Basic Electronics Day 7
Communication Systems

1st Year of 4 year B.Tech.

Communication:

- In the most fundamental sense, communication involves the transmission of information from one point to another
- In telecommunication systems, the physical message such as sound, image etc. is converted into an electrical energy called ‘Signal’
- This electrical energy is conveyed at the distant place , where it is converted back into physical message
- Hence, a communication system has three components:
  - Transmitter
  - Transmission media
  - Receiver

Block diagram of a Communication System

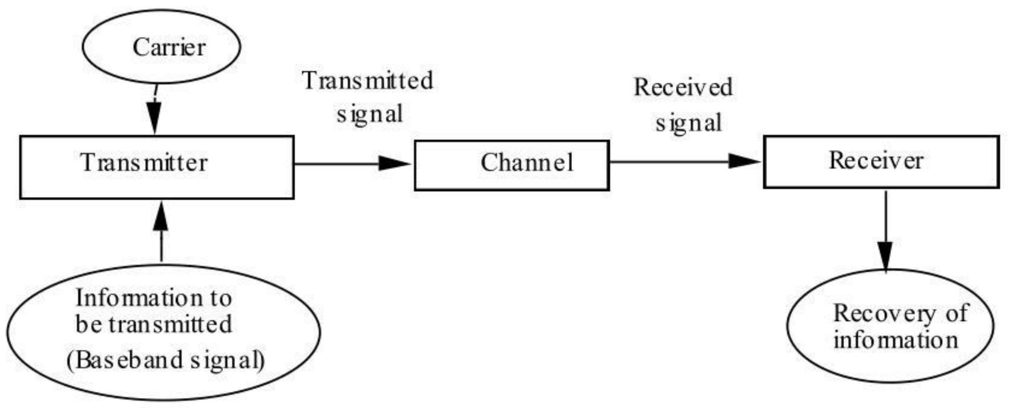
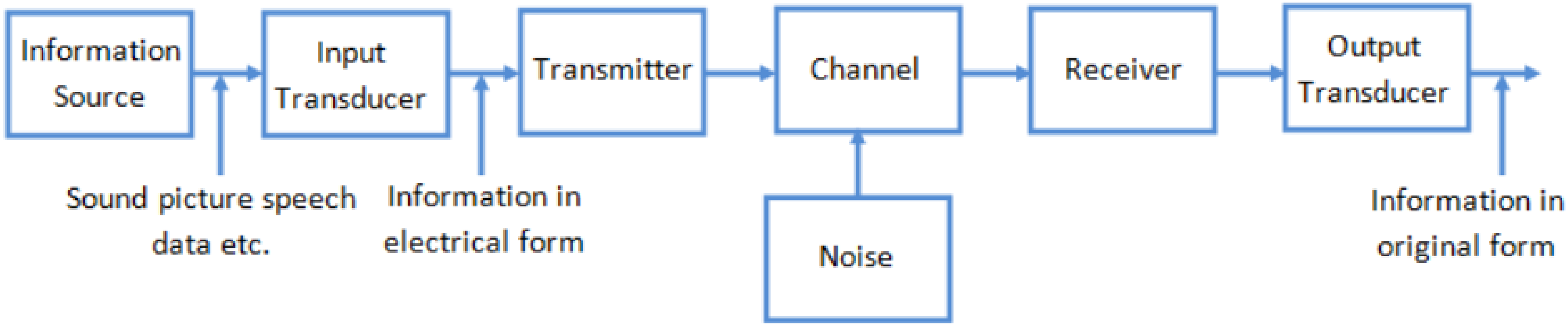


Fig.1 shows the block diagram of a general communication system, in which the different functional elements are represented by blocks.



Modulation

- Modulation is the process by which a some characteristic of a 'carrier' signal is varied in accordance with instantaneous value of another signal called 'modulating' signal
- Signals containing the information to be transmitted is called the modulating signal or the baseband signal
- A high frequency signal called carrier signal (usually frequency is higher than the highest frequency of modulating signal) on which modulation takes place
- Finally, we have the modulated signal-the result of modulation

Why do we require modulation?

- ➢ The message/modulating signals have a very low frequency due to which these signals cannot be transmitted over long distances
- ➢ Practical Length of Antenna: For efficient transmission the transmitting antennas should have length at least equal to a quarter of the wavelength of the signal to be transmitted. For an electromagnetic wave of frequency 15 kHz, the wavelength λ is 20 km and one-quarter of this will be equal to 5 km. Obviously, a vertical antenna of this size is impractible. On the other hand, for a frequency of 1 MHz, this height is reduced to 75 m.
- ➢ Multiplexing: Audio frequencies are within the range of 20 Hz to 20 kHz. Without modulation all signals at same frequencies from different transmitters would be mixed up. There by giving impossible situation to tune to any one of them. In order to separate the various signals, radio stations must broadcast at different frequencies. Each radio station must be given its own frequency band. This is achieved by frequency translation as a result of modulation process.

Recall that any wave has three basic properties:

1) Amplitude – the height of the wave
2) Frequency – a number of waves passing through in a given second
3) Phase – where the phase is at any given moment

Bandwidth (BW) is the difference between the highest and lowest frequencies of the signal. Mathematically, we can write it as

$$BW = f_{max} - f_{min}$$

- In modulation, a continuously varying sine wave is used as a carrier wave that modulates the message signal or data signal. The Sinusoidal wave's general function is shown in the figure below, in which, three parameters can be altered to get modulation – they are mainly amplitude, frequency, and phase, so the **types of analog modulation** are:
- Amplitude modulation (AM)
- Frequency modulation (FM)
- Phase modulation (PM)

Amplitude Modulation

- Amplitude Modulation is a process where the **amplitude of the carrier signal** is altered according to information in a message signal
- Let message signal of modulating signal be

$$m(t) = A_m \cos(\omega_m t) = A_m \cos(2\pi f_m t)$$

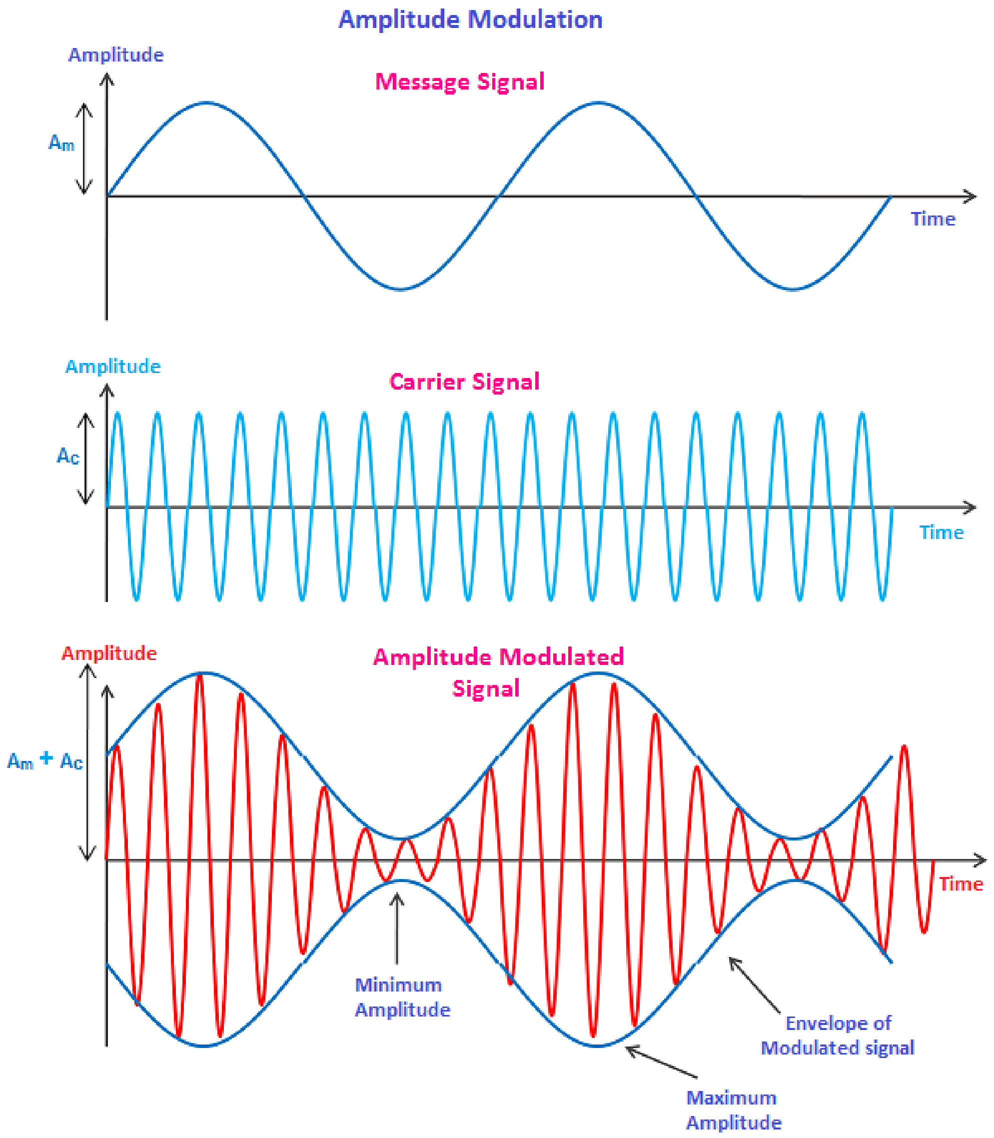
And the carrier signal be

$$c(t) = A_C \cos(\omega_C t) = A_C \cos(2\pi f_C t)$$

$$f_c \gg f_m$$

- Amplitude modulated signal is :

$$s(t) = [A_C + A_m \cos(2\pi f_m t)] \cos(2\pi f_C t)$$



- 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.

$$S(t) = [A_C + A_m \cos(2\pi f_m t)] \cos(2\pi f_C t)$$

- Equation of amplitude modulated wave is

$$s(t) = A_c \left[1 + \left(\frac{A_m}{A_c}\right) \cos(2\pi f_m t)\right] \cos(2\pi f_c t)$$

- Rearranging the above equation,

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

$$\mu = \frac{A_m}{A_c}$$

- μ is the modulation index and is the ration of A_m and A_c

- The modulation index or modulation depth is often denoted in percentage called as Percentage of Modulation. We will get the percentage of modulation, just by multiplying the modulation index value with 100
- Let Amax and Amin be the maximum and minimum amplitudes of the modulated wave

We will get the maximum amplitude of the modulated wave, when $\cos(2\pi f_m t)$ is 1 : $A_{max} = A_c + A_m$

We will get the minimum amplitude of the modulated wave, when $\cos(2\pi f_m t)$ is -1 : $A_{min} = A_c - A_m$

Adding the two equations: $$A_{\max} + A_{\min} = A_c + A_m + A_c - A_m = 2A_c$$

$$\Rightarrow A_c = \frac{A_{\max} + A_{\min}}{2}$$

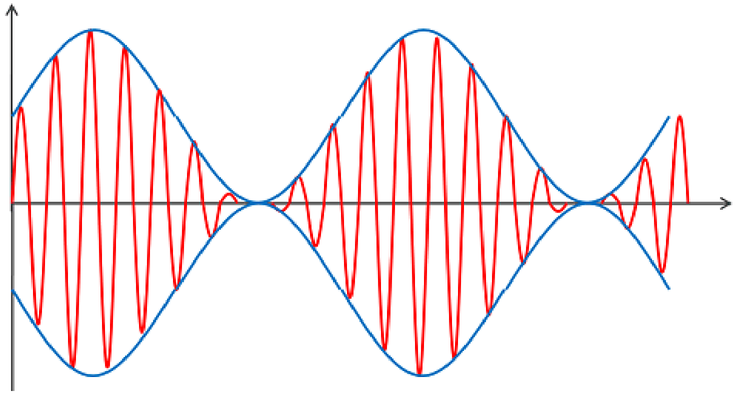
Subtracting the equations: $$A_{\max} - A_{\min} = A_c + A_m - (A_c - A_m) = 2A_m$$

$$\Rightarrow A_m = \frac{A_{\max} - A_{\min}}{2}$$

Therefore, $$\frac{A_m}{A_c} = \frac{(A_{max} - A_{min})/2}{(A_{max} + A_{min})/2}$$

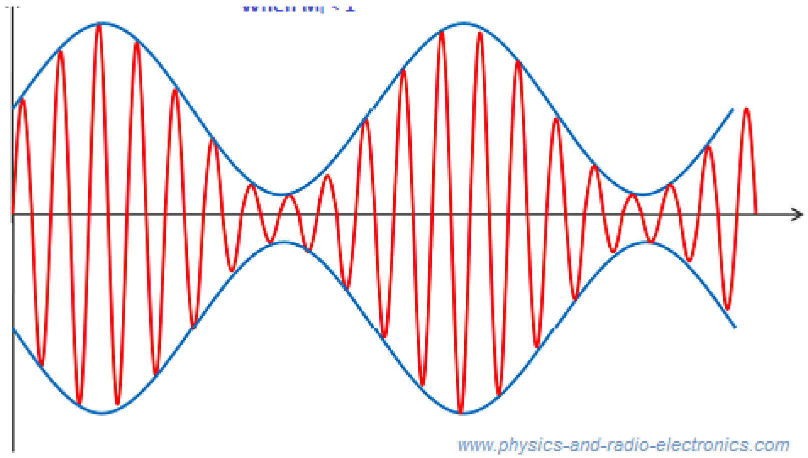
$$\Rightarrow \mu = \frac{A_{\max} - A_{\min}}{A_{\max} + A_{\min}}$$

- For a perfect modulation, the value of modulation index should be 1, which implies the percentage of modulation should be 100%.

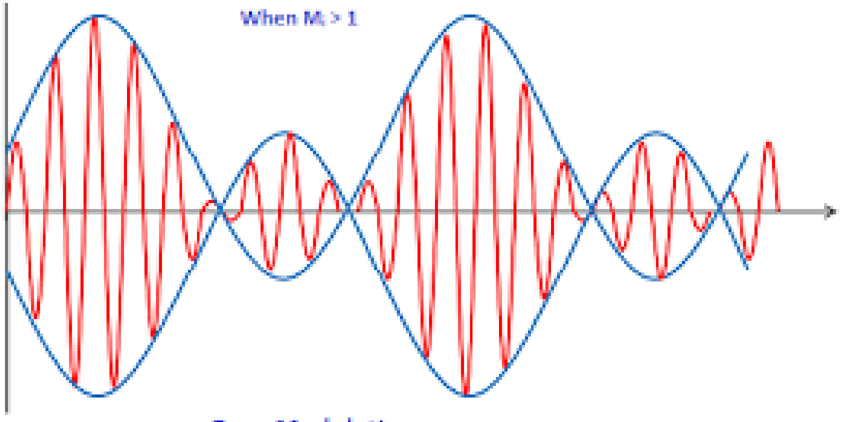


Perfect Modulation

- If this value is less than 1, i.e., the modulation index is 0.5, then the modulated output would look like the following figure. It is called as Under-modulation. Such a wave is called as an under-modulated wave
- If the value of the modulation index is greater than 1, i.e., 1.5 or so, then the wave will be an over-modulated wave.



Under Modulation



Over Modulation

Angle Modulation

The other type of modulation in continuous-wave modulation is **Angle Modulation**.

- Angle Modulation is the process in which the frequency or the phase of the carrier signal varies according to the message signal.

- Let us consider the equation for a carrier wave to be $c(t) = A_C \cos(\omega_C t + \theta_0)$

  where, Where, A_c is the amplitude of the carrier wave, and θ_0 is the phase angle and ω_C is the carrier frequency

Substituting $\phi = \omega_c t + \theta_0$ we have $c(t) = A_C \cos(\phi)$

If ϕ is varied according to the instantaneous value of the message signal, the carrier signal is said to be angle modulated.

Angle modulation is further divided into-

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

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

Phase Modulation

- In Phase modulation, the phase angle ϕ is varied linearly with the modulating signal
- Let unmodulated carrier signal be $c(t) = A_c \cos(\phi)$

or, $c(t) = A_c \cos(\phi)$ where, $\phi = \omega_c t + \theta_0$

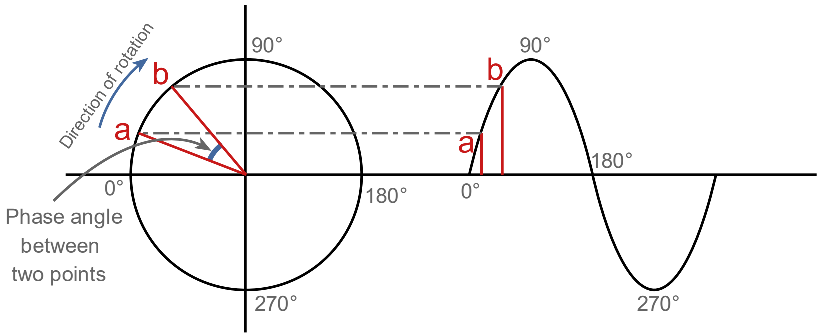
- In phase modulation, phase angle ϕ is varied linearly with the modulating signal m(t)
- Hence,

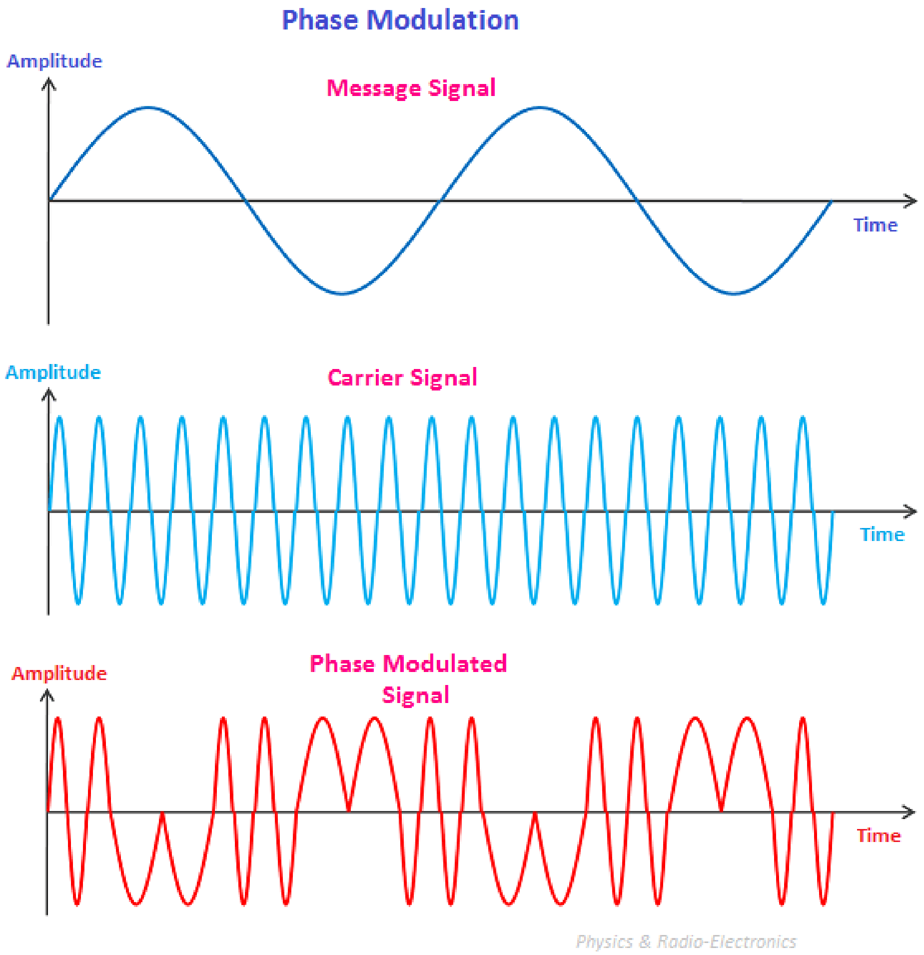
$$\phi_i(t) = \omega_c t + \theta_0 + k_p m(t)$$ :: k_p is a constant called phase sensitivity

Assuming $\theta_0 = 0$, we have $\phi_i(t) = \omega_c t + k_p m(t)$

Resulting modulated wave is

$$s(t) = A_C \cos(\omega_C t + k_P m(t))$$



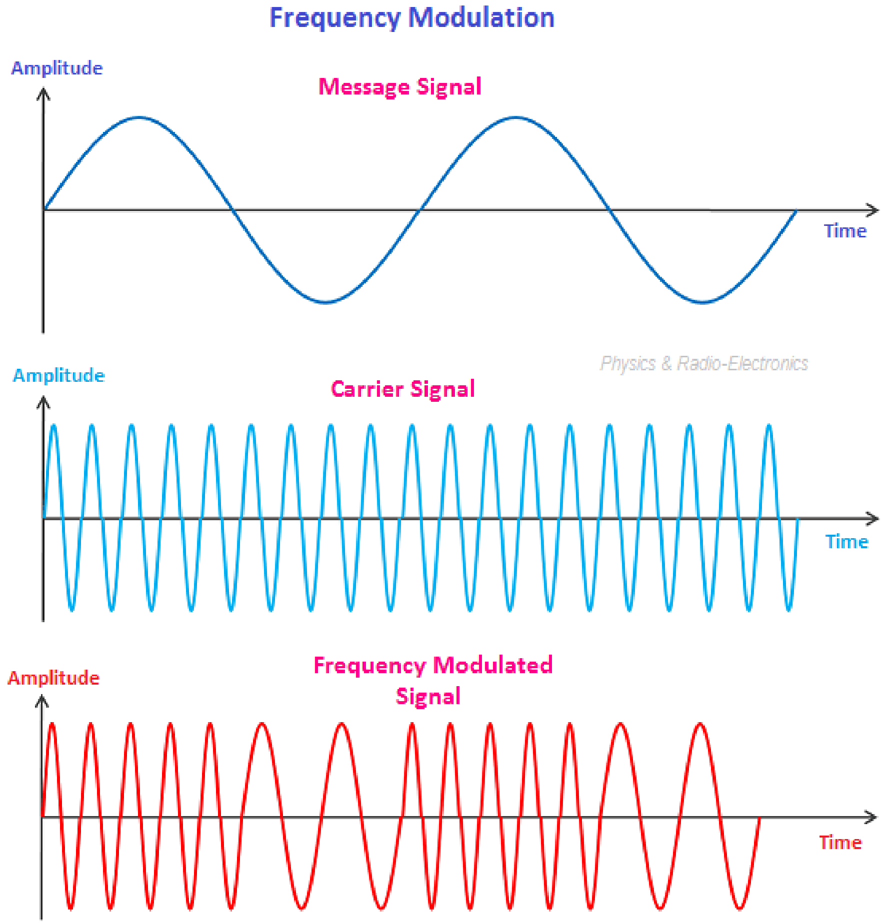


Frequency Modulation

- Frequency Modulation is a modulation in which the frequency of the carrier wave is altered in accordance with the instantaneous amplitude of the modulating signal, keeping phase and amplitude constant

- The frequency of the modulated wave increases, when the amplitude of the modulating or message signal increases.

  Similarly, the frequency of the modulated wave decreases, when the amplitude of the modulating signal decreases.



We know , $\phi = \omega_c t + \theta_0$

Differentiating the above eq, we get $\frac{d\phi}{dt} = \omega_c$

$$\phi = \int \omega_c \, dt$$

Instantaneous phase angle, $\phi_i = \int \omega_i \, dt$

ω_i is the instantaneous frequency of the modulated wave

- Expression for frequency modulated wave is $s(t) = A_c \cos(\phi_i) = A_c \cos(\omega_i t + \theta_0)$
- Putting the value of ϕ_i in the previous equation,

$$\phi_i = \int \left(w_C + k_f m(t) \right) \mathrm{d}t$$

$$= \omega_C t + k_f \int m(t)\, \mathrm{d}(t)$$

Therefore, $s(t) = A_C \cos\left[w_C t + k_f \int m(t)\, \mathrm{d}t\right]$

Now, if phase angle of the unmodulated carrier is taken at t=0, equation for frequency modulated wave is

$$s(t) = A_l \cos\left[\omega_C t + k_f \int_0^1 m(t)\, \mathrm{d}t\right]$$