An FM wave is given by

$$\boldsymbol{s(t) = 20\cos(8\pi \times 106t + 9\sin(2\pi \times 10^3 t))}.$$

Calculate the frequency deviation, bandwidth, and power of FM wave.

Given, the equation of an FM wave as

$$s(t) = 20\cos(8\pi \times 10^6 t + 9\sin(2\pi \times 10^3 t))$$

We know the standard equation of an FM wave as

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

Amplitude of the carrier signal, $\boldsymbol{A_c = 20\,V}$

Frequency of the carrier signal, $\boldsymbol{f_c = 4 \times 10^6\,Hz = 4\,MHz}$

Frequency of the message signal, $\boldsymbol{f_m = 1 \times 10^3\,Hz = 1\,KHz}$

Modulation index, $\boldsymbol{\beta = 9}$

We know the formula for modulation index as

$$\boldsymbol{\beta} = \frac{\Delta \boldsymbol{f}}{\boldsymbol{f_m}}$$

Rearrange the above equation as follows.

$$\Delta \boldsymbol{f} = \boldsymbol{\beta}\, \boldsymbol{f_m}$$

Substitute $\boldsymbol{\beta}$ and $\boldsymbol{f_m}$ values in the above equation.

$$\Delta \boldsymbol{f} = \mathbf{9} \times \mathbf{1}\boldsymbol{K} = \mathbf{9}\ \boldsymbol{KHz}$$

Therefore, **frequency deviation**, Δf is **9 KHz**.

The formula for Bandwidth of Wide Band FM wave is

$$\boldsymbol{BW = 2(\beta + 1)f_m}$$

Substitute $\boldsymbol{\beta}$ and $\boldsymbol{f_m}$ values in the above formula.

$$\boldsymbol{BW = 2(9 + 1)\ 1K = 20\ KHz}$$

power of FM wave is

$$P = \frac{{A_c}^2}{2R}$$

power of FM wave is

$$P = \frac{{A_c}^2}{2R}$$

Assume, $R = 1\,\Omega$ and substitute A_c value in the above equation.

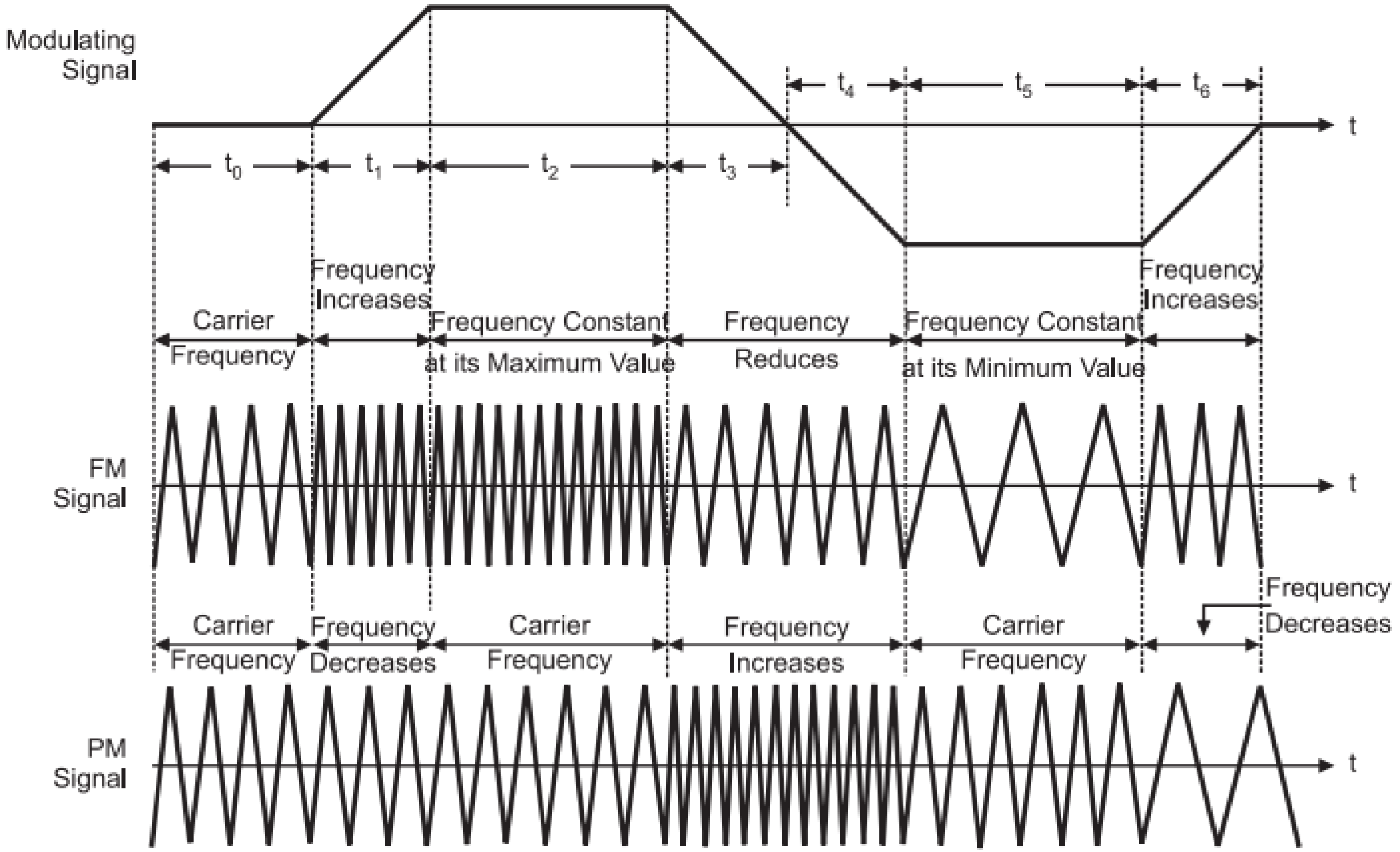
$$P = \frac{(20)^2}{2(1)} = 200\,W$$

Therefore, the **power** of FM wave is **200 watts**.

Frequency Modulation & Phase Modulation

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.**


Modulating Signal
t
t_0
t_1
t_2
t_3
t_4
t_5
t_6
Carrier Frequency
Frequency Increases
Frequency Constant at its Maximum Value
Frequency Reduces
Frequency Constant at its Minimum Value
Frequency Increases
FM Signal
Carrier Frequency
Frequency Decreases
Carrier Frequency
Frequency Increases
Carrier Frequency
Frequency Decreases
PM Signal

Phase Modulation

Phase modulation (PM)

The phase angle is varied linearly with a modulating signal m(t)

$$\theta_i(t) = \omega_c t + k_{PM} m(t) \text{ (or) } \theta_{PM}(t) = \omega_c t + \theta_0 + k_{PM} m(t)$$

where k_{PM} is known as *phase sensitivity* of the modulator.

The PM waveform can then be expressed as

$$s_{PM}(t) = A\cos[\omega_c t + k_{PM} m(t)] \text{ (or) } s_{PM}(t) = A\cos[\omega_c t + \theta_0 + k_{PM} m(t)]$$

Phase Modulation – Single Tone

Phase Modulation – Single Tone

The message signal

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

$$\begin{aligned} s_{PM}(t) &= A \cos[\omega_c t + \theta_0 + k_{PM} m(t)] \\ &= A \cos[\omega_c t + \theta_0 + k_{PM} A_m \cos\omega_m t] \\ &= A \cos[\omega_c t + \theta_0 + m_p \cos\omega_m t] \end{aligned}$$

where $m_p = k_{PM} A_m$ is called the *phase modulation index*, representing the maximum phase deviation $\Delta\theta$.

Relationship between PM and FM

Both the net effect of PM and FM is *variation in total phase angle*.

- ***In PM, phase angle varies linearly with m(t)*** **while** ***in FM, phase angle varies linearly with the integral of m(t).***

$$s_{PM}(t) = A\cos[\omega_c t + \theta_0 + k_{PM} m(t)]$$

$$s_{FM}(t) = A\cos[\omega_c t + \theta_0 + k_{FM} \int m(t)dt]$$

Given the angle-modulated signal

$$x_c(t) = 10\cos\left(2\pi 10^8 t + 200\cos 2\pi 10^3 t\right)$$

what is its bandwidth?

For an FM signal given by

$$v = 60\sin\left(4\pi \times 10^{8} t + 2\sin 2\pi \times 10^{3} t\right)$$

If this signal is input into a 30 ohm antenna, find

the carrier frequency
- the transmitted power
- the modulating index
- the intelligence frequency
- the required bandwidth using Carson's rule