EEE 360 Communications Systems I

Lecture Presentation 21

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☞ Representation of PM and FM Signals: *Section 5.6*

Phase modulation (PM) and frequency modulation (FM) are special cases of angle modulation.

In this type of signaling the complex envelope is

$$g(t) = A_c e^{j\theta(t)} \tag{1}$$

The real envelope $R(t) = |g(t)| = A_c$ is a constant and the phase $\theta(t)$ is a linear function of $m(t)$.

However, $g(t)$ is a nonlinear function of $m(t)$.

The angle-modulated signal is given by

$$s(t) = A_c \cos[\omega_c t + \theta(t)] \tag{2}$$

➢ For PM, the phase is directly proportional to $m(t)$.

$$\theta(t) = D_p m(t) \tag{3}$$

where D_p is the phase sensitivity of the phase modulator.

➢ For FM, the phase is directly proportional to the integral of $m(t)$.

$$\theta(t) = D_f \int_{-\infty}^{t} m(\sigma)\, d\sigma \tag{4}$$

It is important to note that both PM and FM occur at the same time!
Given a bandpass signal

$$s(t) = R(t)\cos\psi(t) \tag{5}$$

The instantaneous frequency is given by

$$f_i(t) = \frac{1}{2\pi}\omega_i(t) = \frac{1}{2\pi}\left[\frac{d\psi(t)}{dt}\right] \tag{6}$$

for the case of FM,

$$f_i(t) = f_c + \frac{1}{2\pi}D_f m(t) \tag{7}$$

Eq. (7) show how the frequency varies with the message signal. The variation is around f_c. The frequency deviation from the carrier frequency is given by

$$f_d(t) = f_i(t) - f_c(t) = \frac{1}{2\pi}\left[\frac{d\theta(t)}{dt}\right] \tag{8}$$

and the peak frequency deviation is

$$\Delta F = \max\left\{\frac{1}{2\pi}\left[\frac{d\theta(t)}{dt}\right]\right\} \tag{9}$$

The peak phase deviation is given by

$$\Delta\theta = \max\left[\theta(t)\right] \tag{10}$$

Two of the most important parameters, the phase modulation index is

$$\beta_p = \Delta\theta \tag{11}$$

where $\Delta\theta$ is the peak phase deviation and the frequency modulation index is

$$\beta_f = \frac{\Delta F}{B} \tag{12}$$

Carson's rule gives an approximate value for the bandwidth of PM and FM signals. It is given by the following simple formula

$$B_T = 2(\beta + 1)B \tag{13}$$

where β is the phase or the frequency modulation index and B is the bandwidth of $m(t)$.

******Look at fig. 5.11