Signal Analysis & Communication ECE 355

Ch. 8.7. Angle Modulation.

Lecture 35

6-12-2023.

Ch. 8.I. ANGLE MODULATION

- Using the modulating sig. to change or vary the angle $\theta_{(t)}$ of the carrier.
- Previously, in AM, the envelope of the carrier varies with the amplitude of the modulating sig.

$$y_{(t)} = x_{(t)} \cos(\omega_c t)$$

- In "angle modulation", the angle of the carrier varies with the amplitude of the modulating sig.

$$y_{(t)} = \underset{\text{fixed.}}{A_c} \cos(\underset{\text{varies with } x_{(t)}}{\theta_{(t)}})$$

- Convention:

  $x_{(t)}$: modulating sig.

  $c_{(t)}$: Carrier $= A_c \cos(\omega_c t)$

  $y_{(t)}$: Modulated sig. $= A_c \cos(\theta_{(t)})$

- There are two special cases of angle modulation.

I. Phase Modulation (PM)

$$\theta_{(t)} = \omega_c t + \underset{\text{Phase sensitivity.}}{k_p} x_{(t)}$$

II. Frequency Modulation (FM)

$$\theta_{(t)} = \omega_c t + k_f \int_0^t x_{(\tau)} \, d\tau .$$

for convenience.
(can be any time in general)

- instataneous freq. of $\theta_{(t)}$

$$\frac{d\theta_{(t)}}{dt} = \omega_c + k_f \, x_{(t)}$$

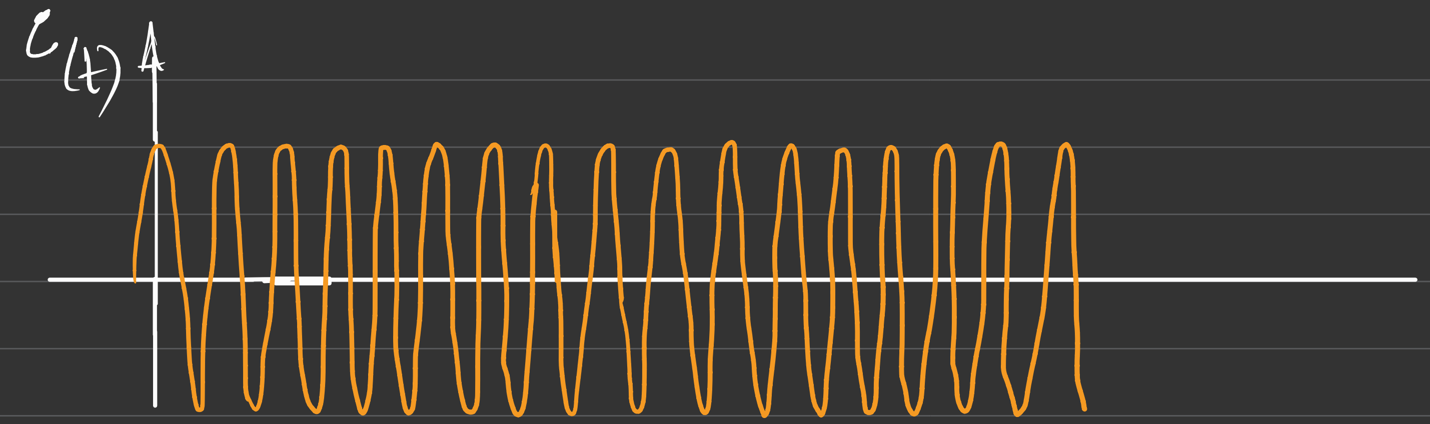
freq. sensitivity.

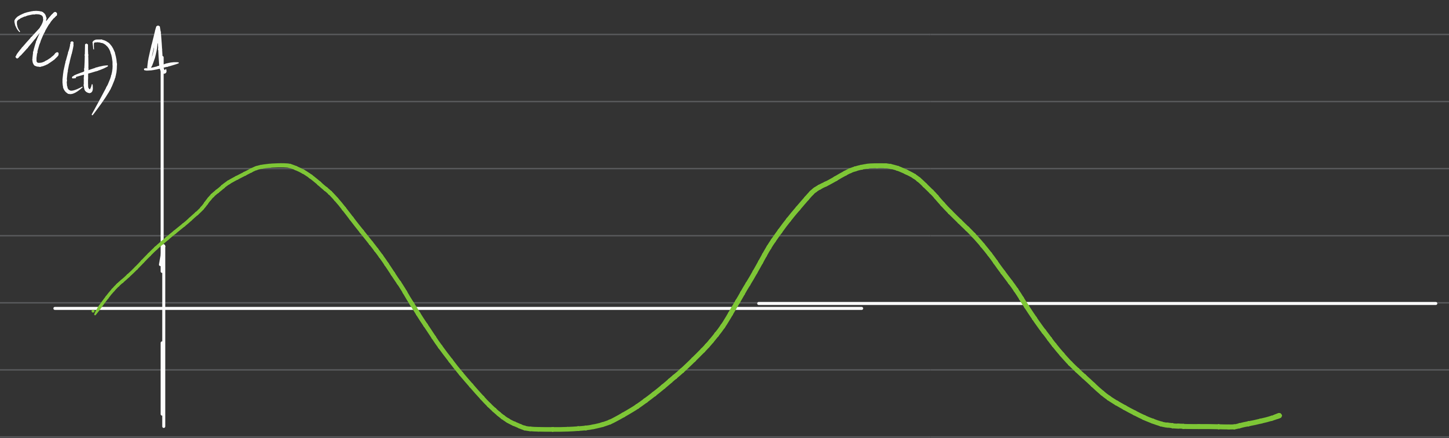
- Although phase & freq. modulation are different forms of angle modulation, they can easily be related.

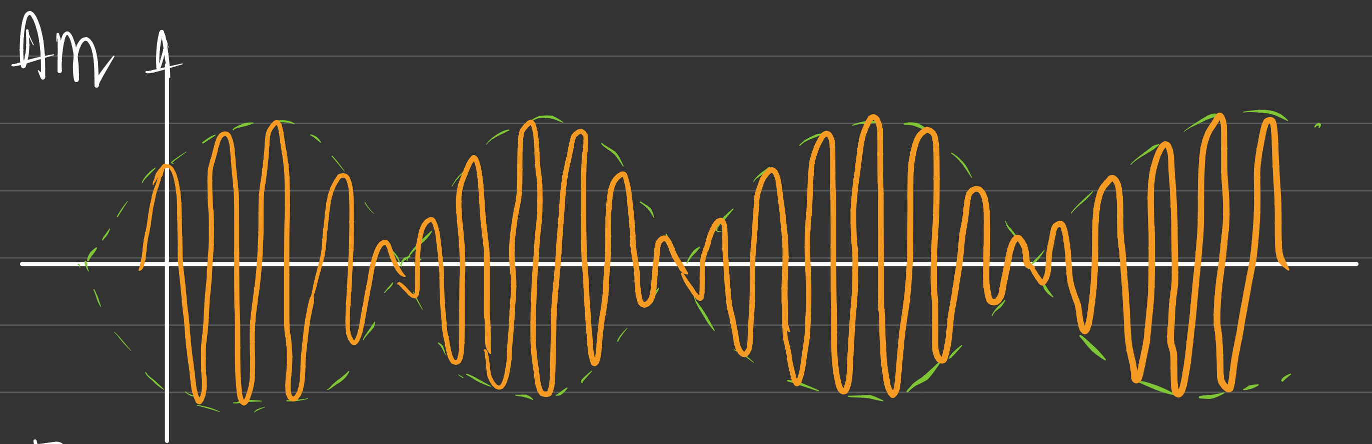
FM with sig. $x_{(t)}$ = PM with sig. $\int_0^t x_{(\tau)} \, d\tau$.

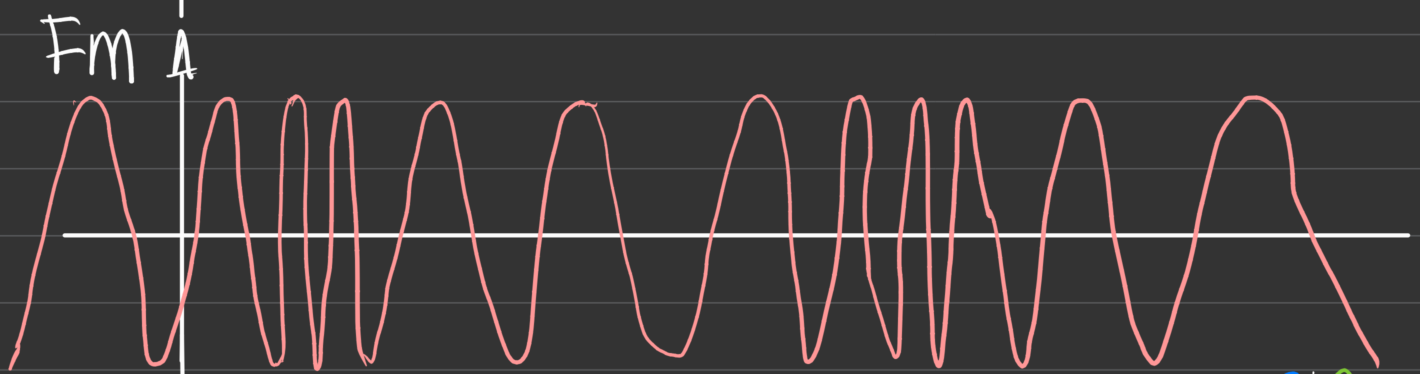
OR

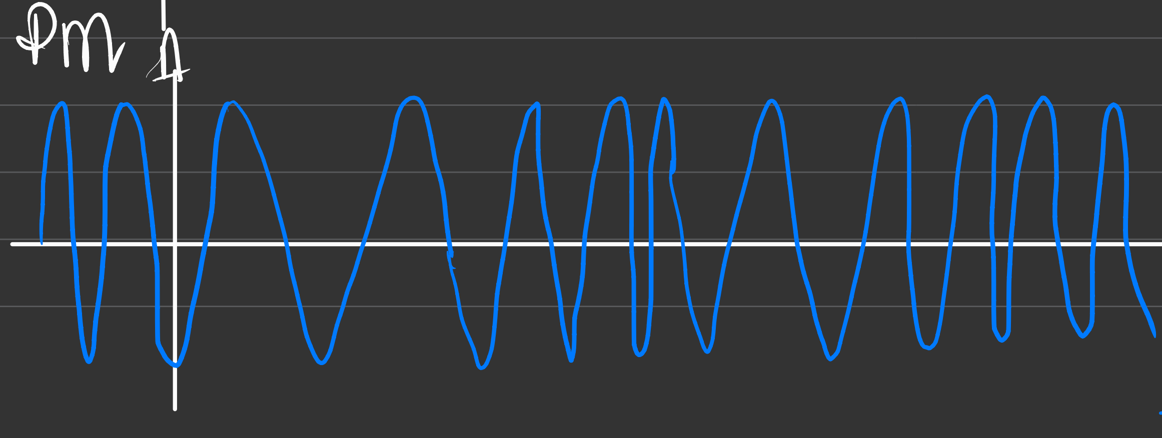
PM with sig. $x_{(t)}$ = FM with sig. $\frac{dx_{(t)}}{dt}$

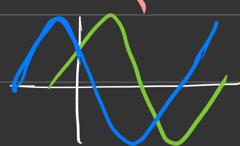












$$\frac{dx_{(t)}}{dt} = \frac{d\sin(t+\Delta)}{dt}$$

$$* = \cos(t+\Delta)$$

Analysis needs to be focussed either on FM or PM.

Properties of FM:

① Transmission power is independent of $x_{(t)}$.

$$|y_{(t)}|^2 = A_c^2 \cos^2(\theta_{(t)})$$

whereas in AM, the amplitude varies with the information sig., which can have large dynamic range & hence large power.

- For any interval T_0, the avg. power is:

$$\frac{1}{T_0}\int_{T_0} |y_{(t)}|^2 dt = \frac{1}{T_0}\int_{T_0} A_c^2 \cos^2(\theta_{(t)})dt.$$

$$= \frac{1}{T_0}\int_{T_0} A_c^2\left(\frac{1}{2} - \frac{1}{2}\cos(2\theta_{(t)}\right)dt.$$

$$\simeq \frac{1}{2}A_c^2 \quad \text{if } \omega_c \text{ is large compared to } \frac{1}{T_0}$$

② The information is contained in zero-crossings of $y_{(t)}$ instead of the amplitude. ⇒ Improved resilience to noise but require more BW.

③ Non-linear modulation process - hard to analyze.

Digital Modulation - OPTIONAL - Discuss in class.

THANK YOU & GOOD LUCK ☺