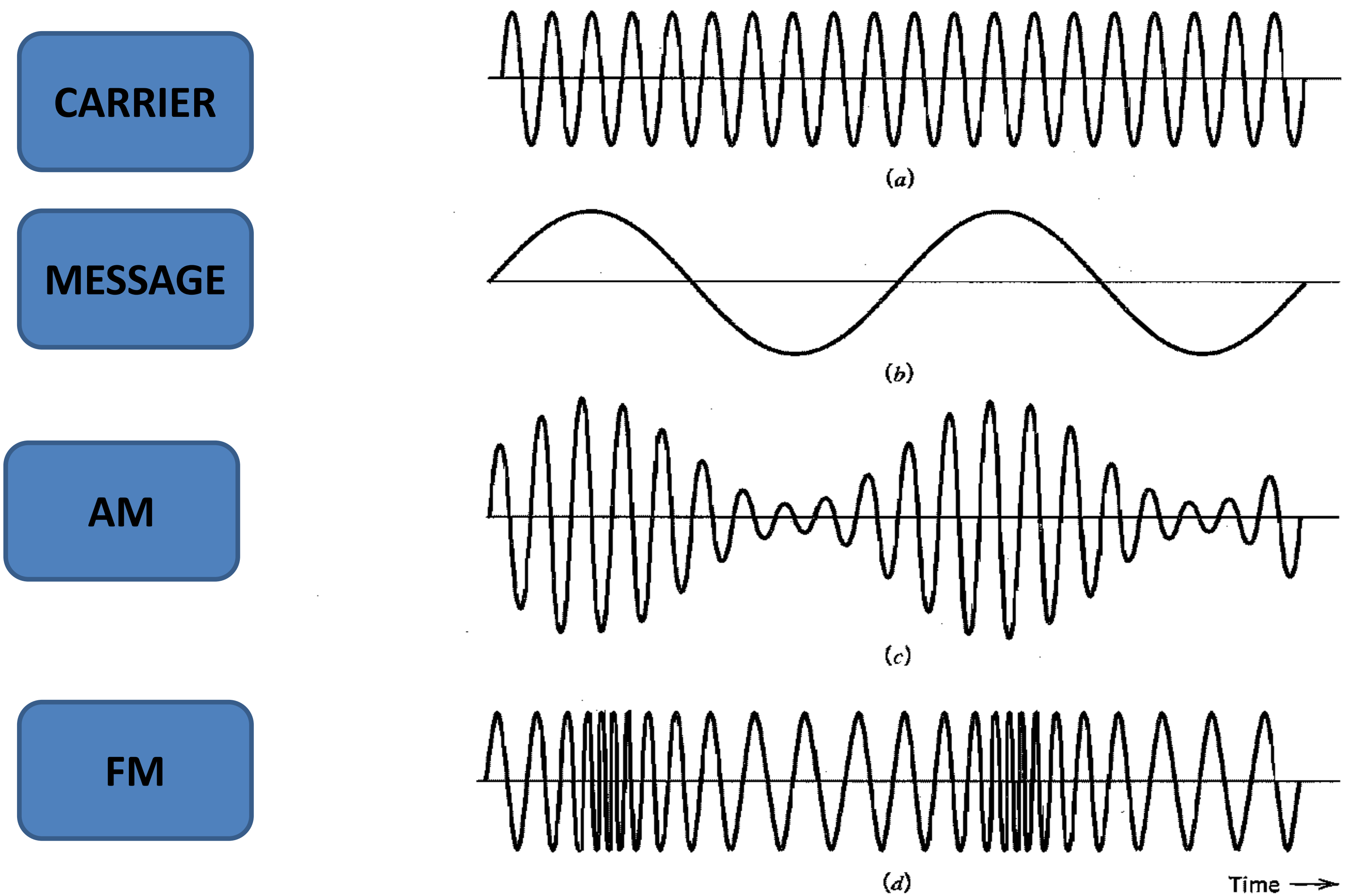


Figure 2.2 Illustrating AM and FM signals produced by a single tone. (*a*) Carrier wave. (*b*) Sinusoidal modulating signal. (*c*) Amplitude-modulated signal. (*d*) Frequency-modulated signal.

Amplitude Modulation

- The amplitude of high-carrier signal is varied according to the instantaneous amplitude of the modulating message signal m(t).

Carrier Signal: $C(t) : A_c \cos(2\pi f_c t)$ or $\cos(\omega_c t)$

Modulating Signal: $m(t): \quad A_m \cos(2\pi f_m t)$ or $\cos(\omega_m t)$

Modulated *Signal:* $s_{AM}(t) = [A_c + m(t)]\cos(2\pi f_c t)$

$$S_{AM}(t) = [A_c + A_m \cos(2\pi f_m t)]\cos(2\pi f_c t)$$
$$= A_c[1 + k\cos(2\pi f_m t)]\cos(2\pi f_c t)$$

Modulation Index **k = A_m/A_c**

AM Signal Math Expression

- Mathematical expression for AM: time domain

$$S_{AM}(t) = (1 + k\cos\omega_m t)\cos\omega_c t$$

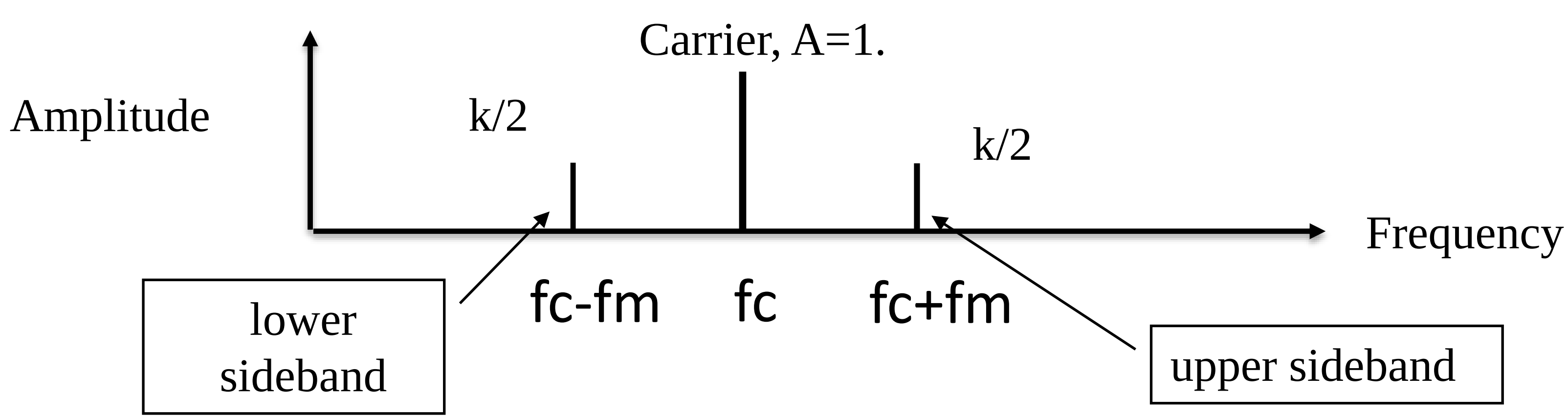
- Expanding this produces:

$$S_{AM}(t) = \cos\omega_c t + k\cos\omega_m t\cos\omega_c t$$

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

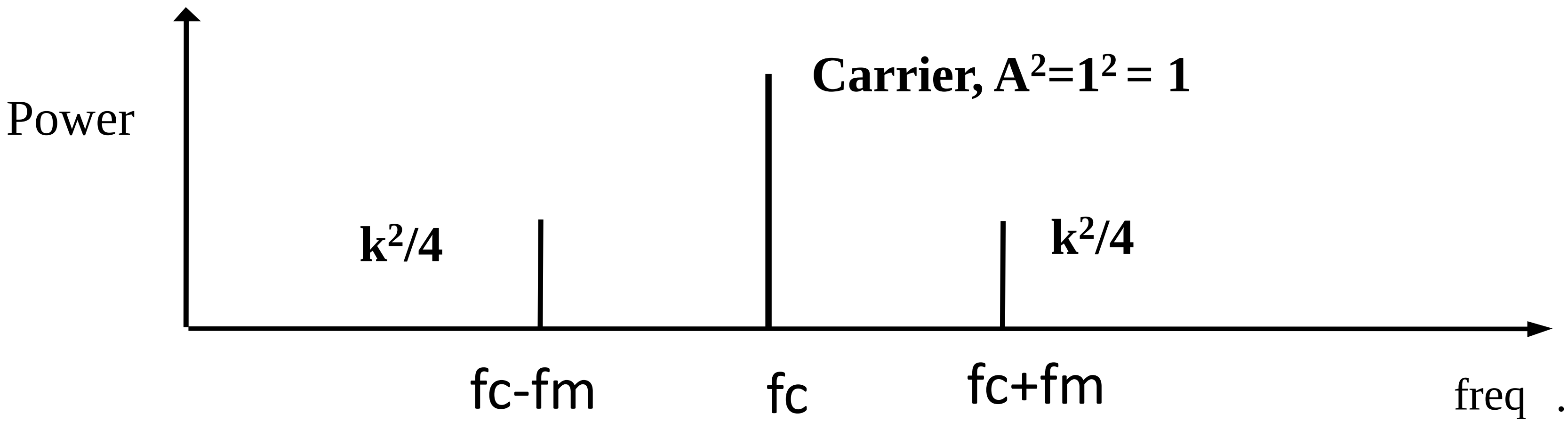
$$S_{AM}(t) = \cos\omega_c t + \frac{k}{2}\cos(\omega_c - \omega_m)t + \frac{k}{2}\cos(\omega_c + \omega_m)t$$

- In the frequency domain this gives:



AM Power Frequency Spectrum

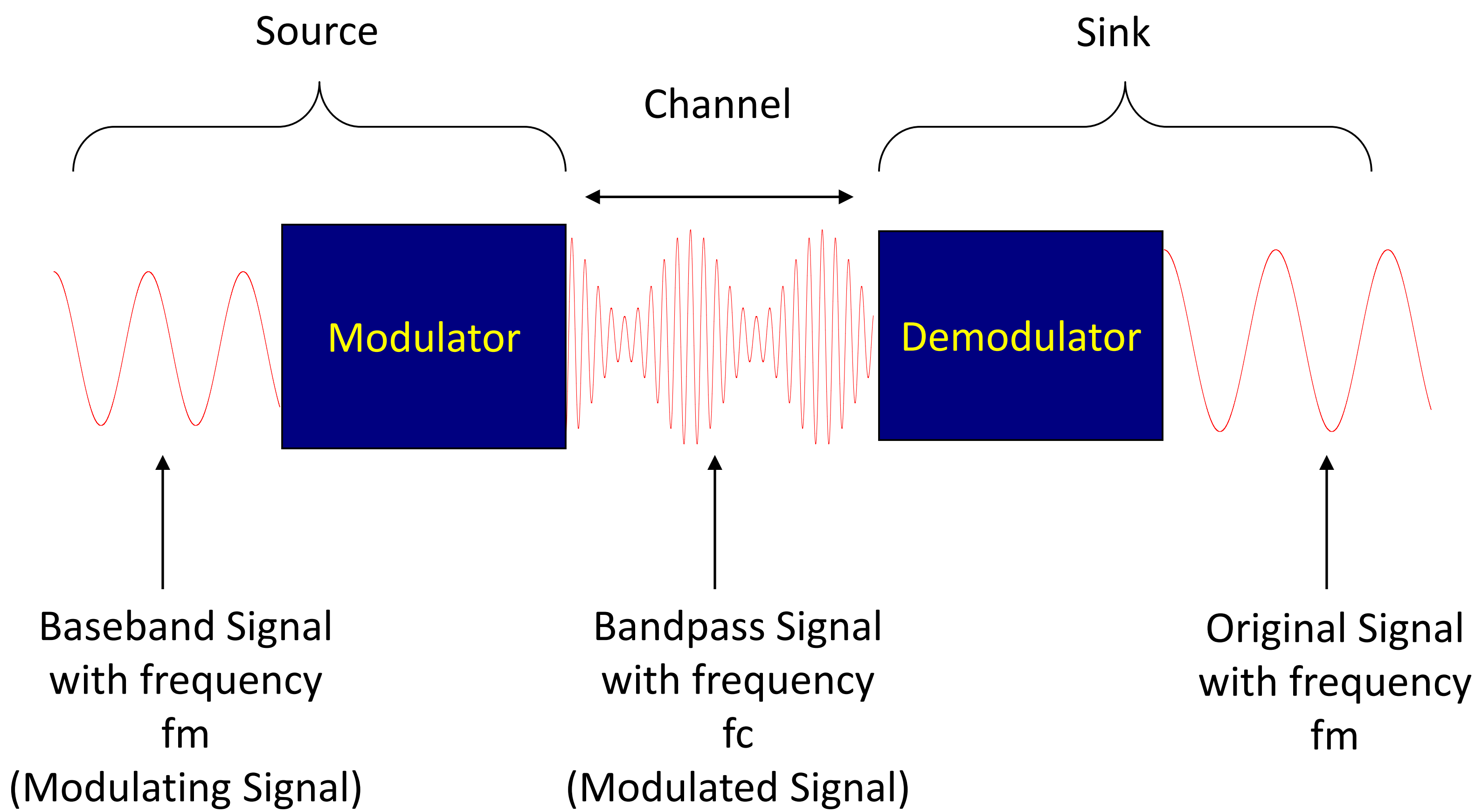
- AM Power frequency spectrum obtained by squaring the amplitude:



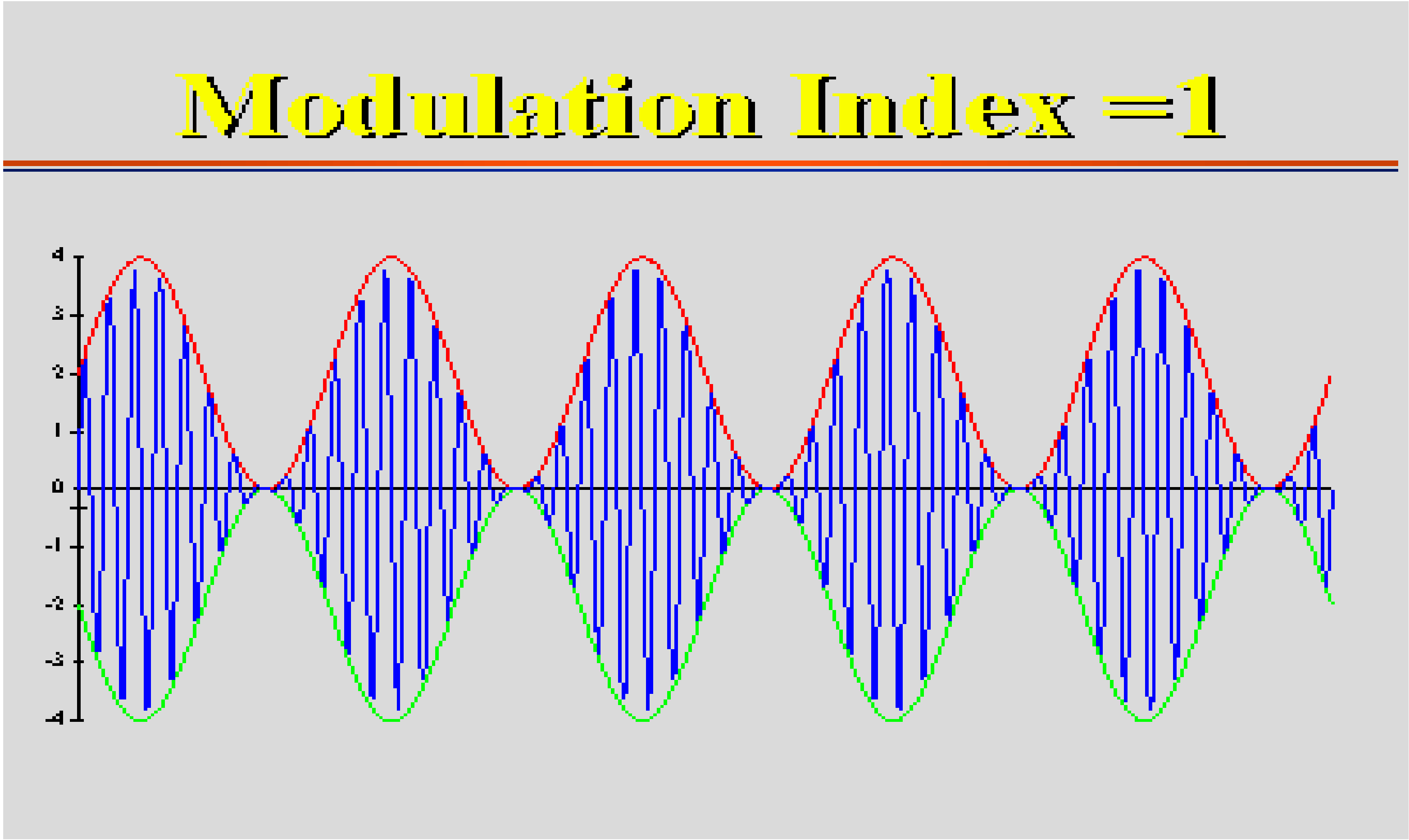
- Total power for AM $= A^2 + \frac{k^2}{4} + \frac{k^2}{4}$

$$= 1 + \frac{k^2}{2}$$

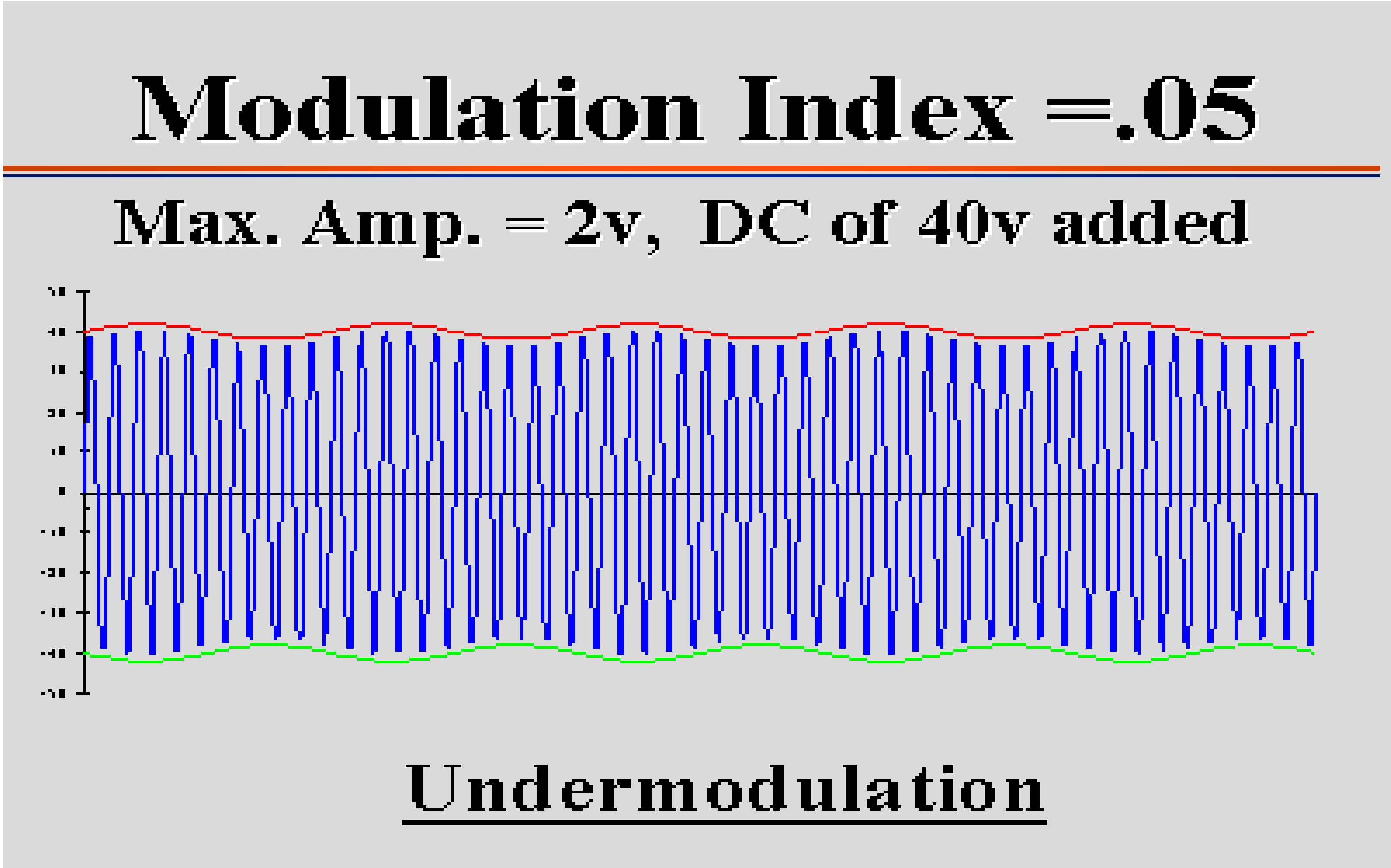
AM Modulation/Demodulation



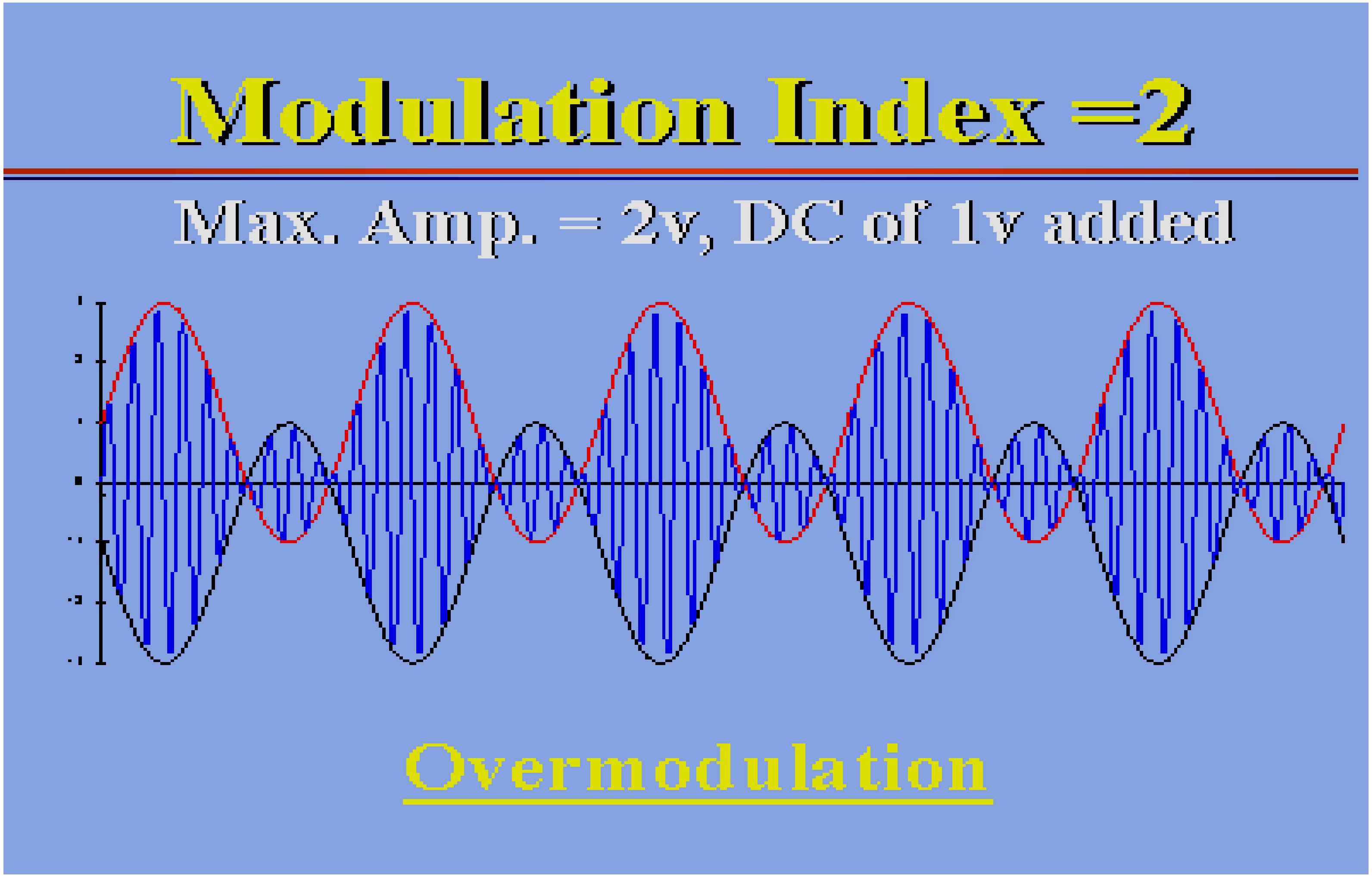
Modulation Index of AM Signal



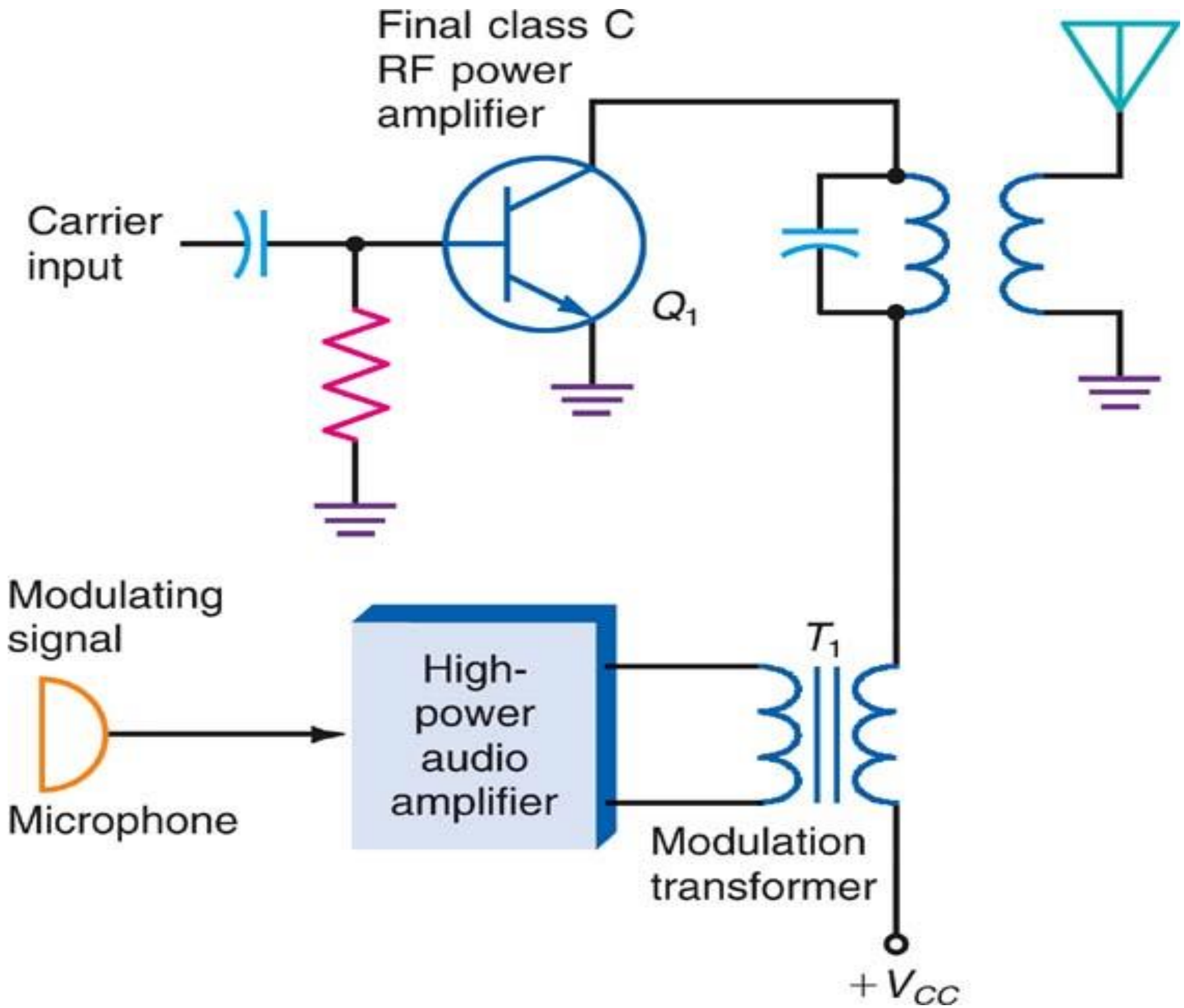
Modulation Index of AM Signal



Modulation Index of AM Signal

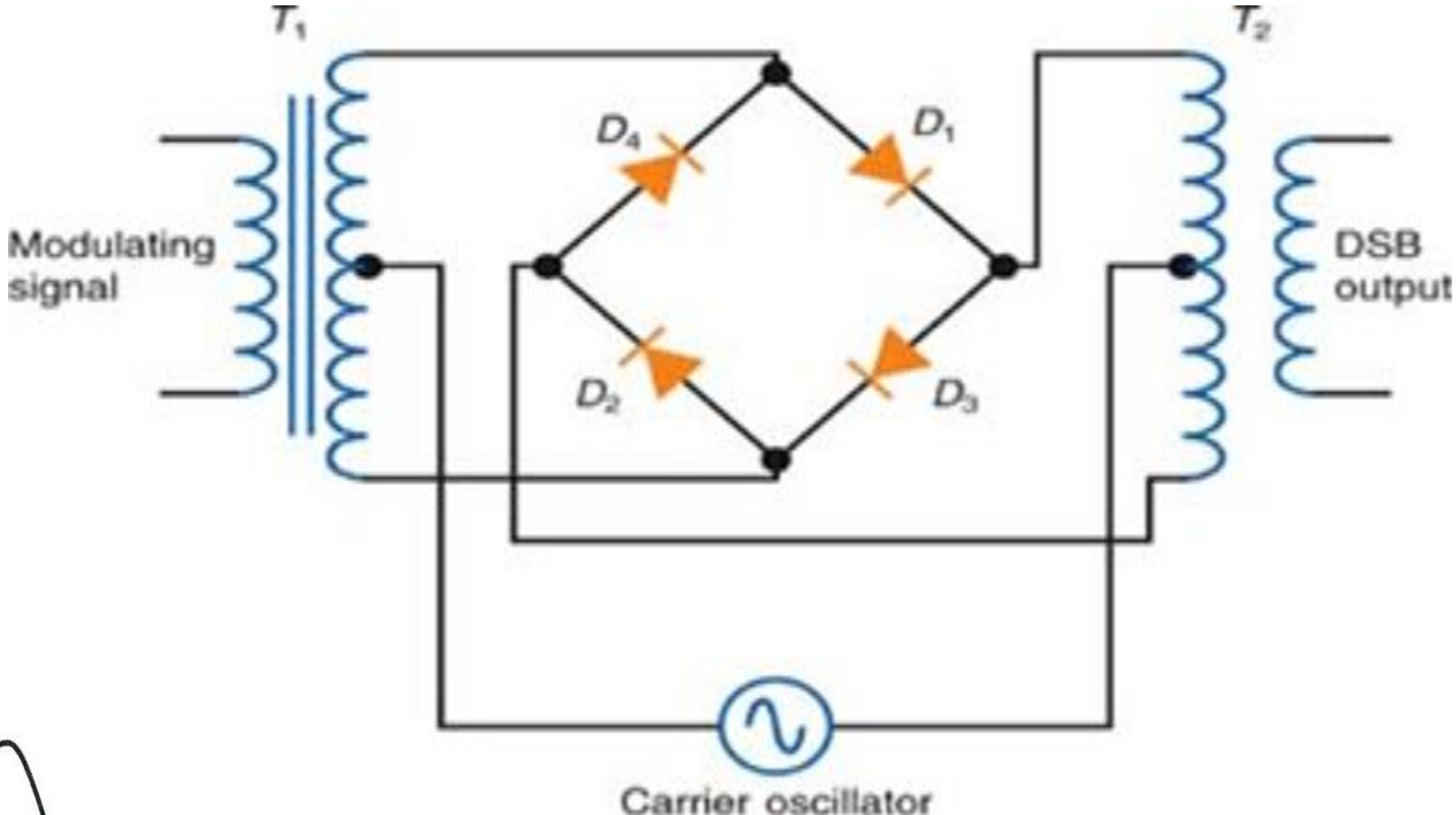


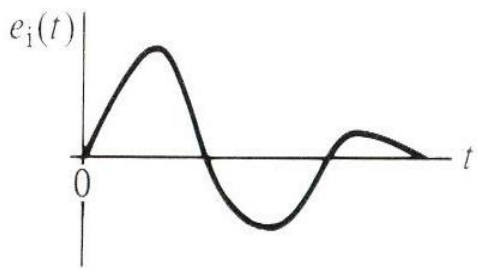
Amplitude Modulators



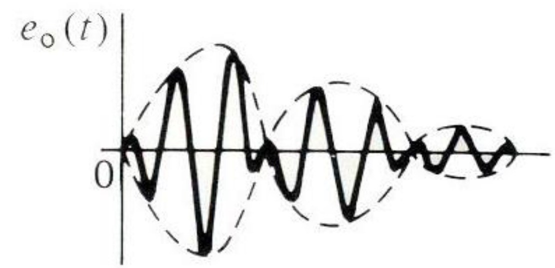
A high-level collector modulator.

Balanced Modulator

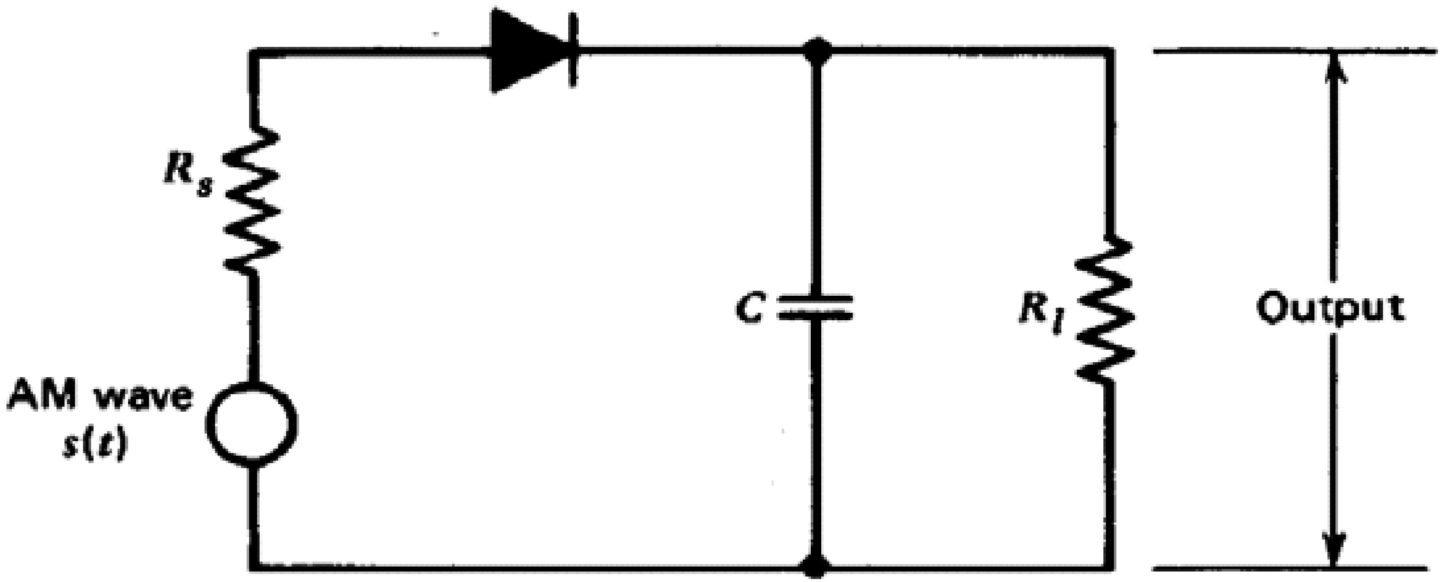


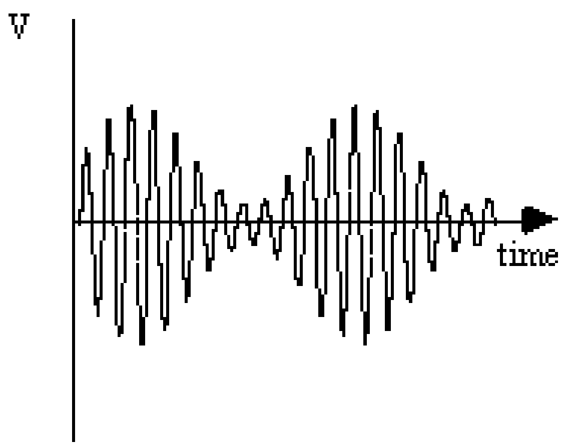


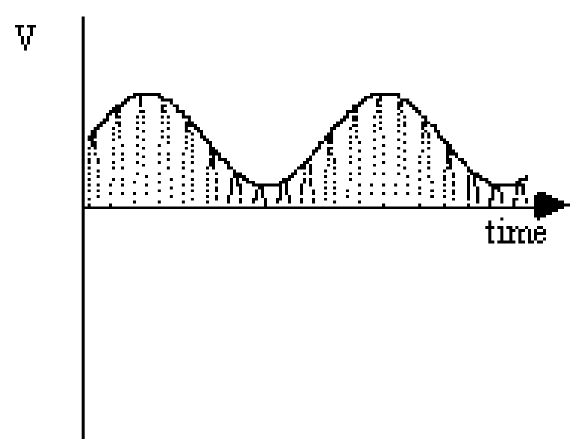
Ring modulator



Demodulator – Envelope detector







Advantages/disadvantages

Advantages of Amplitude Modulation, AM

- It is **simple** to implement
- it can be demodulated using a circuit consisting of **very few components**
- AM receivers are **very cheap** as no specialized components are needed.

Disadvantages of amplitude modulation

- It is not **efficient in terms of its power usage**
- It is not **efficient in terms of its use of bandwidth**, requiring a bandwidth equal to twice that of the highest audio frequency
- It is prone **to high levels of noise** because most noise is amplitude based and obviously AM detectors are sensitive to it.

Angle Modulation

Consider again the general carrier $$v_c\left(t\right)=V_c\cos\left(\omega_c t+\varphi_c\right)$$

$\omega_c t+\varphi_c$ represents the angle of the carrier.

There are two ways of varying the angle of the carrier.

$$v_c\left(t\right)=V_c\cos\left(\omega_c t+\varphi_c\right)$$

Frequency Modulation is the process of varying the frequency of the carrier signal linearly with the message signal.

Phase Modulation is the process of varying the phase of the carrier signal linearly with the message signal.

Frequency Modulation

In FM, the message signal $m(t)$ controls the frequency f_c of the carrier. Consider the carrier

$$v_c(t) = V_c \cos(\omega_c t)$$

then for FM we may write: $$v_s(t) = V_c \cos(2\pi(f_c + \text{frequency deviation})t)$$

where the frequency deviation will depend on $m(t)$.

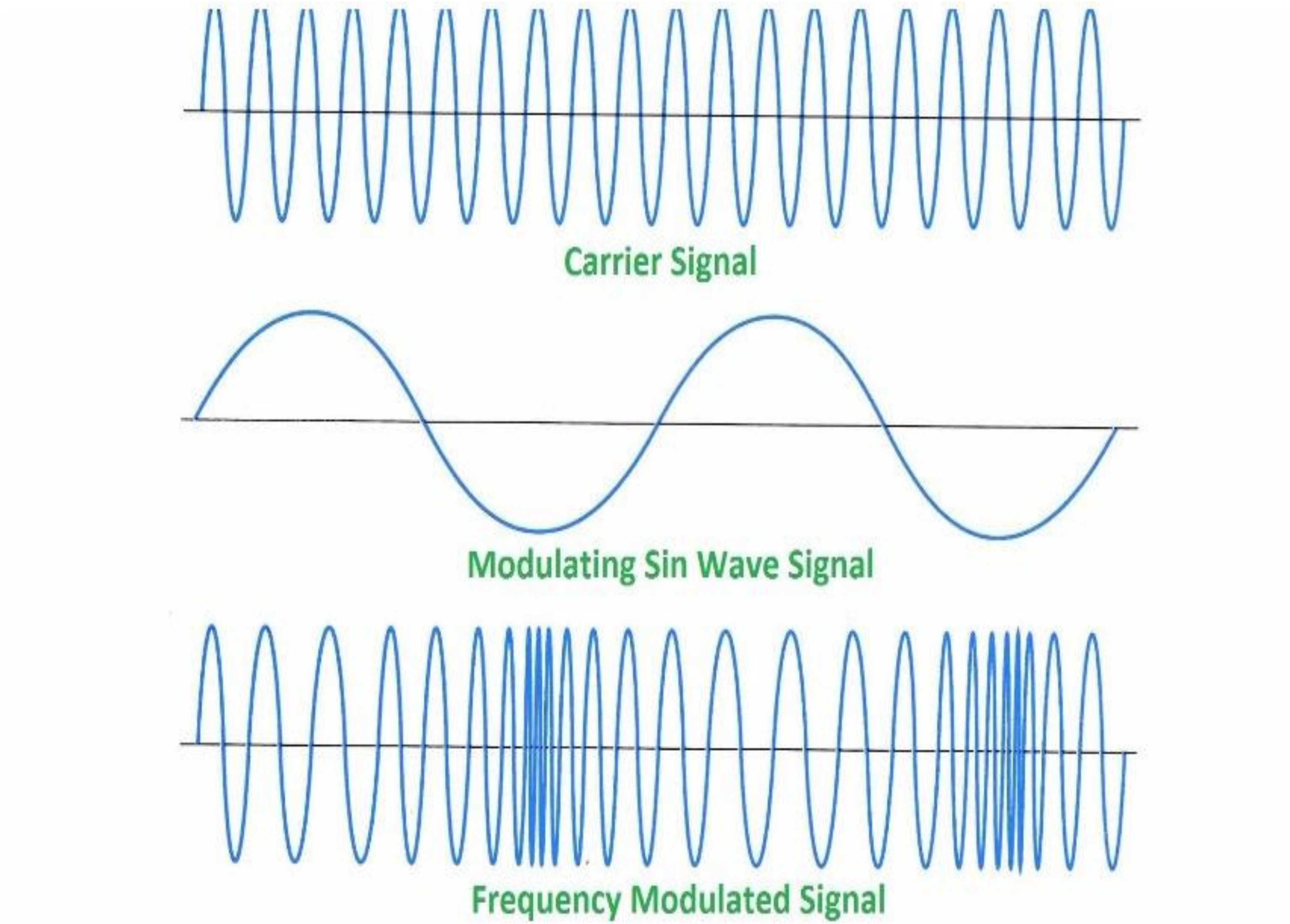
Given that the carrier frequency will change we may write for an instantaneous carrier signal

$$V_c \cos(\omega_i t) = V_c \cos(2\pi f_i t) = V_c \cos(\theta_i)$$

where Φ_i is the instantaneous angle = $\omega_i t = 2\pi f_i t$

f_i is the instantaneous frequency.

Frequency Modulation



Frequency Modulation

Since $\varphi_i = 2\pi f_i t$ then $\dfrac{d\varphi_i}{dt} = 2\pi f_i$ or $f_i = \dfrac{1}{2\pi}\dfrac{d\varphi_i}{dt}$

i.e. frequency is proportional to the rate of change of angle.

If f_c is the unmodulated carrier and f_m is the modulating frequency, then we may deduce that

$$f_i = f_c + \Delta f \ \mathrm{A_m} \cos \ \omega_m t \ = \frac{1}{2\pi}\frac{d\varphi_i}{dt}$$

Δf is the peak deviation of the carrier.

Hence, we have

$$\frac{1}{2\pi}\frac{d\varphi_i}{dt} = f_c + \Delta f \ \mathrm{A_m} \cos \ \omega_m t$$

,i.e.

$$\frac{d\varphi_i}{dt} = 2\pi f_c + 2\pi\Delta f \ \mathrm{A_m} \cos \ \omega_m t$$

Frequency Modulation

After integration *i.e.*

$$\int \omega_c + 2\pi \Delta f_c \ \mathrm{A_m} \cos \ \omega_m t \quad dt$$

$$\theta_i = \omega_c t + \frac{2\pi \Delta f_c \mathrm{A_m} \sin \ \omega_m t}{\omega_m}$$

$$\theta_i = \omega_c t + \frac{\Delta f_c}{f_m} \mathrm{A_m} \sin \ \omega_m t$$

Hence for the FM signal,

$$v_s \ \ t \ = V_c \cos \ \theta_i$$

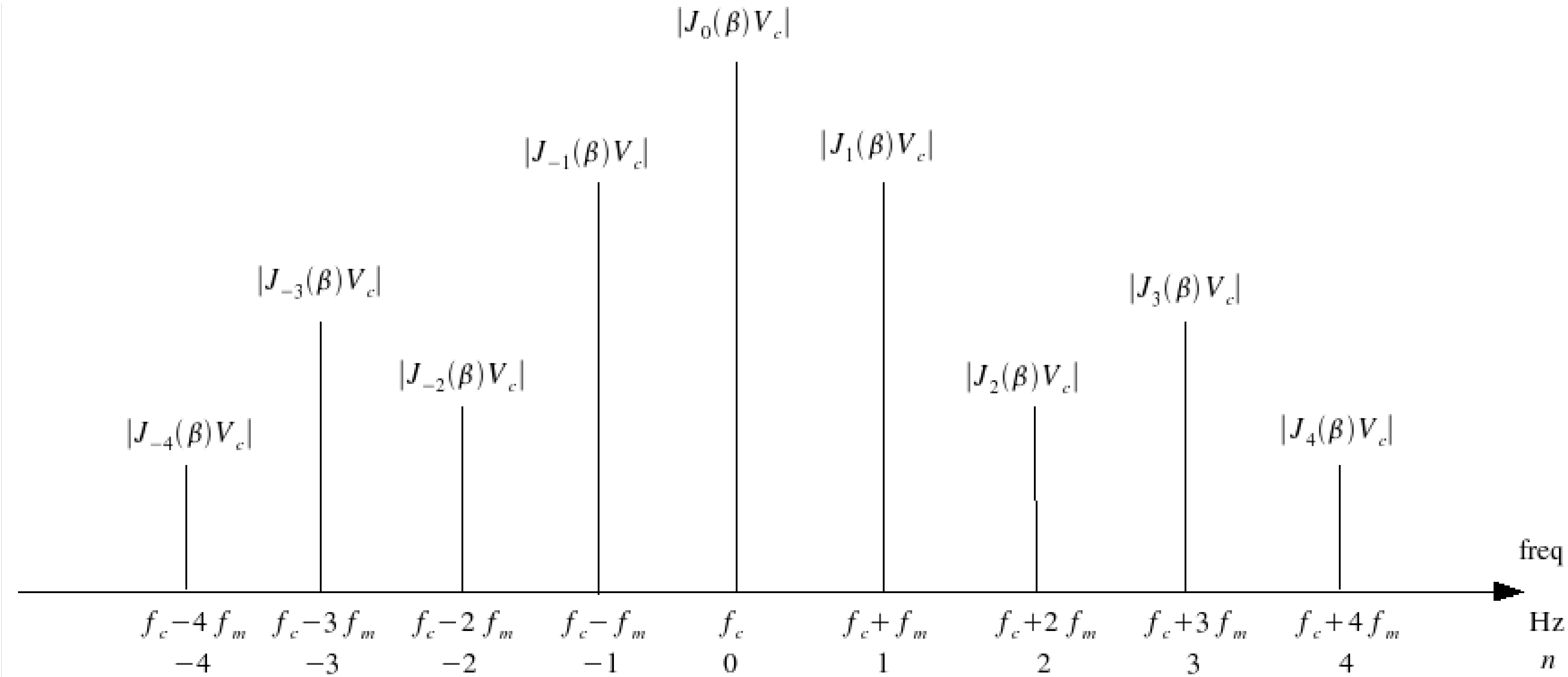
$$v_s \ \ t \ = V_c \cos \left(\omega_c t + \frac{\Delta f_c}{f_m} \mathrm{A_m} \sin \ \omega_m t \ \right)$$

Frequency Modulation

The ratio $\dfrac{\Delta f_c}{f_m}$ is called the **Modulation Index** denoted by β *i.e.*

$$\beta = \frac{\text{Peak frequency deviation}}{\text{modulating frequency}}$$

FM Signal Spectrum.



- Carson's Rule provides an adequate approximation for determining FM signal bandwidth:

$$B = 2\left(\Delta f + f_{m(\max)}\right) = 2f_m(\beta+1)$$

Frequency Modulation

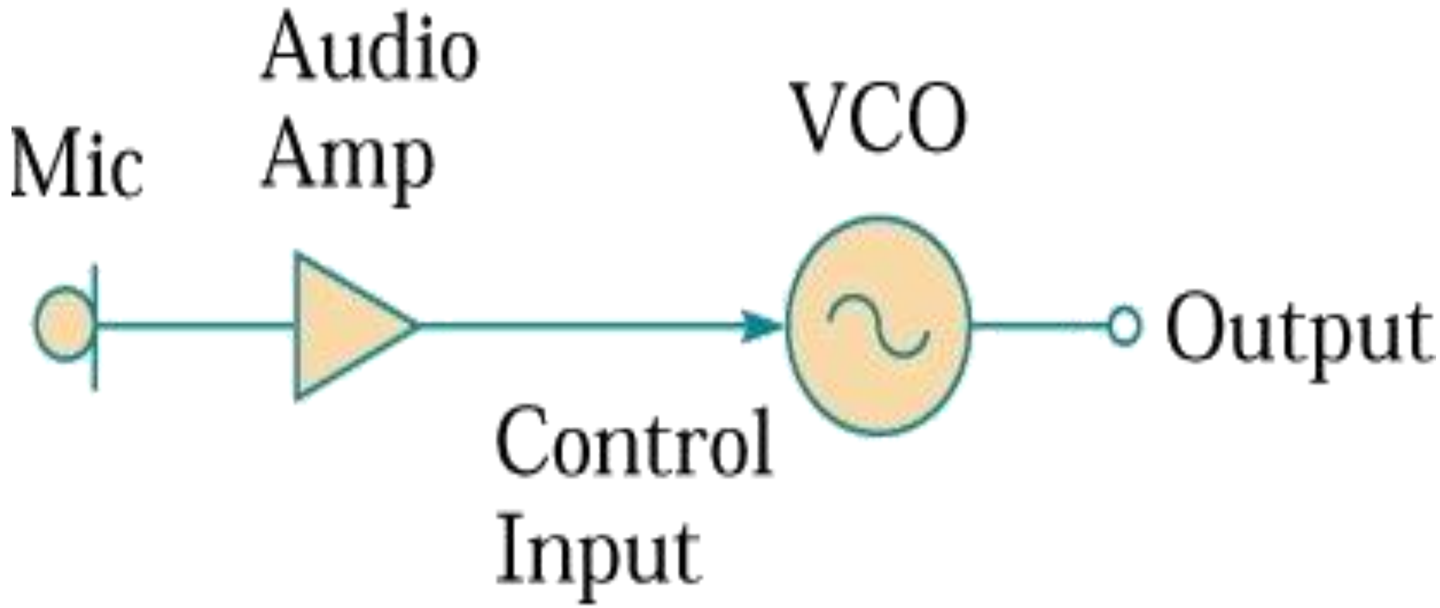
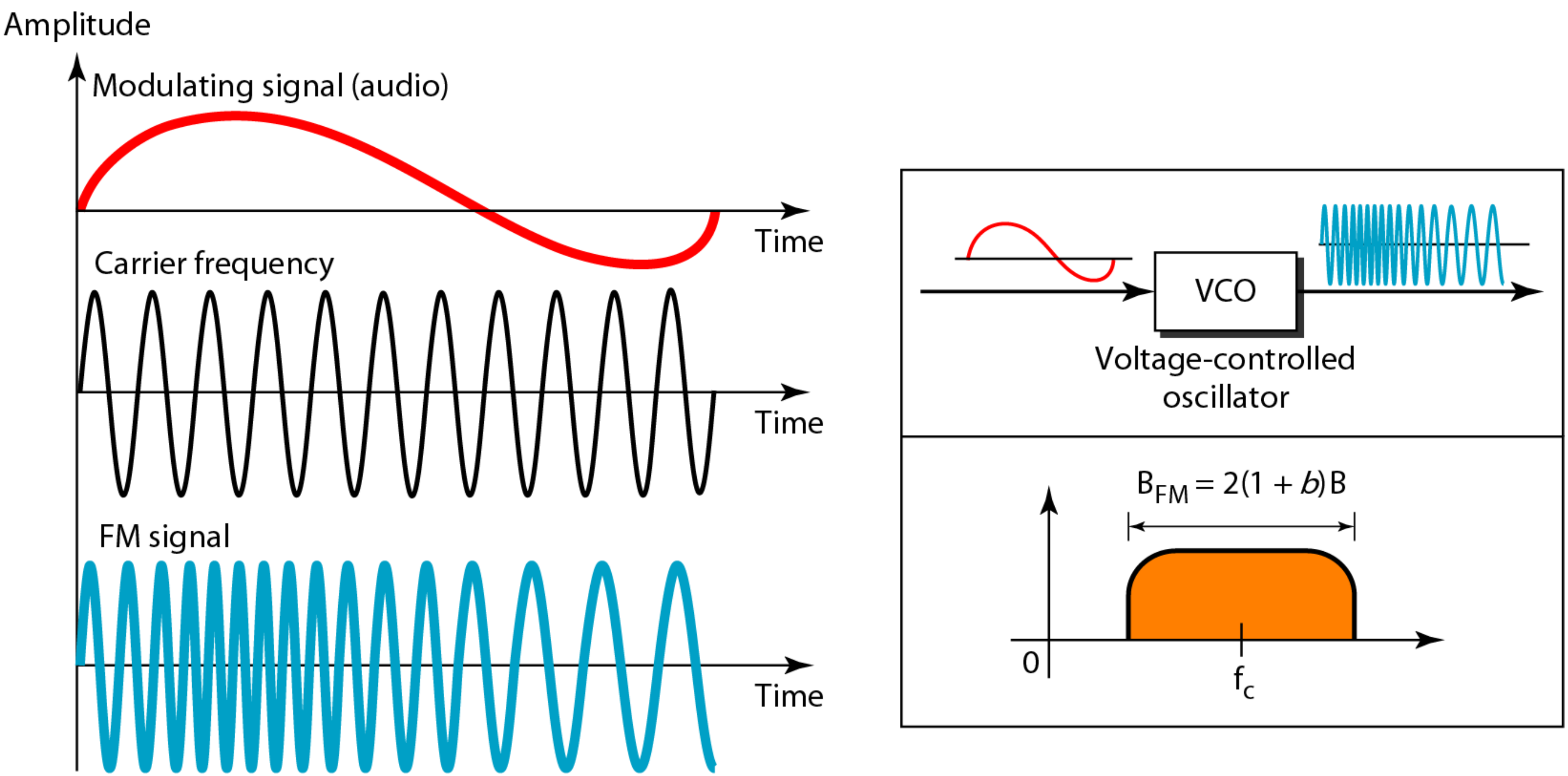
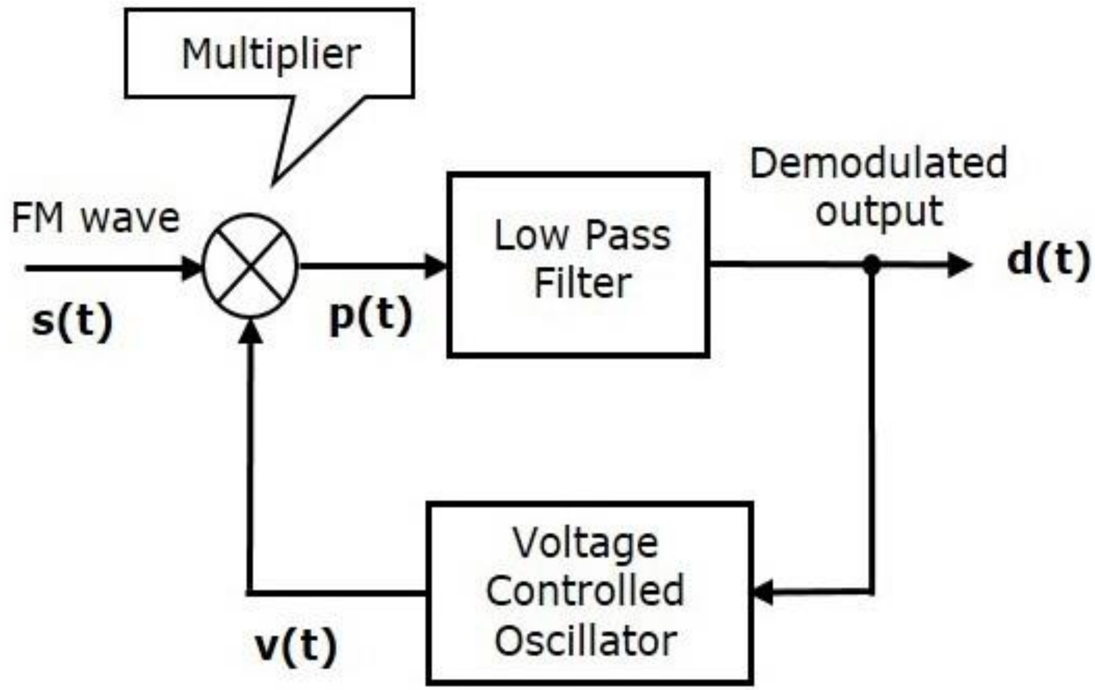


Figure 5.18 *Frequency modulation*



FM demodulator



Advantage:

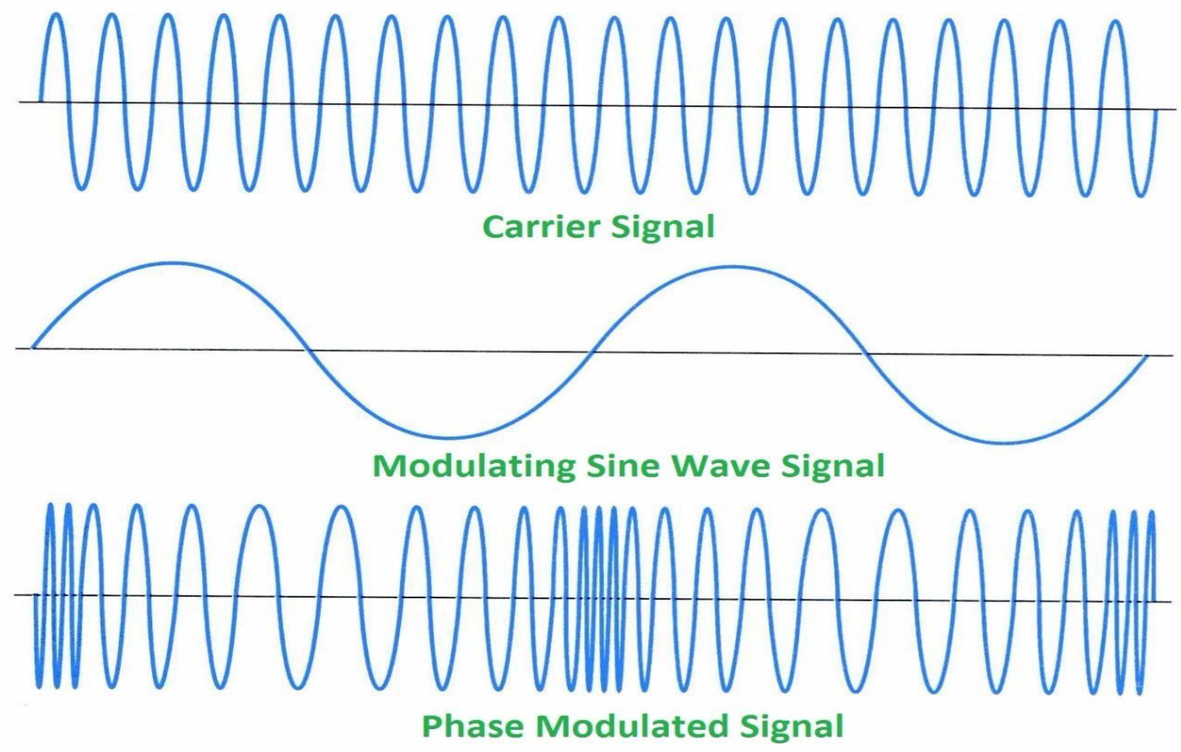
1. FM has characteristics of audio quality and immunity to noise. Most forms of static and electrical noise are naturally AM, and an FM receiver will not respond to AM signals.
2. By increasing the frequency deviation in Fm, It is possible to improve signal to noise ratio.
3. The Power is constant. Because amplitude of modulated FM wave is constant.
4. All transmitted power is useful. Incase of AM, 67% of transmitted power is in carrier.

Disadvantage :

1. FM requires the larger bandwidth.
2. The service area of FM transmitter is much less than that for AM.
3. FM transmitter and receiver are quite complicated.

Phase Modulation

In **Phase Modulation (PM)**, the phase of the carrier signal varies in accordance with the instantaneous amplitude of the modulating signal.



The equation for instantaneous phase ϕ_i in phase modulation is

$\phi_i=k_p m(t)$

Where,

- k_p is the phase sensitivity
- $m(t)$ is the message signal

The standard equation of angle modulated wave is

$s(t)=A_c\cos(2\pi f_c t+\phi_i)$

Substitute, ϕ_i value in the above equation.

$s(t)=A_c\cos(2\pi f_c t+k_p m(t))$

This is the **equation of PM wave**.

If the modulating signal, $m(t)=A_m\cos(2\pi f_m t)$

then the equation of PM wave will be

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

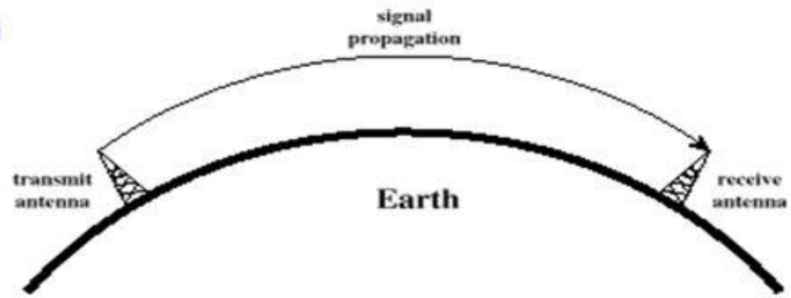
Where,

- β = ***modulation index*** = $\Delta\phi=k_p A_m$
- $\Delta\phi$ is phase deviation

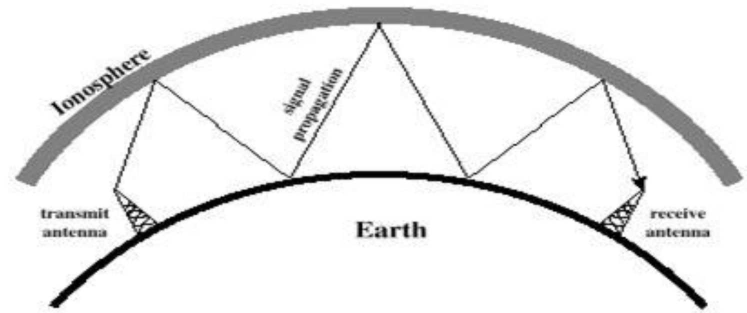
Phase modulation is used in mobile communication systems, while frequency modulation is used mainly for FM broadcasting.

Propagation Modes

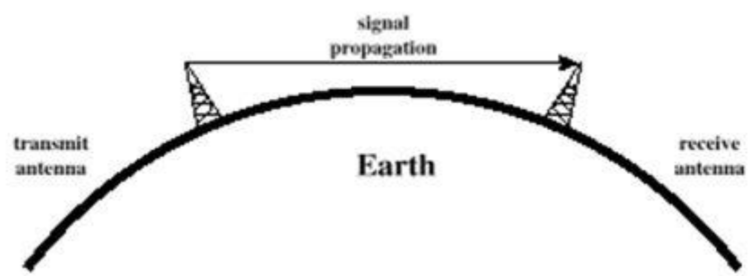
- Radio signal behaves like light in free space
- Ground Wave
  - Frequencies up to 2 MHz
  - Follows contour of the earth
  - Example: AM Radio

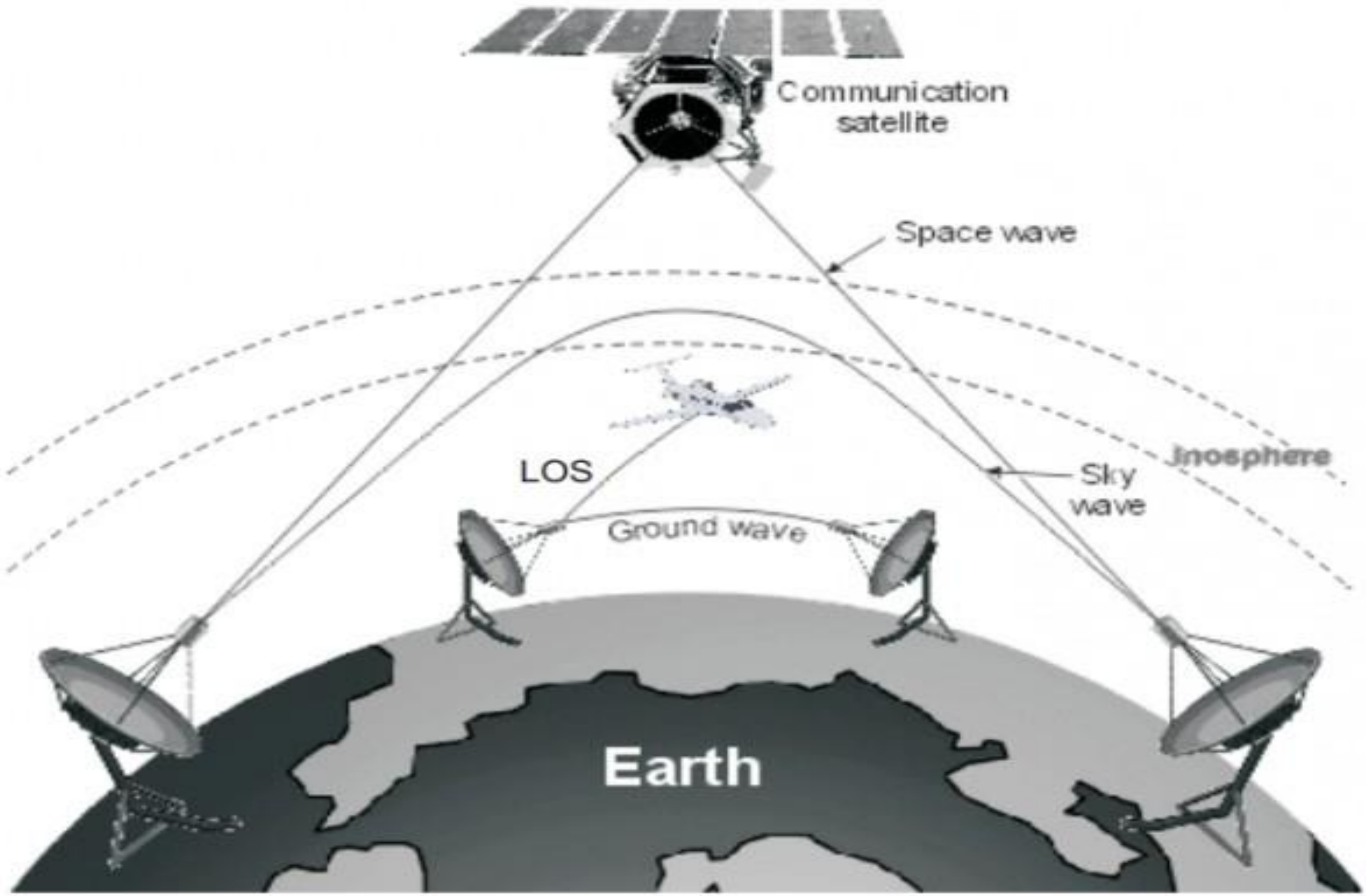


- Sky Wave
  - Signal reflected from ionosphere and earth's surface
  - Can travel thousands of kilometers
  - Frequency: 2-30MHz
  - Amateur Radio, Military Comm.



- Line of Sight
  - Transmitting and receiving antennas must be within line of sight
  - Frequency: More then 30MHz
  - TV, satellite, optical comm.





Three propagation modes of em waves

	Frequency	Common Uses
VLF	3-30 kHz	underwater communications
LF	30-300 kHz	AM radio
MF	300-3000 kHz	AM radio
HF	3-30 MHz	AM radio, long distance aviation communications
VHF	30-300 MHz	FM radio, television, short range avaiation communications, weather radio
UHF	300-3000 MHz	television, mobile phones, wireless networks, Bluetooth, satellite radio, GPS
SHF	3-30 GHz	satellite television and radio, radar systems, radio astronomy
EHF	30-300 GHz	radio astronomy, full body scanners

Basic analog communications system