Analog Haberleşme

Açı modülasyonu: FM üretimi ve demodülasyonu

Orijinal not: Final-notu.pdf

UYARI Bu belge, el yazısı ders notlarından Claude (Anthropic) yardımıyla dijitale aktarılmıştır. Yardımcı kaynak olarak hazırlanmıştır; hata veya eksik içerebilir. Lütfen orijinal notları ve ders kaynaklarını esas alın.

NOTICE *This document was transcribed from handwritten lecture notes with the help of Claude (Anthropic). It is meant as a supplementary resource and may contain errors or omissions. Always check against the original notes and official course material.*

orj. s. 1

Ders#3 Açı modülasyonu lineersizliğe dayanıklıdır

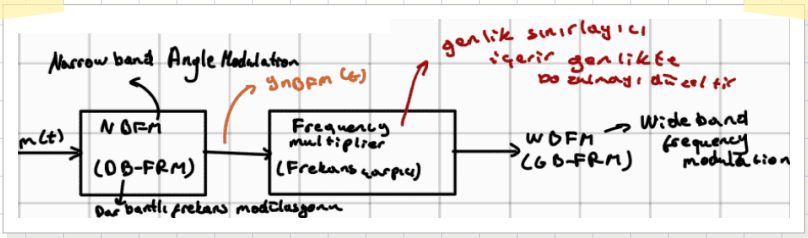
$$\cos^3(\alpha) = \frac{3}{4}\cos(\alpha) + \frac{1}{4}\cos(3\alpha)$$

$$|\phi(t)| \ll 1 \Rightarrow \cos\phi(t) \cong 1, \qquad \sin\phi(t) \cong \phi(t)$$

Create FM

1) Dolaylı metod (Indirect method)

(Armstrong tekniği)



orijinal çizim, s. 1

– Genlik ve faz bozulmasına sebep olur

$$g(t) = A_c\cos(2\pi f_c t + \phi(t))$$
$$= A_c\left[\cos(2\pi f_c t)\underbrace{\cos(\phi(t))}_{\cong 1} - \sin(2\pi f_c t)\underbrace{\sin(\phi(t))}_{\cong \phi(t)}\right]$$

$$\underset{\text{NBFM}}{g(t)} = A_c\left[\cos(2\pi f_c t) - \phi(t)\sin(2\pi f_c t)\right]$$

when $\phi(t) = 2\pi k_f \int m(z)\,dz$

$$a\cos x + b\sin x = c\cos(x+\theta)$$
$$c = \sqrt{a^2+b^2}, \qquad \theta = \tan^{-1}(-b/a)$$

$$\underset{\text{NBFM}}{y(t)} = A_c E(t)\cos(2\pi f_c t + \alpha(t))$$
$$E(t) = \sqrt{1+\phi^2(t)}, \qquad \alpha(t) = \arctan(\phi(t))$$
$$\phi(t) = 2\pi k_f \int m(z)\,dz$$

$$f_i(t) - f_c = \frac{1}{2\pi}\frac{d\alpha(t)}{dt}$$
$$= \frac{1}{2\pi}\frac{\dot\phi(t)}{1+\phi^2(t)} = \frac{1}{2\pi}\frac{2\pi k_f m(t)}{1+\phi^2(t)}$$
$$f_i(t) - f_c = k_f m(t)\underbrace{\left[1-\phi^2(t)+\phi^4(t)-\cdots\right]}_{1/(1+\phi^2(t))}$$

2) Direct Method

Voltage controlled oscillator (Hartley ve Colpitts osilatörlerinde osilasyon frekansı)

Gko

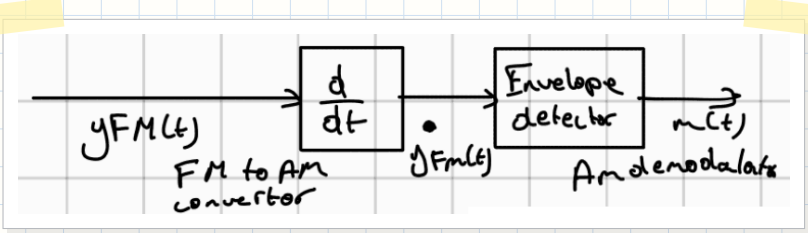
$$f_i(t) = \frac{1}{2\pi\sqrt{LC}}, \qquad C = C_0 - k\,m(t) \quad \text{(varactor)}$$
$$= \frac{1}{2\pi\sqrt{L[C_0 - k\,m(t)]}} = \frac{1}{2\pi\sqrt{LC_0\left[1-\frac{k\,m(t)}{C_0}\right]}}$$
$$= \frac{1}{2\pi\sqrt{LC_0}}\cdot\frac{1}{\left[1-\frac{k\,m(t)}{C_0}\right]^{1/2}} = f_c\left[1-\frac{k\,m(t)}{C_0}\right]^{-1/2}$$

f_c * $|x| \ll 1 \Rightarrow (1+x)^n \cong 1+nx$

$$\frac{k\,m(t)}{C_0} \ll 1 \;\Rightarrow\; f_i(t) \cong f_c\left[1+\frac{k\,m(t)}{2C_0}\right]$$
$$f_i(t) = f_c + \underbrace{\frac{kf_c}{2C_0}}_{k_f} m(t)$$

* frekans kararlılığı çok iyi değil

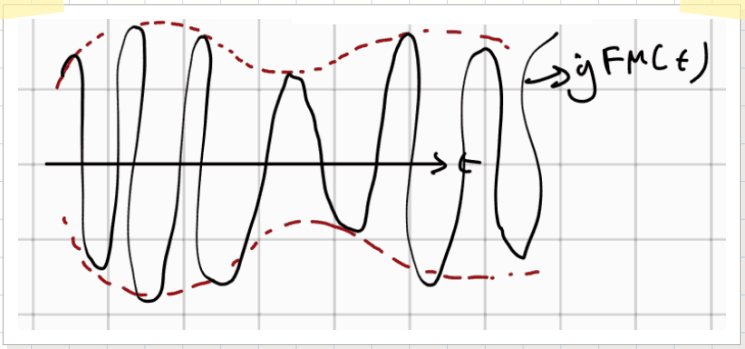
FRM (FM)'nin Demodülasyonu



orijinal çizim, s. 1

$$g_{FM}(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} m(z)\,dz\right)$$

$$\frac{dg_{FM}(t)}{dt} = -A_c \underbrace{\left[2\pi f_c + 2\pi k_f m(t)\right]}_{\text{zarf}} \sin(\theta(t))$$



orijinal çizim, s. 1

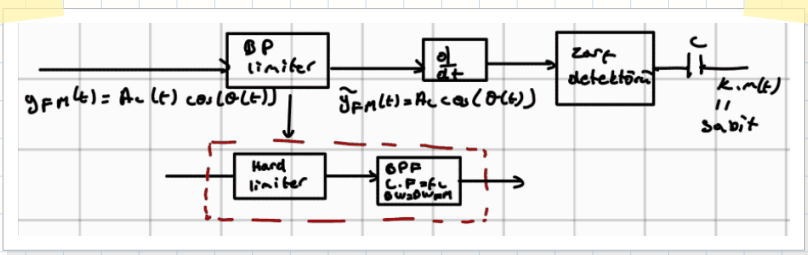
$$\frac{dy_{FM}(t)}{dt} = -A_c \underbrace{\left[2\pi f_c + 2\pi k_f m(t)\right]}_{\text{zarf}>0} \sin(\theta(t))$$

$\forall t$ zarf > 0 olması gerekir

$\forall t$ $f_c + k_f m(t) > 0$

$\forall t$ $f_c > k_f \underbrace{\text{maks}|m(t)|}_{m_p}$

A_c sabit olmalıdır



orijinal çizim, s. 1

Pratik FM demodülatörleri

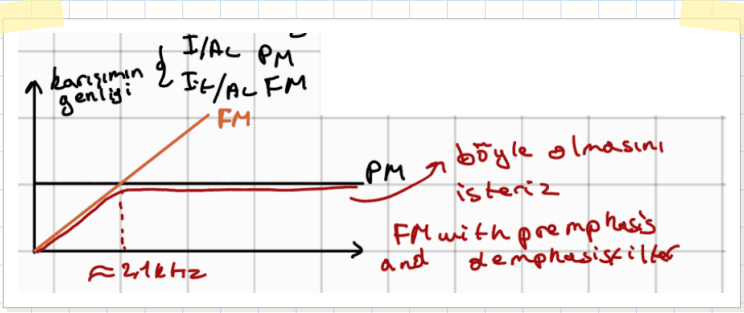
- Balanced modulators: slope detector / balanced discriminator / ratio detector
- Zero-crossed detector
- Phase Locked loop (PLL) *(Düşük maliyetli ve yüksek performansı ?nedeniyle)*

Açı modülasyonunda karışım (interference)

Mesajsız taşıyıcı

$$r(t) = \underbrace{A_c \cos(2\pi f_c t)}_{\text{Unmodulated Carrier}} + \overbrace{I \cos[2\pi(f_c + f_i)t]}^{\text{karışım}}$$

$$\text{Demodülatör çıkışı: } y_d(t) = \begin{cases} \frac{I}{A_c} \sin(2\pi f_i t) & \text{PM} \\ \frac{I f_i}{A_c} \cos(2\pi f_i t) & \text{FM} \end{cases}$$



orijinal çizim, s. 1

orj. s. 2

Başta zaten FM, sonra türevini alıp PM'e geçebiliriz. Bunu yapan filtreye ön vurgulama filtresi denir.

Additive White Gaussian Noise

AWGN: kanal gürültüsü

$$r(t) = y(t) + \underbrace{n(t)}_{\text{AWGN}}$$