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EE1205 : Signals and Systems
Indian Institute of Technology Hyderabad

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I. Question E.C.(45)

Question: Let a frequency modulated (FM) signal : $x(t) = A\cos(\omega_c t + k_f \int_{-\infty}^{t} m(\lambda)d\lambda)$, where $m(t)$is a message signal of bandwidth W. It is passed through a non-linear system with output $y(t) = 2x(t) + 5(x(t))^2$. Let $B_T$denote the FM bandwidth. The minimum value of ω_c required to recover $x(t)$ from $y(t)$ is:

(A) $B_T + W$

(B) $\frac{3}{2}B_T$

(C) $2B_T + W$

(D) $\frac{5}{2}B_T$

Solution:

$$x(t) = A\cos(\omega_c t + k_f \int_{-\infty}^{t} m(\lambda)d\lambda) \tag{1}$$

$$y(t) = 2x(t) + 5(x(t))^2 \tag{2}$$

$$= 2A\cos(\omega_c t + k_f \int_{-\infty}^{t} m(\lambda)d\lambda) + 5A^2\cos^2(\omega_c t + k_f \int_{-\infty}^{t} m(\lambda)d\lambda) \tag{3}$$

$$= 2A\cos(\omega_c t + k_f \int_{-\infty}^{t} m(\lambda)d\lambda) + \frac{5}{2}A^2\cos(2\omega_c t + k_f \int_{-\infty}^{t} m(\lambda)d\lambda) + \frac{5}{2}A^2 \tag{4}$$

To recover $x(t)$ from $y(t)$

$$2\omega_c - B_T > \omega_c + \frac{B_T}{2} \tag{5}$$

$$\omega_c > \frac{3B_T}{2} \tag{6}$$

$$\therefore (\omega_c)_{min} = \frac{3B_T}{2} \tag{7}$$