Summary of Angle (Exponential) Modulation (Ver 2.1)

EE370 : Communication Engineering

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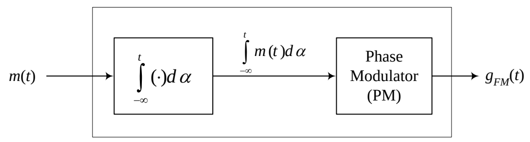
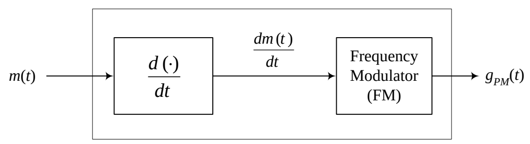
- Any sinusoidal (cos) signal can be completely specified by its amplitude and angle
$$x(t) = A(t)\cos\left(\omega_c t + \varphi(t)\right)$$
- The angle of the cosine $\theta(t)$ = $\omega_c t + \varphi(t)$
- The **Instantaneous frequency** is given by $\omega_i(t) = \dfrac{d\theta(t)}{dt}$.
- **Phase Modulation (PM)**: the modulated signal have the form
$$g_{PM}(t) = A \cdot \cos\left[\omega_c t + k_p m(t)\right],$$
The phase and instantaneous frequency of this signal are
$$\theta_{PM}(t) = \omega_c t + k_p m(t),$$
$$\omega_i(t) = \omega_c + k_p \frac{dm(t)}{dt} = \omega_c + k_p \dot{m}(t).$$
- **The frequency Modulation (FM):** the modulated signal have the form
$$g_{FM}(t) = A \cdot \cos\left[\omega_c t + k_f \int_{-\infty}^{t} m(\alpha)d\alpha\right]$$
The phase and instantaneous frequency of this signal are
$$\theta_{FM}(t) = \omega_c t + k_f \int_{-\infty}^{t} m(\alpha)d\alpha,$$
$$\omega_i(t) = \omega_c + k_f \frac{d}{dt}\left[\int_{-\infty}^{t} m(\alpha)d\alpha\right] = \omega_c + k_f m(t).$$
- Given a signal $m(t)$ you should be able to sketch the FM and PM Modulated signals. See Examples 5.1 & 5.2, notice the continuity issue.
- **Relation between PM and FM**

Frequency Modulator (FM)



Phase Modulator (PM)



- **Bandwidth of Angle Modulated signals**

In terms of Bandwidth FM/PM can be classified into Wideband and Narrowband. The condition for Narrowband is $k_f\ a(t) << 1$ for FM and $k_p\ m(t) << 1$ for the PM case. Note that
$$a(t) = \int_{-\infty}^{t} m(\alpha)d\alpha$$

In general FM can also be written as
$$g_{FM}(t) = \mathrm{Re}\left\{\hat{g}_{FM}(t)\right\}$$
$$= A \cdot \left[\cos(\omega_c t) - k_f a(t)\sin(\omega_c t) - \frac{k_f^{\,2} a^2(t)}{2!}\cos(\omega_c t) + \frac{k_f^{\,3} a^3(t)}{3!}\sin(\omega_c t) + \frac{k_f^{\,4} a^4(t)}{4!}\cos(\omega_c t) + \dots\right]$$

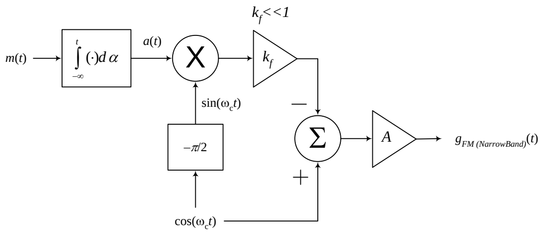
For the case of narrow band

$$g_{FM\,(Narrowband)}(t) \approx A \cdot \left[\cos(\omega_c t) - k_f\, a(t)\sin(\omega_c t)\right]$$

$$g_{PM\,(Narrowband)}(t) \approx A \cdot \left[\cos(\omega_c t) - k_p m(t)\sin(\omega_c t)\right]$$

Like DSB+C (with some difference). Therefore, the bandwidth of the narrowband FM signal is approximately 2*B*, where *B* is the bandwidth of the message.

Generation/Construction of Narrowband Frequency and Phase Modulators



Beta is the modulation index (frequency deviation ratio) : $\beta = \dfrac{\Delta f}{B}$

$\Delta f_{FM} = \dfrac{k_f m_p}{2\pi}$, $\Delta f_{PM} = \dfrac{k_p \dot{m}_p}{2\pi}$, m_p is the maximum negative peak of *m*(*t*), and $\dot{m}_p$ is the maximum negative peak of the derivative of *m*(*t*)

Carson's Rule $\boxed{BW = 2(\Delta f + B) = 2B(\beta + 1)}$

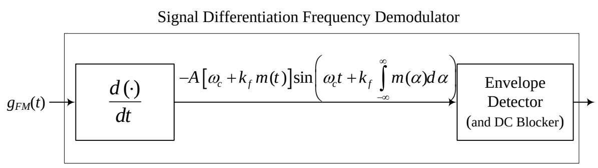
See Examples 5.3, 5.4, 5.5

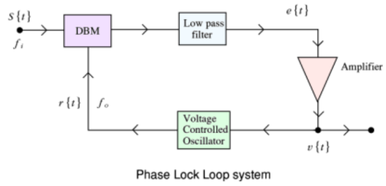
- If FM is not efficient in terms of BW compared with AM , **Why FM ?** (mention three reasons)
- Analysis of performance of FM signals under nonlinearity
- Generation of Wideband FM (WBFM):
    - Direct Method VCO (+,-)
    - Indirect Armstrong Method (*See Examples*)

Demodulation of FM/PM signals

1) **Frequency Discriminator**
2) **Phase Locked Loop (PLL)**
3) Zero Crossing Detector
4) Ratio Detector

- Sketch how their block diagram, how they work , Advantages and disadvantages of each.
- A bandpss limiter which eliminates amplitude variations is a hard limiter followed by a BPF.





DBM: Double balanced modulator (multiplier)

FM Receiver

88-108 MHz , 200 kHz/ Channel, IF=10.7 MHz

Super-heterodyne concept with envelope detector replaced by PLL or frequency discriminator.

Monophonic & compatibility with stereophonic (1dB). *Fully understand Figure 5.18, 5th Ed.*

Note:

- Spectral Analysis of Tone Frequency Modulation (Bessel Functions) is not required. (p 214-216 5th ed.)
- PLL (error analysis is not included p233-234 , 5th ed.)