Analog Haberleşme

BT-ÇYB-GM (DSB-LC-AM) modülatörleri ve demodülatörleri

Orijinal not: Ders9.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.

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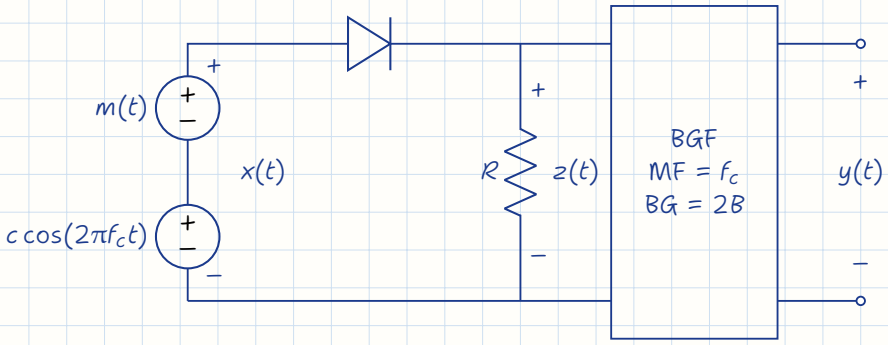
orj. s. 1

BT - ÇYB - GM (DSB - LC - AM)

Modülatörleri

$$y(t) = A_c\left[1 + \mu\, m_n(t)\right]\cos(2\pi f_c t)$$

Anahtarlama modülatörü



$$x(t) = m(t) + c\cos(2\pi f_c t)$$
$$z(t) = \left[m(t) + c\cos(2\pi f_c t)\right] w(t)$$
$$w(t) = \left[\frac{1}{2} + \frac{2}{\pi}\left(\cos(2\pi f_c t) - \frac{1}{3}\cos(2\pi\, 3 f_c t) + \frac{1}{5}\cos(2\pi\, 5 f_c t) + \cdots\right)\right]$$

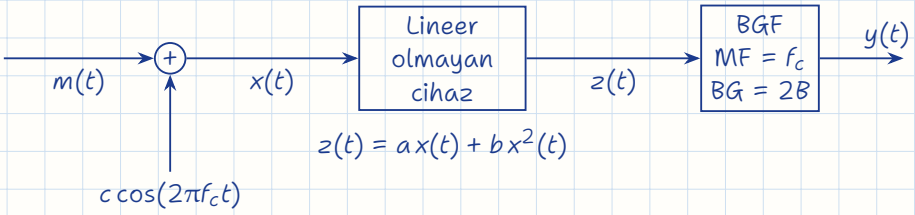
Filtreden geçmez (kırmızı ile işaretli terimler):

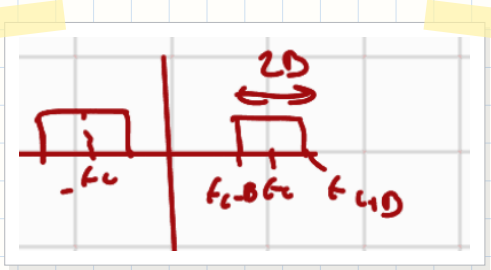
$$z(t) = \frac{1}{2}m(t) + \frac{2}{\pi}m(t)\cos(2\pi f_c t) +$$
$$+ \alpha_k\, m(t)\cos(2\pi k f_c t)\text{'li terimler} \quad (k = 3,5,7,\ldots)$$
$$+ \frac{c}{2}\cos(2\pi f_c t) + \underbrace{\frac{2c}{\pi}\cos^2(2\pi f_c t)}_{\frac{1}{2}[1+\cos(2\pi\, 2 f_c t)]}$$
$$+ \beta_m \cos(2\pi m f_c t)\text{'li terimler} \quad m:\ 2,4,6,\ldots$$

$$y(t) = \frac{c}{2}\cos(2\pi f_c t) + \frac{2}{\pi} m(t)\cos(2\pi f_c t)$$
$$= \underbrace{\frac{c}{2}}_{A_c}\left[1 + \underbrace{\boxed{\frac{4}{\pi c}}}_{\mu/m_p} m(t)\right]\cos(2\pi f_c t)$$

Lineer olmayan modülatör

(Non linear modulator. Power law modulator)





orijinal çizim, s. 1

$$x(t) = m(t) + c\cos(2\pi f_c t)$$
$$z(t) = a\,x(t) + b\,x^2(t) = a\,m(t) + a\,c\cos(2\pi f_c t)$$

orj. s. 2

$$+ b\left[m^2(t) + c^2 \underbrace{\cos^2(2\pi f_c t)}_{\frac{1}{2}[1+\cos(2\pi\, 2f_c t)]} + 2\,m(t)\,c\cos(2\pi f_c t)\right]$$
$$= a\,m(t) + a\,c\cos(2\pi f_c t) + b\,m^2(t) + \frac{b\,c^2}{2} + \frac{b\,c^2}{2}\cos(2\pi\, 2f_c t)$$
$$+ 2bc\,m(t)\cos(2\pi f_c t)$$

(Kırmızı gösterilen terimler el yazısında kırmızı okla/çizgiyle işaretlenmiş.)

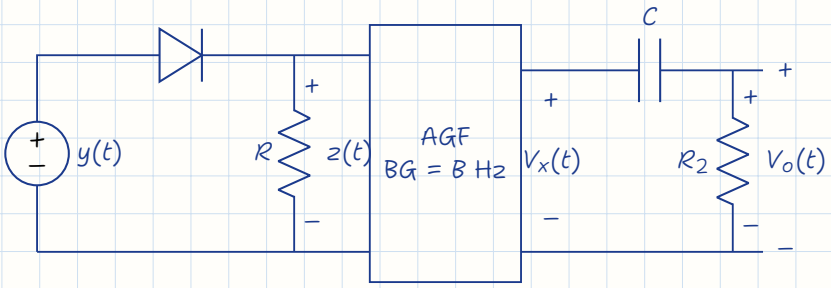
$$y(t) = a\,c\cos(2\pi f_c t) + 2bc\,m(t)\cos(2\pi f_c t)$$
$$= a\,c\left[1 + \frac{2b}{a} m(t)\right]\cos(2\pi f_c t)$$

BT - ÇYB - GM (DSB-LC-AM)

Demodülatörler:

$y(t) = A_c\left[1 + \mu\, m_n(t)\right]\cos(2\pi f_c t)$
Non coherent demodulation (Faz tahminsiz demodülasyon)

Doğrultucu Detektör (Rectifier detector)



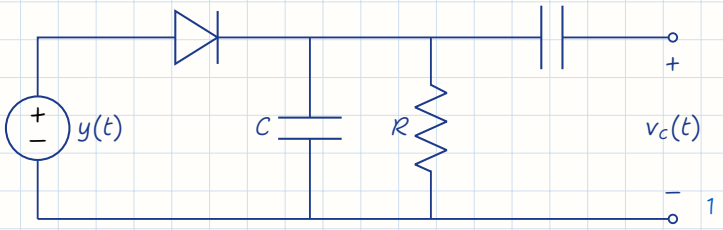
$z(t) = y(t)\,w(t)$

$$V_x(t) = \frac{A_c}{\pi}\left[1 + \mu m_n(t)\right]$$

$$V_o(t) = \frac{A_c\,\mu}{\pi}\,m_n(t)$$

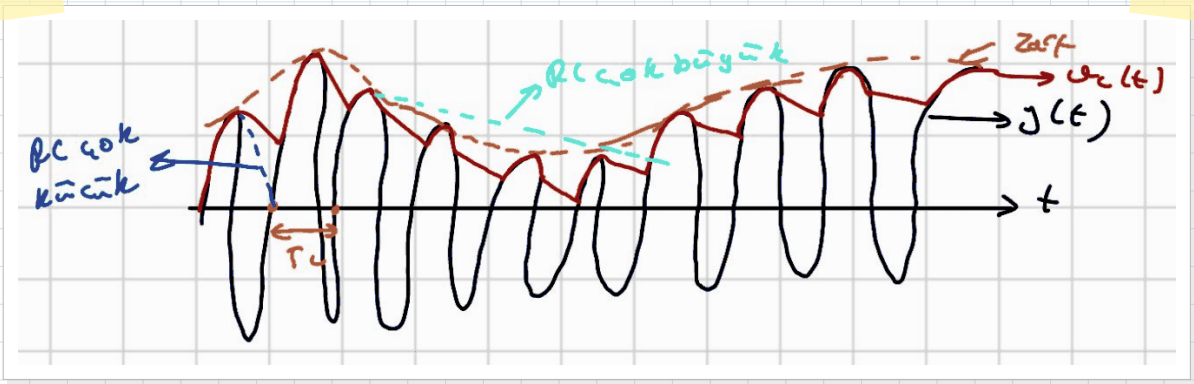
Zarf Detectörü

(Envelope detector)
$BG\{m(t)\} = B$ Hz , $f_c \gg B$



$y(t) = A_c\left[1 + \mu m_n(t)\right]\cos(2\pi f_c t)$

orj. s. 3



orijinal çizim, s. 3

$$\frac{1}{f_c} \ll RC \ll \underbrace{\frac{1}{B}}_{\text{mesajın zamandaki değişimi}}$$

[1] Çıkıştaki seri kondansatör el yazısında sonradan mavi kalemle eklenmiş.

$$v_c(t) = \alpha\left(\frac{A_c}{\pi}\left[1 + \mu m_n(t)\right]\right) + \text{yüksek frekanslı dalgacık (ripple)}$$
$$= \cancel{\alpha_1} + \alpha_2 m(t) + \text{Ripple}$$
$$\longrightarrow v_2(t) = \alpha_2 m(t) + \text{Ripple}$$

→ bundan kurtulmak için alçak geçirenden geçirebilirsin

$R_c \cong 40\,k\Omega$
$BG\{y(t)\} = 10\,kHz$

Bant genişliğini verimli kullanmak için

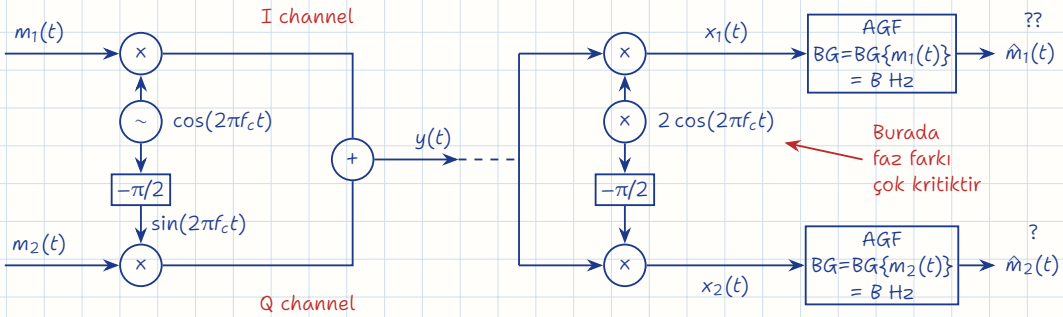
Quadrature Amplitude Modulation (QAM) / Dörtlü Genlik modülasyonu

Quadrature multiplexing (Çoklama)

$BG\{m_1(t)\} = BG\{m_2(t)\} = B\ Hz$

$$y(t) = m_1(t)\cos(2\pi f_c t) + m_2(t)\sin(2\pi f_c t)$$

orj. s. 4



$$x_1(t) = y(t)\,2\cos(2\pi f_c t)$$
$$= 2\left[m_1(t)\cos(2\pi f_c t) + m_2(t)\sin(2\pi f_c t)\right]\cos(2\pi f_c t)$$

$$\cos a \cdot \cos b = \frac{1}{2}\left[\cos(a-b) + \cos(a+b)\right]$$
$$\sin a \cdot \sin b = \frac{1}{2}\left[\cos(a-b) - \cos(a+b)\right]$$
$$\sin a \cos b = \frac{1}{2}\left[\sin(a-b) + \sin(a+b)\right]$$

$$x(t) = 2\,m_1(t)\underbrace{\cos^2(2\pi f_c t)}_{\frac{1}{2}[1+\cos(2\pi\,2 f_c t)]} + m_2(t)\left[0 + \sin(2\pi\,2 f_c t)\right]$$

$$x_1(t) = m_1(t) + \underbrace{m_1(t)\cos(2\pi\,2 f_c t)}_{\text{geçmez}} + \underbrace{m_2(t)\sin(2\pi\,2 f_c t)}_{\text{geçmez}}$$

$$z_1(t) = m_1(t)$$

$$x_2(t) = y(t) \cdot 2\sin(2\pi f_c t)$$
$$= \left[m_1(t)\cos(2\pi f_c t) + m_2(t)\sin(2\pi f_c t)\right] 2\sin(2\pi f_c t)$$
$$= m_1(t)\left[0 + \sin(2\pi\, 2f_c t)\right] + m_2(t)\left[\cos 0 - \cos(2\pi\, 2f_c t)\right]$$
$$= m_2(t) + m_1(t)\underbrace{\sin(2\pi\, 2f_c t)}_{0} - m_2(t)\underbrace{\cos(2\pi\, 2f_c t)}_{0}$$

$$z_2(t) = m_2(t)$$

⋆ $BG\{m_1(t)\} = B$ Hz
$BG\{m_2(t)\} = B$ Hz
ÇYB → $BG = 2B$ Hz

$$\frac{2B \text{ Hz}}{2 \text{ mesaj}} = B \text{ Hz/mesaj}$$

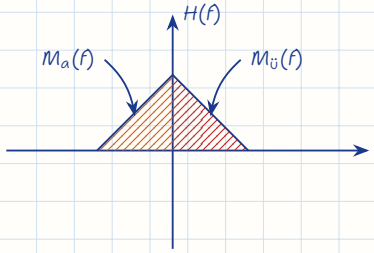
co channel

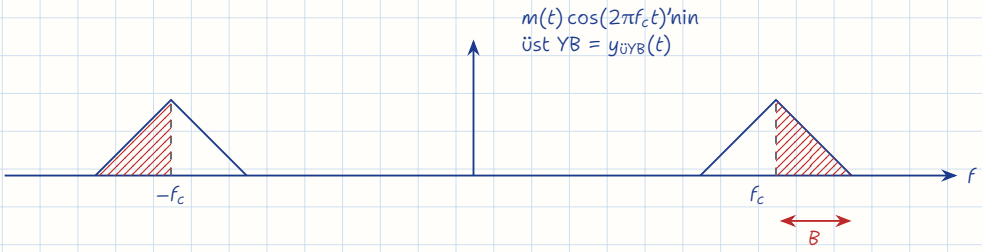
OFtm tekniği buradan geliyor: O → ortogonal, F → frequency, tm → tone modulation

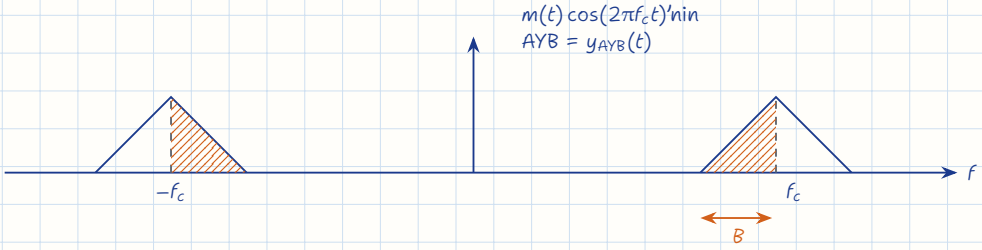
orj. s. 5

Tek yönlü Bandlı (TYB) GM

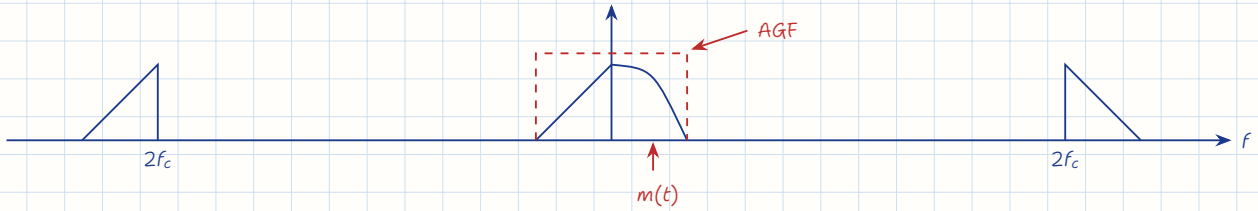
Single Sideband (SSB)-AM



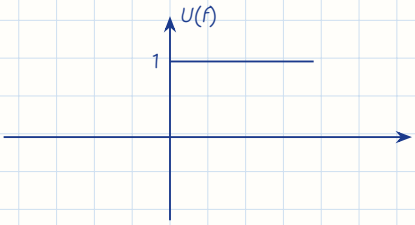




$$\mathcal{F}\{y_{üYB}(t)\cos(2\pi f_c t)\} = \frac{1}{2}\left[Y_{üYB}(f - f_c) + Y_{üYB}(f + f_c)\right]$$

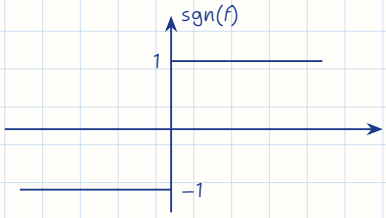


$$M_{ü}(f) = M(f)\,U(f)$$



$$M_a(f) = M(f)\,U(-f)$$

orj. s. 6



$$U(f) = \frac{1}{2}\left[1 + \operatorname{sgn}(f)\right]$$

$$\begin{aligned} M_{ü}(f) &= M(f)\,U(f) \\ &= M(f)\,\tfrac{1}{2}\left[1 + \operatorname{sgn}(f)\right] \\ M_{ü}(f) &= \tfrac{1}{2}M(f) + \tfrac{1}{2}M(f)\operatorname{sgn}(f) \\ &\quad\ \mathcal{F}^{-1}\big\downarrow \\ m_{ü}(t) &= \tfrac{1}{2}m(t) + \tfrac{1}{2}\underbrace{\mathcal{F}^{-1}\left\{M(f)\operatorname{sgn}(f)\right\}}_{m(t) * \mathcal{F}^{-1}\{\operatorname{sgn}(f)\}} \end{aligned}$$

$$x(t) = \operatorname{sgn}(t) \longleftrightarrow \frac{1}{j\pi f} = X(f)$$

$$X(t) = \frac{1}{j\pi t} \longleftrightarrow \operatorname{sgn}(-f) = x(-f) = -\operatorname{sgn}(f)$$

$$\frac{-1}{j\pi t} \longleftrightarrow \operatorname{sgn}(f)$$

$$\mathcal{F}^{-1}\left\{\operatorname{sgn}(f)\right\} = \frac{-1}{j\pi t} = \frac{j}{\pi t}$$

$$m_{ü}(t) = \frac{1}{2}\left[m(t) + m(t) * \frac{j}{\pi t}\right]$$
$$= \frac{1}{2}\left[m(t) + j \underbrace{\left(m(t) * \frac{1}{\pi t}\right)}_{=m_h(t)} \right]$$

$m(t)$'nin Hilbert dönüşümü

$$m_{ü}(t) = \frac{1}{2}\left[m(t) + j m_h(t)\right]$$

$$M_a(f) = M(f)\,U(-f)$$
$$= M(f)\,\frac{1}{2}\left[1 - \operatorname{sgn}(f)\right]$$
$$= \frac{1}{2}\left[M(f) - M(f)\operatorname{sgn}(f)\right]$$

orj. s. 7

$$\mathcal{F}^{-1}\downarrow \qquad m_a(t) = \frac{1}{2}\left[m(t) - j m_h(t)\right]$$

$$Y_{ÜYB}(f) = M_{ü}(f - f_c) + M_a(f + f_c)$$
$$\mathcal{F}^{-1}\downarrow$$
$$y_{ÜYB}(t) = m_{ü}(t)\,e^{j2\pi f_c t} + m_a(t)\,e^{-j2\pi f_c t}$$
$$= \frac{1}{2}\left[m(t) + j m_h(t)\right]e^{j2\pi f_c t}$$
$$+ \frac{1}{2}\left[m(t) - j m_h(t)\right]e^{-j2\pi f_c t}$$

$$y_{ÜYB}(t) = m(t)\cos(2\pi f_c t)$$
$$+ m_h(t)\underbrace{\left[\frac{j e^{j2\pi f_c t} - j e^{-j2\pi f_c t}}{2}\right]}$$
$$\underbrace{j \cdot j}_{=-1}\underbrace{\left[\frac{e^{j2\pi f_c t} - e^{-j2\pi f_c t}}{2j}\right]}_{\sin(2\pi f_c t)}$$

$$y_{ÜYB}(t) = m(t)\cos(2\pi f_c t) - m_h(t)\sin(2\pi f_c t)$$

$$y_{ÜYB}(t) = m(t)\cos(2\pi f_c t) - m_h(t)\sin(2\pi f_c t)$$

$$Y_{AYB}(f) = M_a(f - f_c) + M_{ü}(f + f_c)$$
$$y_{AYB}(t) = \underbrace{m_a(t)}_{\frac{1}{2}[m(t) - j m_h(t)]}\,e^{j2\pi f_c t} + \underbrace{m_{ü}(t)}_{\frac{1}{2}[m(t) + j m_h(t)]}\,e^{-j2\pi f_c t}$$

$$y_{TYB}(t) = m(t)\cos(2\pi f_c t) \overset{\text{ÜYB}}{\underset{\text{AYB}}{\mp}} m_h(t)\sin(2\pi f_c t)$$

orj. s. 8

hilbert dönüşümü mesaj işaretine 90° ? okunamadı