OSK - auditorne vol-1

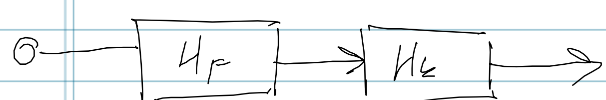
4 zadatka iz skripte za auditorne vježbe.

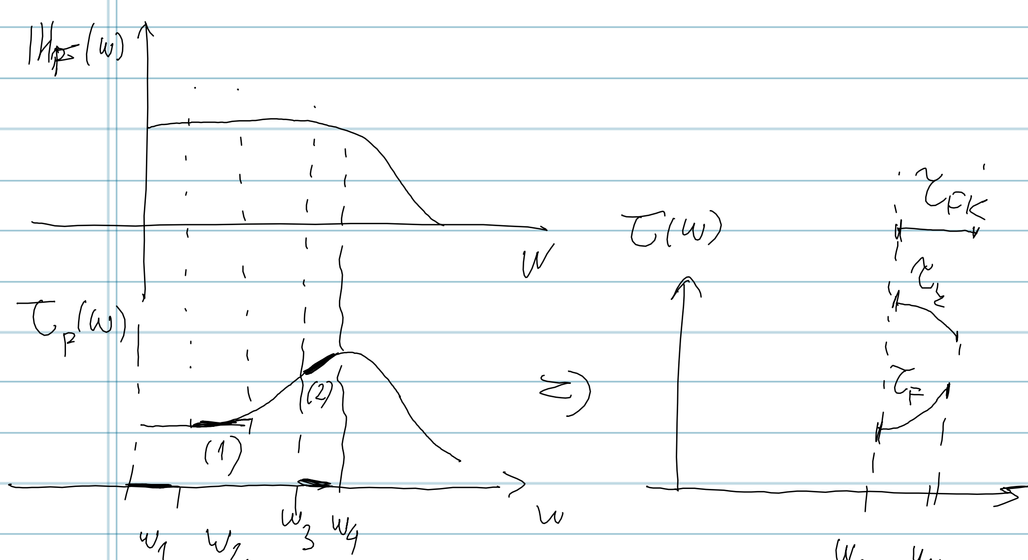
① Lin. izobličenja

$$H_F(s) = \frac{10}{s^2+2s+10}$$ N.P. filtar 2. reda

$$H_k(s) = \frac{s-2}{s+2}$$

Fazni korektor je svepropusni filtar koji korigira fazu zadanog filtra u danom frekv. području.





u (2) gledamo

U području (1) nije potrebna korekcija, dok u (2) je potrebna.

a) Polovi filtra (Sustavi se mogu • Z - P - K
opisati/modelirati nule - polovi - pojačanje
• ~~polovima~~ i nultočkama u polinomima
• varijablama stanja - matrice A B C D ?)

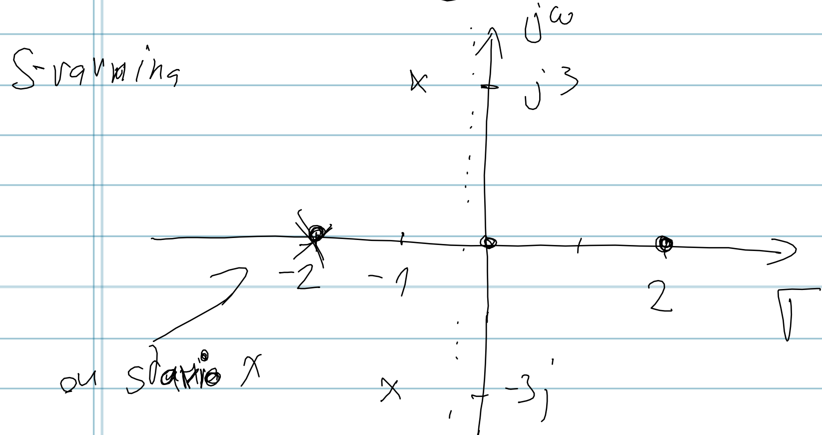
$s^2 + 2s + 10 = \phi$

Polovi filtra $p_{F1,2} = -1 \pm 3j$

polovi korektora
$s + 2 = \phi \Rightarrow p_K = -2$

Nule korektora
$z_k = 2$

S-ravnina



$s = j\omega \Rightarrow$ frekvencijska karakteristika

b) grupno kašnjenje – prvo podijeme faktorizacija!

$$H_{FK}(w) = \frac{10}{(s+1+3j)(s+1-3j)} \cdot \frac{s-2}{s+2} \quad !$$

$\boxed{s = jw}$

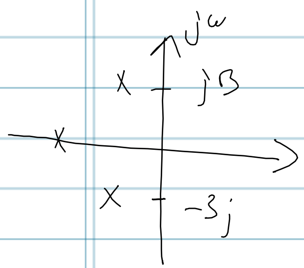
$$H_{FK}(w) = \frac{10}{(1+j(w+3))(1+j(w-3))} \cdot \frac{-2+jw}{2+jw}$$

Faza je:
$$\varphi_{FK}(w) = \underbrace{-\operatorname{arctg}(w+3) - \operatorname{arctg}(w-3)}_{\text{faza filtra } (\varphi_F(w))} \underbrace{-2\operatorname{arctg}\left(\frac{w}{2}\right)}_{\text{faza korektora } (\varphi_K(w))}$$

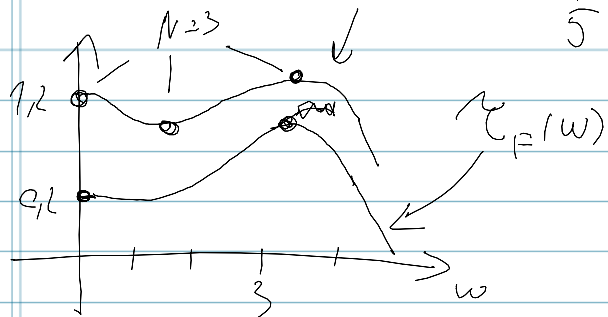
$$\tau_{FK}(w) = -\frac{d\varphi_{FK}(w)}{dw} \qquad \left\{ (\operatorname{arctg}(x))' = \frac{1}{1+x^2} \right.$$

$$\tau_{FK}(w) = \underbrace{\frac{1}{1+(w+3)^2} + \frac{1}{1+(w-3)^2}}_{\tau_F(w)} + \underbrace{\frac{4}{4+w^2}}_{\tau_K(w)}$$

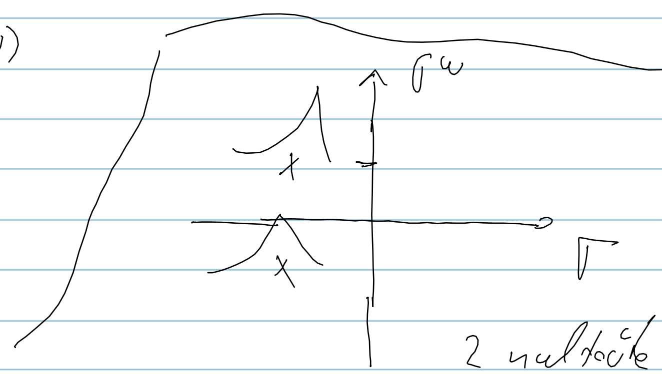
Koji ω uzeti? – očitavanjem iz polova



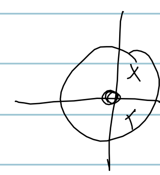
ω	$\tau_F(\omega)$	$\tau_{FK}(\omega)$
0	0,2	1,2
1	0,3	1,1
2	0,5	1
3	~~0,5~~ 1	1,3
4	0,5	0,7
5	0,2	0,4



cca



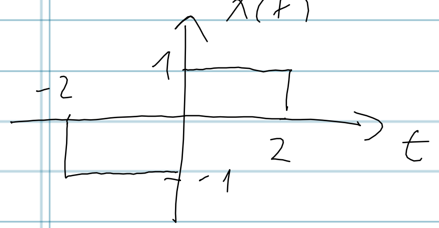
2 nultočke u ∞



2 nultočke u 0

U većini slučajeva se iz krivulje grupnog kašnjenja (amplitude) može izravno očitati red sustava. To je broj svih lokalnih ekstrema.

② Analitički signal



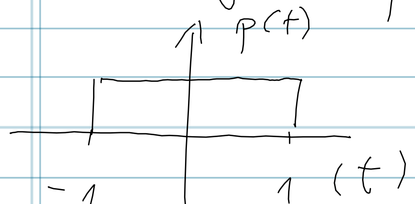
ovo treba biti veliko slovo

$$z(t) = x(t) + j\,\hat{x}(t)$$

↳ hilbertova transformacija $x(t)$-a

$$\hat{x}(t) = \mathcal{H}[x(t)] = x(t) * \frac{1}{\pi t}$$

Uvodimo novi signal: (jednoznačno definiran)



$$x(t) = p(t-1) - p(t+1)$$

H. trans. je linearan operator pa je:

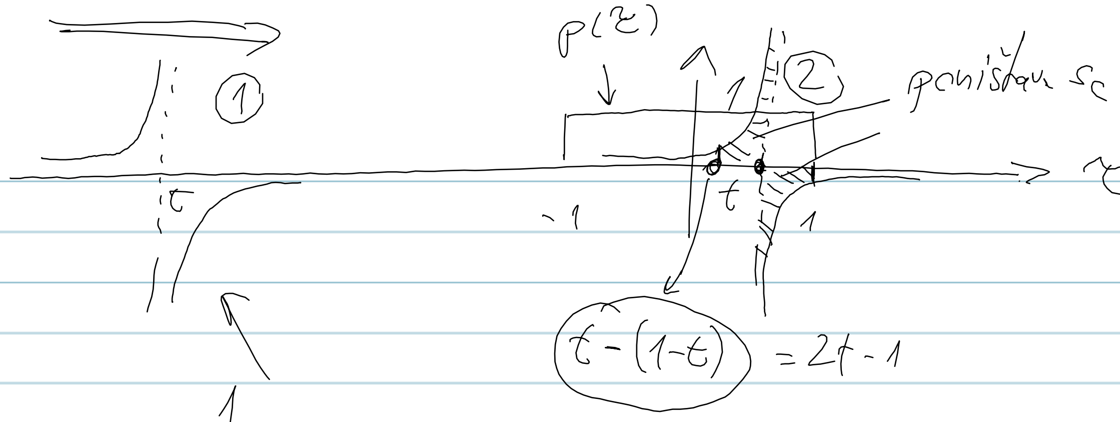
$$\hat{x}(t) = \hat{p}(t-1) - \hat{p}(t+1) \Rightarrow \hat{p}(t) = ?$$

Računanje H.t.: 1) računanje H. integrala (direktno)

2) (neizravno) prebacivanjem u freq domenu, potom računanjem inverzne F. transformacije

1) idemo ovim načinom

$$\hat{p}(t) = \frac{1}{\pi}\, p.v. \int_{-\infty}^{\infty} \frac{p(t)}{t-\tau}\, d\tau$$



p.v. integral s lijeva pa s desna

1) $t \le -1, \; t \ge 1$

$$\hat{p}(t) = \frac{1}{\pi} \cdot \int_{-1}^{1} \frac{1}{t-\tau}\, d\tau = -\frac{1}{\pi} \ln|\tau - t| \Big|_{\tau=-1}^{1} = \frac{1}{\pi} \ln\left(\frac{t+1}{t-1}\right)$$

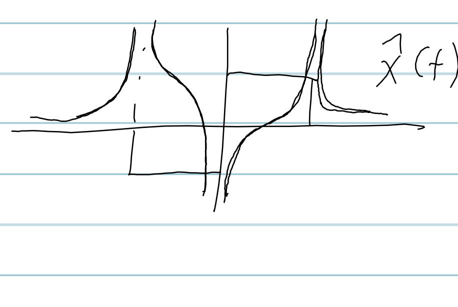
$-(\tau - t)$

2) $-1 \le t \le 1$

$$\hat{p}(t) = \frac{1}{\pi} \int_{-1}^{2t-1} \frac{d\tau}{t-\tau} = \dots = \frac{1}{\pi} \ln\left|\frac{t+1}{t-1}\right|$$

SLUČAJNO JE ISTO !!

$$\hat{x}(t) = \frac{1}{\pi} \ln\left|\frac{t}{t-2}\right| - \frac{1}{\pi} \ln\left|\frac{t+2}{t}\right| = \frac{1}{\pi} \ln\left|\frac{t^2}{t^2-4}\right|$$



$Z(\omega) = ?$ $\quad Z(\omega) = \begin{cases} \phi, & \omega < \phi \\ X(\omega), & \omega = \phi \\ 2X(\omega), & \omega > \phi \end{cases}$

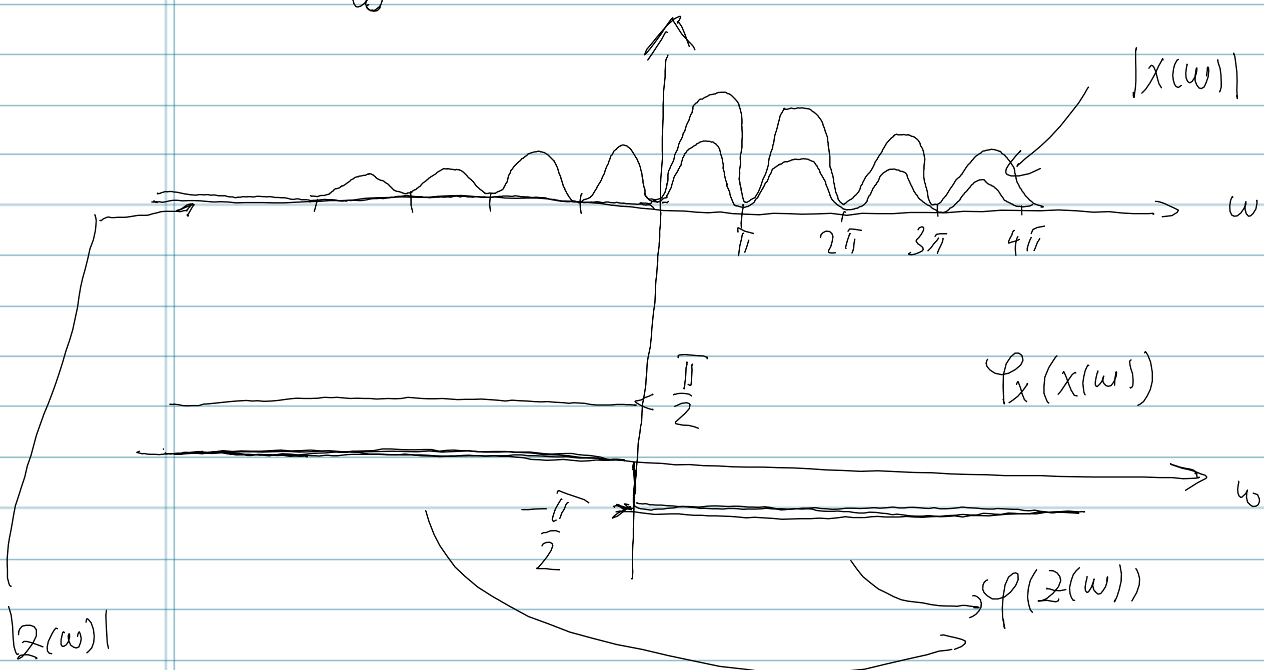
čvo je uvijek $\leq \phi$

$$X(\omega) = \int_{-\infty}^{\infty} x(t) \cdot e^{-j\omega t}\, dt = -j2 \int_{\phi}^{2} 1 \cdot \sin(\omega t)\, dt = j2 \left(\frac{\cos(2\omega) - 1}{\omega} \right)$$

$x(t) \rightarrow$ NEPARNA

svodimo da bude pozitivni

$$= -j2 \cdot \frac{1 - \cos(2\omega)}{\omega} = 2 \cdot \frac{1 - \cos(2\omega)}{\omega} \cdot e^{-j\frac{\pi}{2}}$$



③ SSB - AM

$$u_m(t) = \frac{\omega_g}{\pi} \operatorname{sinc}(\omega_g t)$$

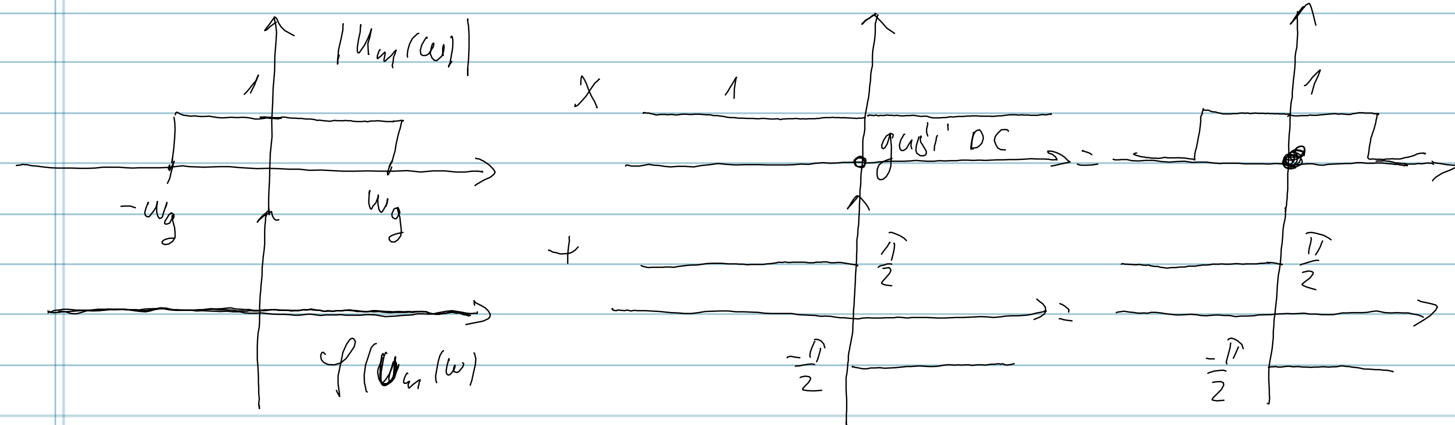
$$u_{SSB}(t) = u_m(t) \cdot \cos(\omega_0 t) \pm \hat{u}_m(t) \cdot \sin(\omega_0 t)$$

+ LSB
− USB

$$\hat{u}_m(t) = u_m(t) * \frac{1}{\pi t}$$

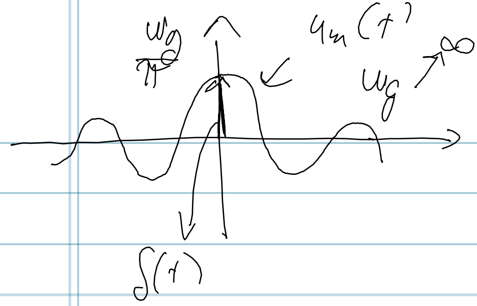
$$\hat{U}_m(\omega) = U_m(\omega) \cdot \underbrace{H_{HT}(\omega)}_{= -j \cdot \operatorname{sgn}(\omega)}$$

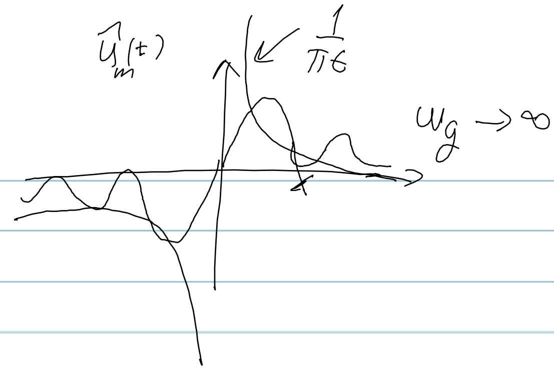
(ovo ne izvamo 2)



$$\hat{u}_m(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} \hat{U}_m(\omega) e^{j\omega t} d\omega = \frac{1}{2\pi} \left\{ \int_{-\omega_g}^{0} 1 \cdot \underbrace{e^{j\frac{\pi}{2}}}_{j} \cdot e^{j\omega t} dt + \int_{0}^{\omega_g} 1 \cdot \underbrace{e^{-j\frac{\pi}{2}}}_{-j} \cdot e^{j\omega t} dt \right.$$

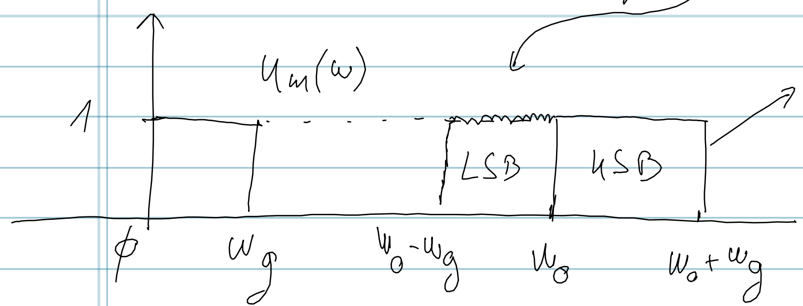
$$= \left[\int e^{j\omega t} d\omega = \frac{e^{j\omega t}}{jt} \right] = \frac{1}{2\pi} \cdot \frac{1 - e^{-j\omega_g t} - e^{j\omega_g t} + 1}{t} = \frac{1 - \cos(\omega_g t)}{\pi t}$$





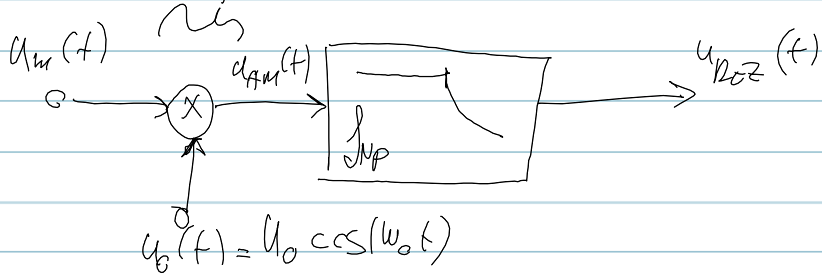
$$u_{USB}(t) = \frac{\omega_g}{\pi}\, sinc(\omega_g t)\cos(\omega_0 t) \underset{+}{-} \frac{1-\cos(\omega_g t)}{\pi t}\sin(\omega_0 t)$$

Opet idemo u frekvencijsko područje



$$e_{USB}\,[\text{ENERGIJA}] = \frac{1}{2\pi}\int_{-\infty}^{\infty} |U_{USB}(\omega)|^2 d\omega = \frac{1}{2\pi}\cdot 2\cdot 1^2\cdot \omega_g = \frac{\omega_g}{\pi}$$

(4) DSB-SC-AM



$f_{NP} = 3,4\, kHz$

$u_m(t)$: $f_d = 200\, Hz$

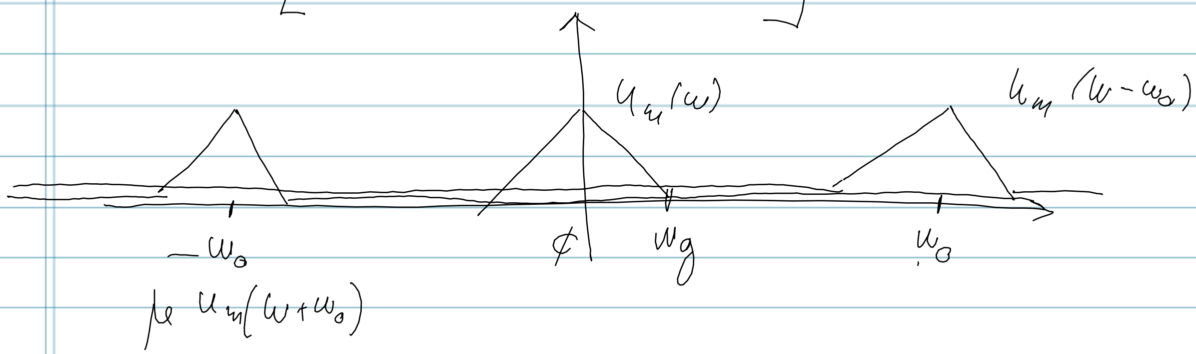
$f_g = 3,4\, kHz$

$f_0 = 3,6\, kHz$

$$u_{AM}(t) = u_m(t) \cdot u_0(t) \circ\!\!-\!\!\bullet\ U_{AM}(\omega) = \frac{1}{2\pi} U_m(\omega) * U_0(\omega)$$

izvod na predavanjima (4.2) ← zbog ω i f

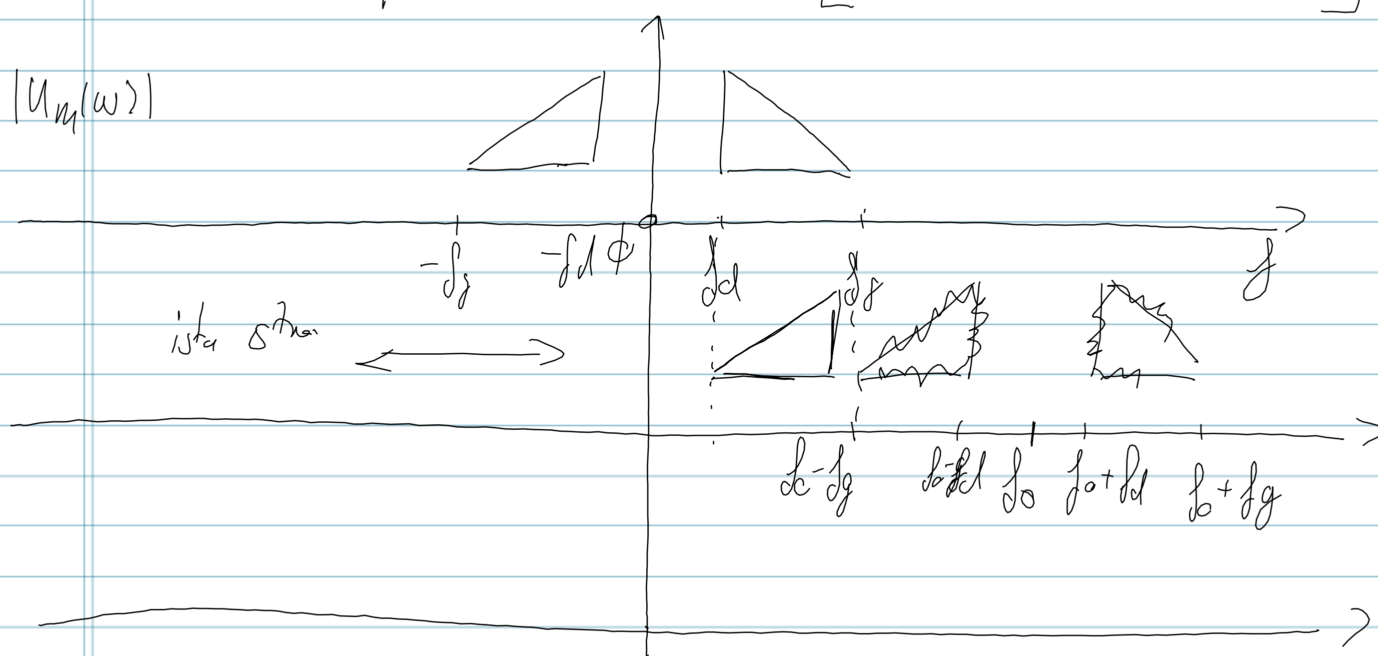
$$U_{AM}(\omega) = \frac{U_0}{2}\left[U_m(\omega+\omega_0) + U_m(\omega-\omega_0)\right]$$



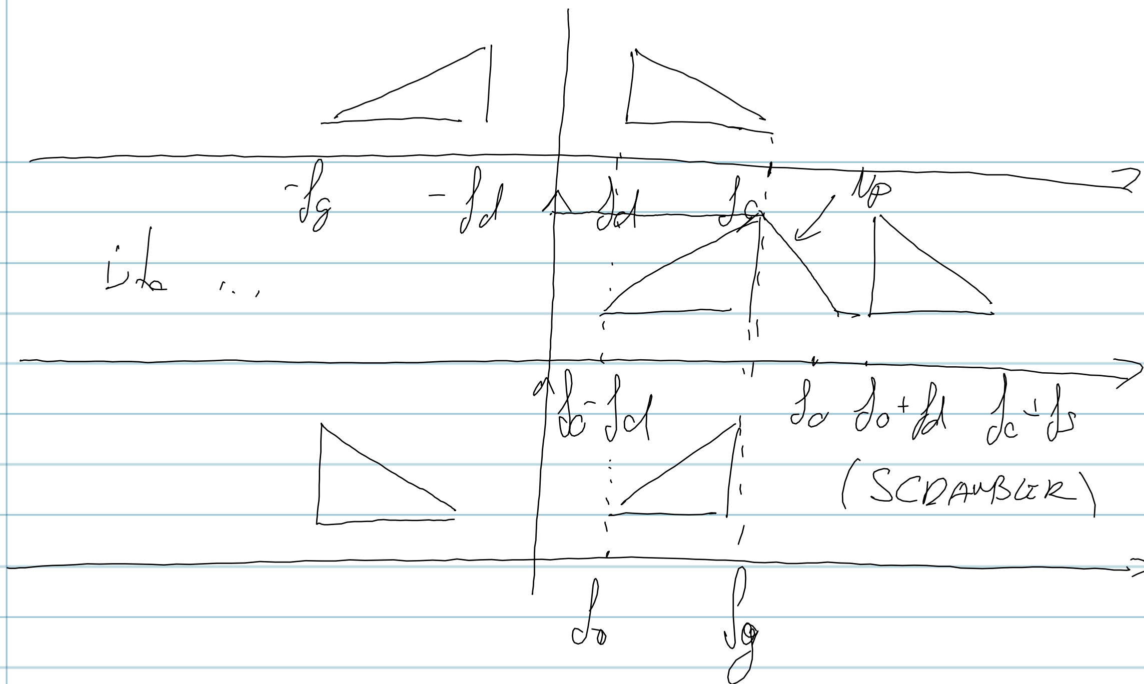
$|U_{AM}(\omega)| = ?$

Za $\omega_0 > \omega_g$ vrijedi $|U_{AM}(\omega)| = \frac{U_0}{2}\left[|U_m(\omega+\omega_0)| + |U_m(\omega-\omega_0)|\right]$

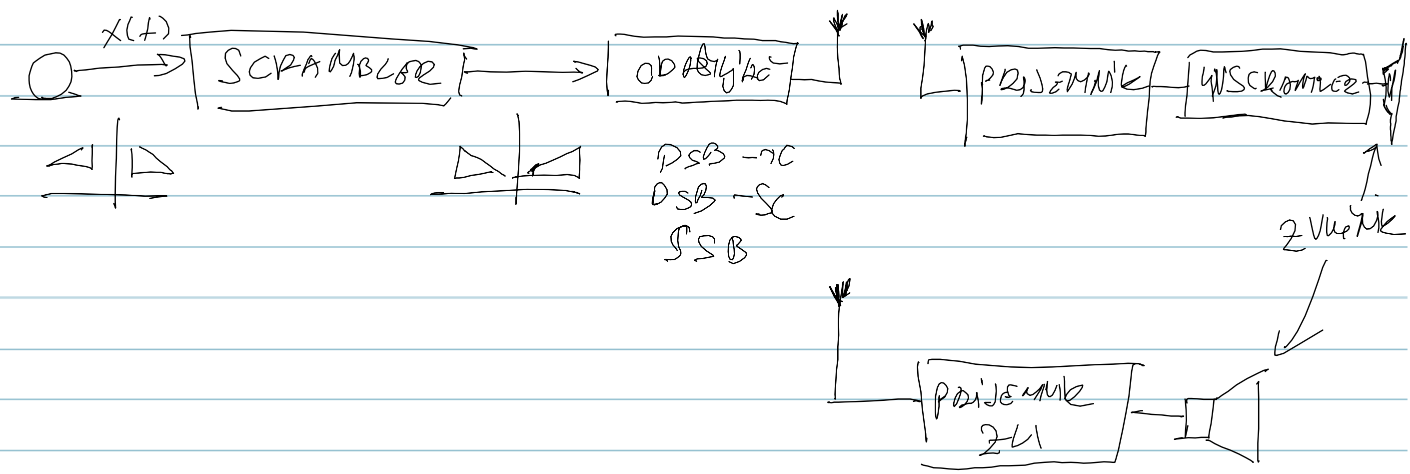
$|U_m(\omega)|$



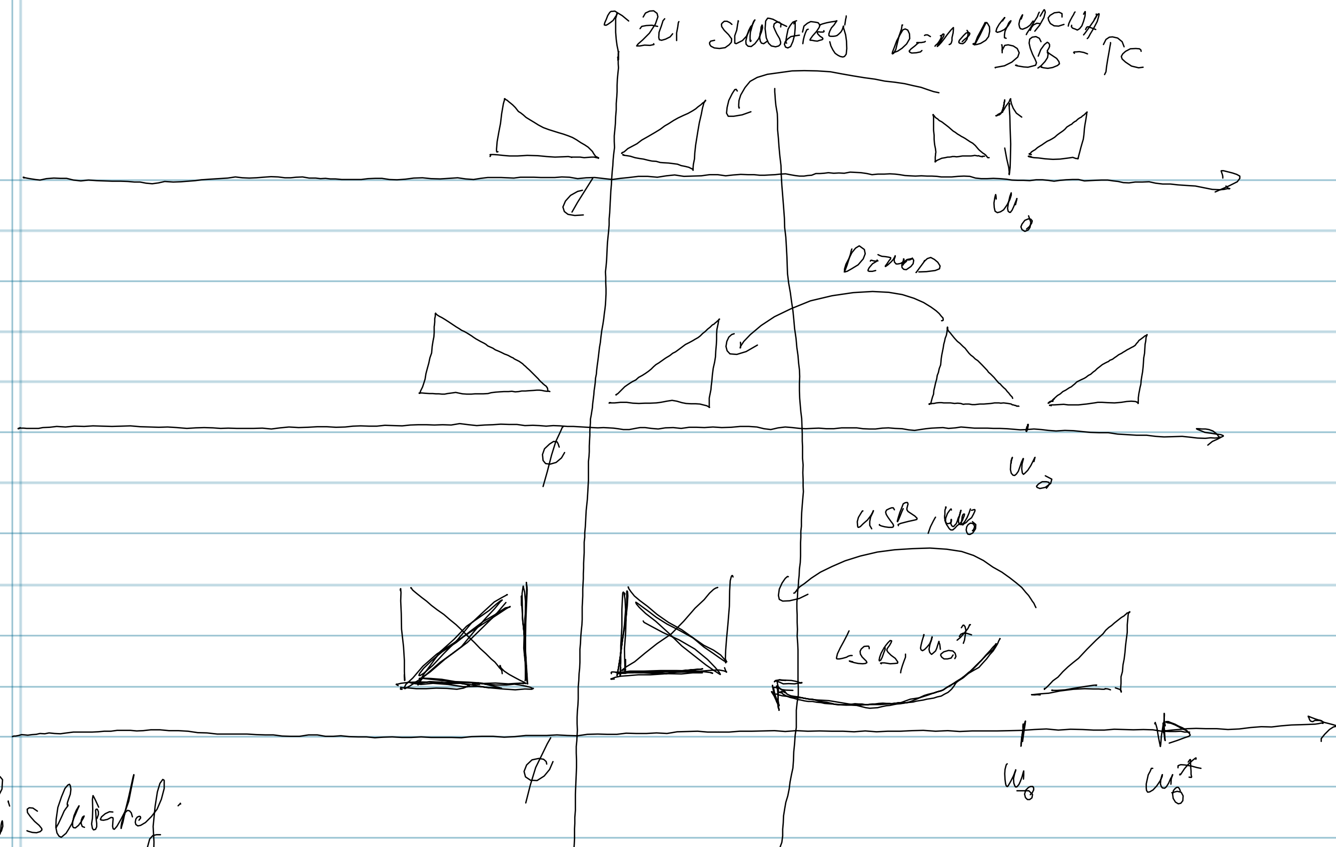
idem ponovo zato sam usporio



Pretpostavimo da je ovaj sklop postavljen na ulaz odašiljača, te na izlaz prijemnika koji podržava sva 3 tipa amp. modulacije.
U kojem slučaju opisani sklop ne osigurava šifriranje signala i zašto?



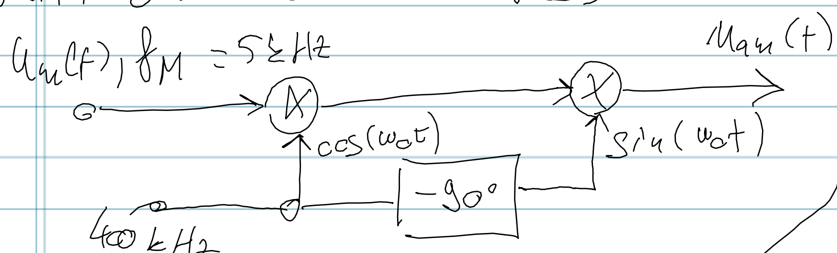
Opet imamo 3 slučaja ⇒ sljedeća str.

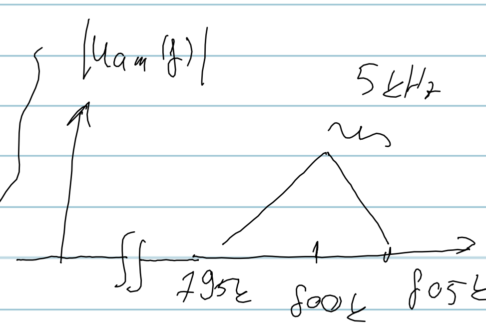


Ako zli slučaj:

√ ω_0^* postavi (prijemnika) tc postavi prima LSB kanala, tada opisani sklop ne osigurava dešifriranje jer prilikom demodulacije dolazi izvorni govorni signal.

(5) Jedan brzi zadatak ... DSB-SC-AM





f_M je granična frekv.

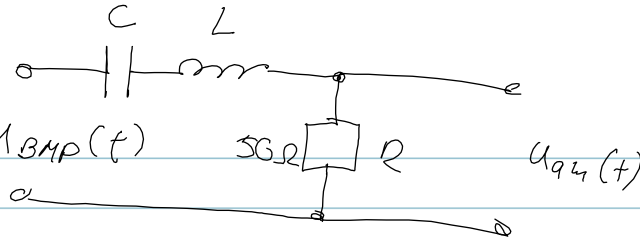
$$u_{AM}(t) = u_m(t) \cdot \cos(\omega_0 t) \cdot \sin(\omega_0 t) = \frac{1}{2} u_m(t) \sin(2\omega_0 t)$$

Ovo je DSB-SC-AM na frekvenciji $2f_0$ i sad slika

OSK, a vol. 2.

(6) $f_g = 5\,kHz$

$f_0 = 400\,kHz$



$A_p = 0{,}05\,dB \rightarrow 5\%$ $(\cdot 10)$

$L, C = ?$

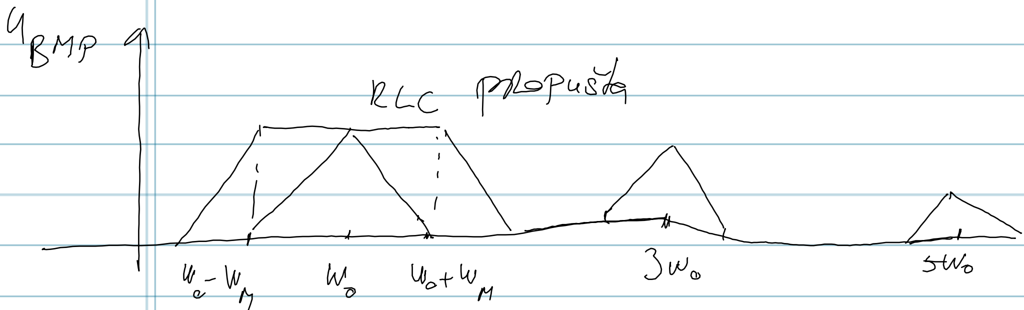
$A_s = ?$

$$u_{BMP}(t) = u_m(t) \cdot Sgn\left(U_0 \cos(\omega_0 t)\right)$$

$$= u_m(t) \cdot square(\omega_0 t)$$

$$= \frac{4}{\pi}\left[\underbrace{u_m(t)\cos(\omega_0 t)}_{\text{DSB-SC-AM}} - \frac{1}{3}u_m(t)\cos(3\omega_0 t) + \frac{1}{5}u_m(t)\cos(5\omega_0 t) \ldots\right]$$

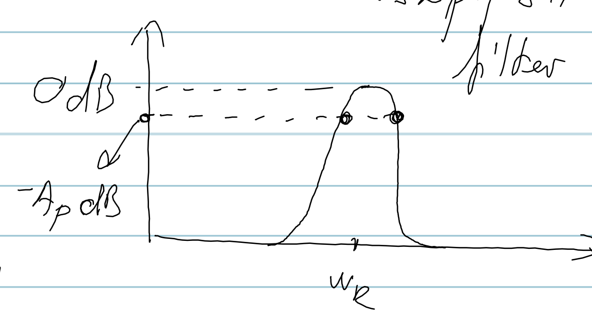
SPEKTAR



$$H(\omega) = \frac{R}{R + j\underbrace{\left(\omega L - \frac{1}{\omega C}\right)}_{0}}$$

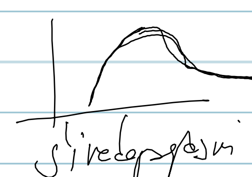
$$0 \Rightarrow \underbrace{\omega_R = \frac{1}{\sqrt{LC}} = \omega_0}$$

uskopojasni filter



$$C = \frac{1}{4\pi^2 f_0^2 L} \Rightarrow ?$$

uskopojasni $\rightarrow$ simetrične



$$20\log\left|H(\underbrace{f_0 - f_M}_{f_1 = 400 - 5 = 395\,kHz})\right| \geq -A_p$$

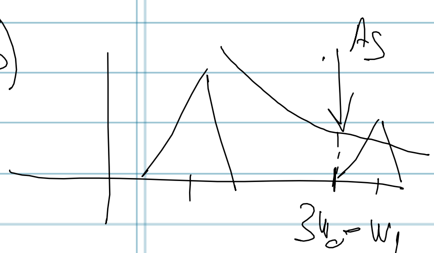
$$\frac{R}{\sqrt{R^2+\left(\omega_1 L-\frac{1}{\omega_1 C}\right)^2}} = 10^{-\frac{A_P}{20}} \quad \Big/^{2}$$

$$\left(\omega_1 L - \frac{1}{\omega_1 C}\right)^2 = R^2\left(10^{\frac{A_P}{10}}-1\right) \quad \Big/\sqrt{}$$

$$L\cdot\left|\omega_1 - \underbrace{\frac{1}{\omega_1 LC}}_{\frac{\omega_0^2}{\omega_1}=2\pi\frac{f_0^2}{f_1}}\right| = R\sqrt{\left(10^{\frac{A_P}{10}}-1\right)}$$

$$L=\frac{R\cdot\sqrt{10^{\frac{A_P}{10}}-1}}{2\pi\left|f_1-\frac{f_0^2}{f_1}\right|} = \underline{\underline{85\ \mu H}} \Rightarrow C = \underline{\underline{1{,}8\ nF}}$$

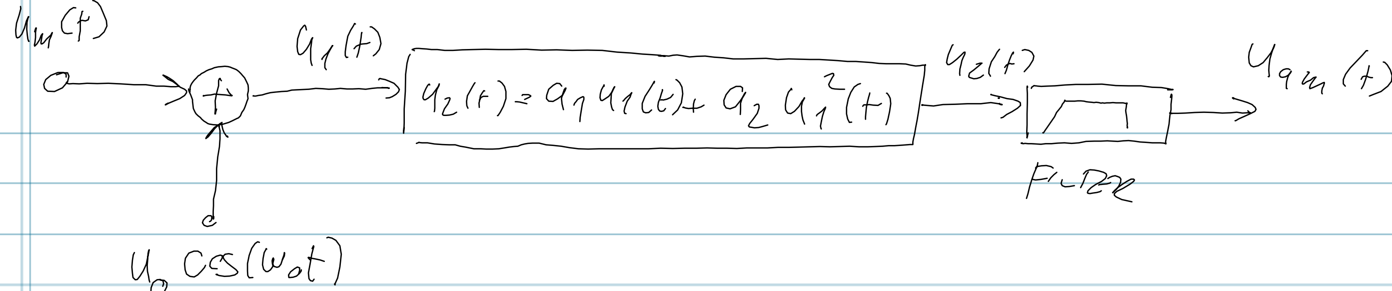
b)



$$A_S = -20\log\left|\frac{1}{3}H(\underbrace{3f_0-f_1}_{1195k})\right| = \underline{\underline{30{,}2\ dB}}$$

20log gubitak

7

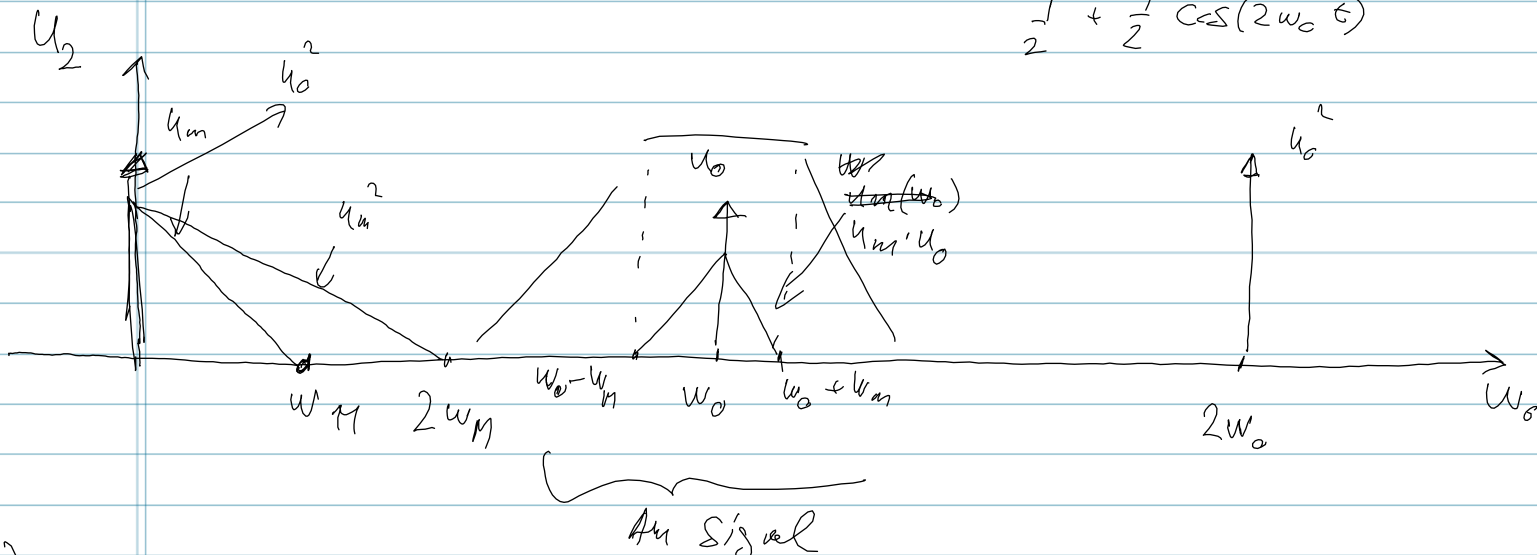


a) $u_1(t) = u_m(t) + u_0 \cos(\omega_0 t)$

$$u_2(t) = a_1 u_m(t) + \underbrace{a_1 U_0 \cos(\omega_0 t)} + a_2 \cdot u_m^2(t) + \underbrace{2 a_2 U_0 u_m(t) \cdot \cos(\omega_0 t)}$$

$$+ a_2 \cdot u_0^2 \cdot \cos^2(\omega_0 t)$$

$$\frac{1}{2} + \frac{1}{2}\cos(2\omega_0 t)$$



b) BPF $[\omega_0 - \omega_m, \omega_0 + \omega_m]$

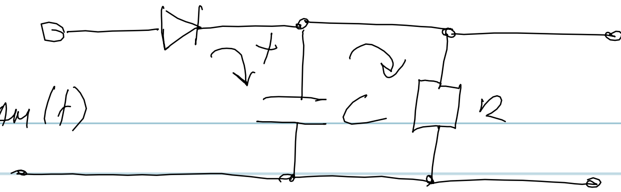
c) $u_{am}(t) = ? = a_1 u_0 \cos(\omega_0 t) + 2 a_2 U_0 \cdot u_m(t) \cdot \cos(\omega_0 t)$

d) $u_{am}(t) = [U_{0,AM} + K_a \cdot u_m(t)] \cdot \cos(\omega_0 t)$

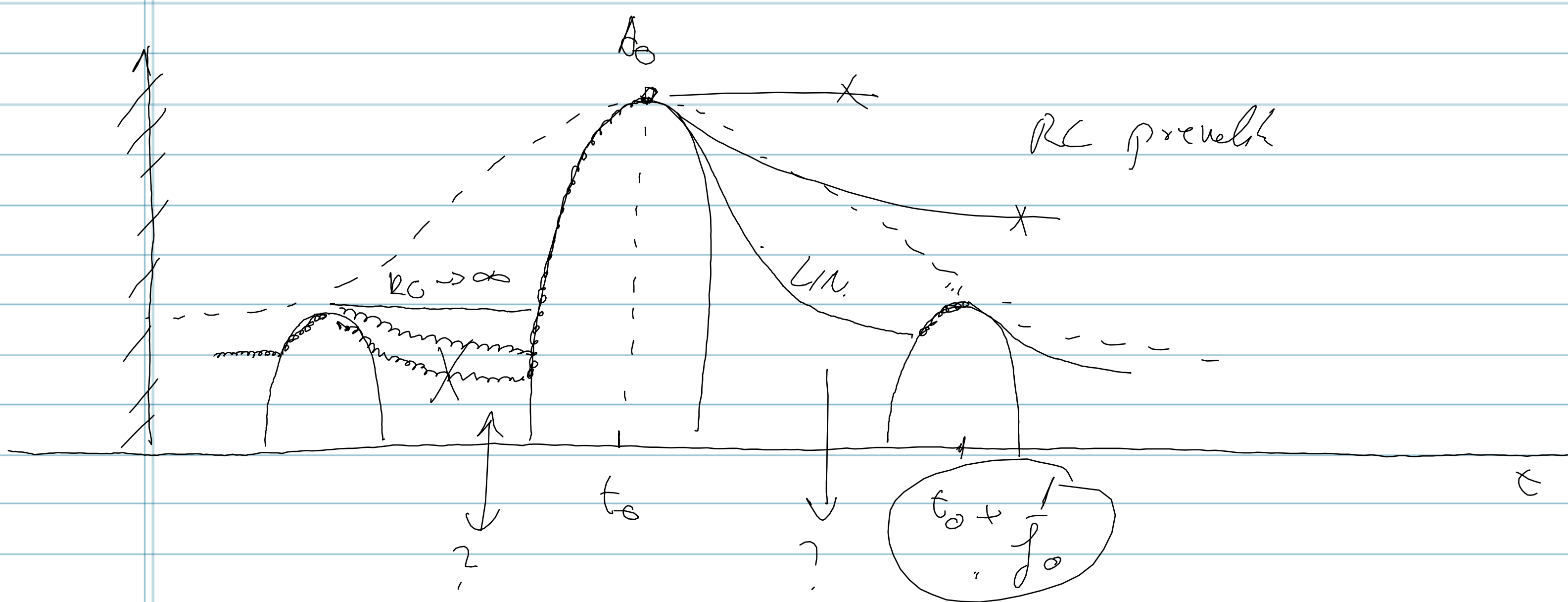
$U_{0,AM} = ? = a_1 \cdot U_0$

$K_a = 2 a_2 \cdot U_0$

(8) Detektor anvelope (DSB-TC-AM)



C – se uvijek izbija preko R
– tijekom pozitivne poluperiode od $u_{AM}(t)$ → NABIJA



• Iz trenutka kada anvelopa raste možemo odrediti donju ogradu za RC
t_0 je $RC \gg \frac{1}{\omega_0}$

• Iz trenutka kada pada (drugi ?) možemo odrediti gornju ogradu za RC.

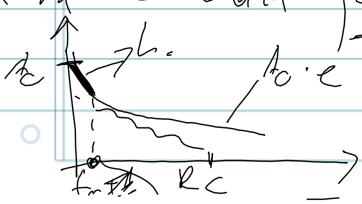
$u_{AM}(t)$ je zadan u zadatku $= (U_0 + k_a u_m(t))\cos(\omega_0 t) = U_0(1 + m\cos(\omega_m t))\cos(\omega_0 t)$

$u_m(t) = U_a \cos(\omega_m t)$

iz toga

Pretpostavimo da se kondenzator izbija od max vrijednosti $A_0 = U_0(1 + m\cos(\omega_m t_0))$

Napon na RC člana je $e^{-\frac{t}{RC}}$ $\quad U_{ADM}(t) = A_0 \cdot e^{-\frac{(t-t_0)}{RC}}$



$t_0 + \frac{1}{f_0}$

L_1 je linearni dio

$e^x \approx 1 + x$ za x jako mali

Za $RC >> \omega_0$ vrijedi aproksimacija:

$$u_{ADM}(t) \approx A_0 \left(1 - \frac{t - t_0}{RC}\right)$$

Napon na kondenzatoru ne smije prijeći maksimum u sljedećoj ~~polo~~ poluperiodi.

$$u_{ADM}\left(t_0 + \frac{1}{f_0}\right) \leq U_0 \cdot \left(1 + m \cdot \cos\left(\omega_m \left(t_0 + \frac{1}{f_0}\right)\right)\right)$$

$$\underbrace{\cancel{U_0}(1 + m\cos(\omega_m t_0))}_{A_0} \cdot \left(1 - \frac{1}{RC f_0}\right) \leq \cancel{U_0}\left[1 + \underbrace{m\cos\left(\omega_m t_0 + \frac{\omega_m}{f_0}\right)}\right]$$

$$= m \cdot \cos(\omega_m t_0) \underbrace{\cos\left(\frac{\omega_m}{f_0}\right)}_{\approx 1} - m \sin(\omega_m t_0) \underbrace{\sin\left(\frac{\omega_m}{f_0}\right)}_{\approx \frac{\omega_m}{f_0}}$$

Za $\omega_m << \omega_0$ vrijedi $\longrightarrow$

$$\cancel{1} + \cancel{m\cos(\omega_m t_0)} - \frac{1}{RC\cancel{f_0}}(1 + m\cos(\omega_m t_0)) \leq \cancel{1} + \cancel{m \cdot \cos(\omega_m t_0)} - \frac{m\,\omega_m}{\cancel{f_0}} \sin(\omega_m t_0) \quad / \cdot (-)$$

$$\frac{1}{RC} + \frac{m}{RC}\cos(\omega_m t_0) \geq m \cdot \omega_m \cdot \sin(\omega_m t_0)$$

$$\frac{1}{RC} \geq m \underbrace{\left(\omega_m \sin(\omega_m t_0) - \frac{1}{RC}\cos(\omega_m t_0)\right)}_{\leq \sqrt{\omega_m^2 + \left(\frac{1}{RC}\right)^2}}$$

$$\boxed{a \sin\varphi + b\cos\varphi \leq \sqrt{a^2 + b^2}}$$

Najgori slučaj kad je to $=$ $\Rightarrow \frac{1}{RC} \geq m\sqrt{\omega_m^2 + \left(\frac{1}{RC}\right)^2} \quad /\ ^2 \Rightarrow$

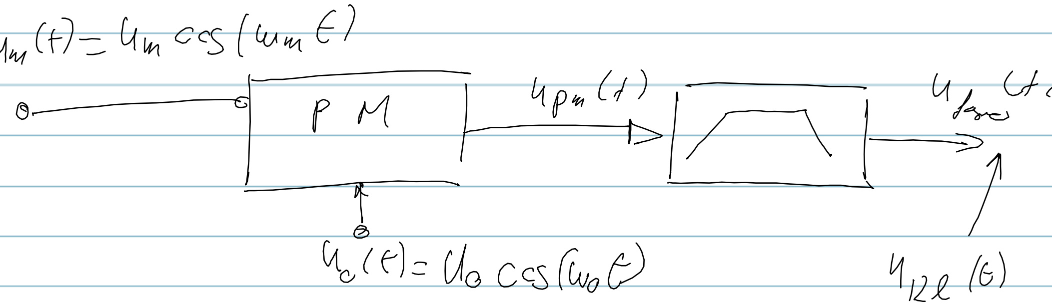
$$\boxed{RC \le \frac{1}{\omega_m}\,\frac{\sqrt{1-m^2}}{m}} \qquad \text{da je } RC \gg \frac{1}{\omega_0}$$

Pr. $f_m = 3\ kHz$, $f_0 = 1\ MHz$, $m = 0{,}9$

$$RC \gg 1{,}6\cdot 10^{-7}\ s \quad , \quad RC \le 2{,}6\cdot 10^{-5}\ s$$

LCL

9) Ludilo



$U_0 = 1{,}5\ V$

$f_0 = 1\ MHz$

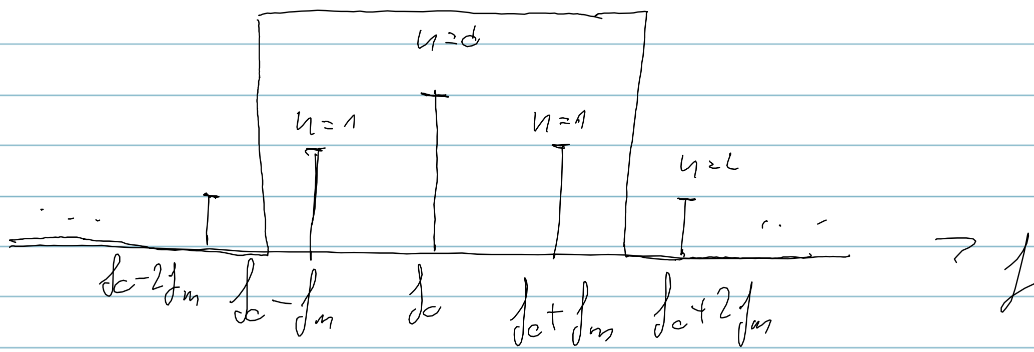
$f_m = 5\ kHz$

$\Delta\varphi = 0{,}5\ rad \Rightarrow m = 0{,}5$ (za faze)

$f_c = 1\ MHz = f_0$

$B = 15\ kHz$

$m_{AM} = ?$

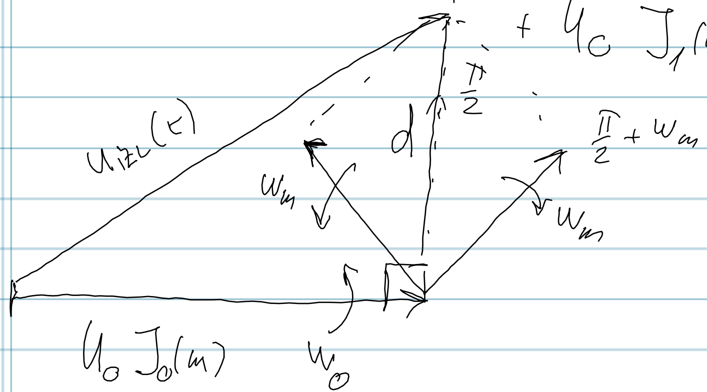


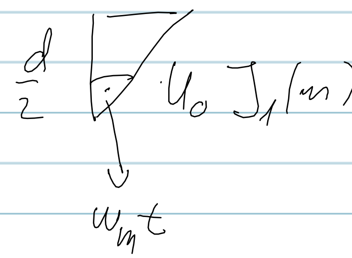
$$u_{PM}(t) = U_0\cos\left[\omega_0 t + k_p u_m(t)\right] = U_0\cos\left[\omega_0 t + \underbrace{m}_{k_p\cdot|u_m(t)|_{max}}\cdot\cos(\omega_m t)\right]$$

Na predavanjima je izvedeno

$$u_{PM}(t) = U_0 J_0(m)\cos(\omega_0 t) + U_0 \sum_{n=1}^{\infty} J_n(m)\left\{\cos\left[(\omega_0-\omega_m)t + \frac{n\pi}{2}\right] + \cos\left((\omega_0 - n\omega_m)t + \frac{n\pi}{2}\right)\right\}$$

$$u_{izl}(t) = U_0 J_0(t)\cos\omega_0 t + U_0 J_1(m)\cos\left[\omega_0 t + \frac{\pi}{2} - \omega_m t\right] +$$
$$+ U_0 J_1(m)\cos\left(\omega_0 t + \frac{\pi}{2} + \omega_m t\right)$$

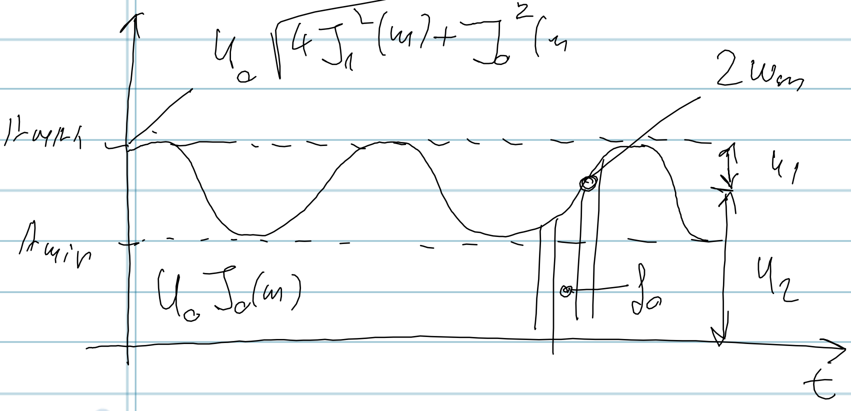




$$d = 2U_0 J_1(m)\cos(\omega_m t)$$

$$u_{anvelopa}(t) = \text{anvelopa od } u_{izl}(t)$$
$$= \sqrt{d^2 + U_0^2 J_0^2(m)} \qquad (\text{slika})$$
$$= U_0\sqrt{4J_1^2(m)\underbrace{\cos^2(\omega_m t)}_{=\frac{1}{2}+\frac{1}{2}\cos(2\omega_m t)} + J_0^2(m)}$$
$$= U_0\sqrt{2J_1^2(m)\cos(2\omega_m t) + 2J_1^2(m) + J_0^2(m)}$$

PARAZITNA AM!



$$m_{AM} = \frac{u_1}{u_2} = \frac{A_{max} - A_0}{A_0}$$

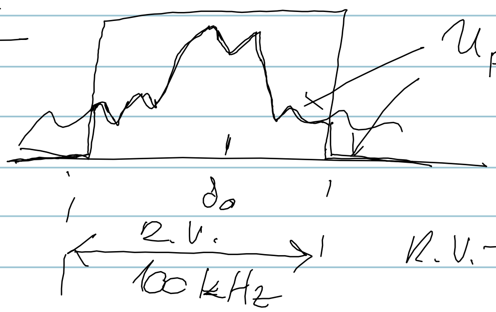
$$A_0 = \frac{A_{max} + A_{min}}{2}$$

$$m_{AM} = \frac{\sqrt{4J_1^2(m) + J_0^2(m)} - J_0(m)}{\sqrt{\text{—//—}} + J_0(m)} = \left| \begin{array}{l} J_0(0{,}5) = 0{,}92 \\ J_1(0{,}5) = 0{,}26 \end{array} \right| = \underline{0{,}07}$$

Perveznije daske!

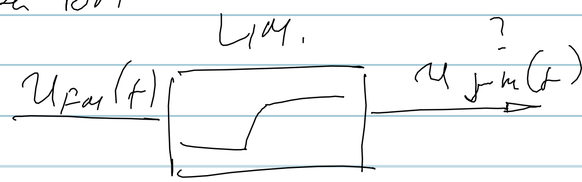
Ograničavanje beskonačnog spektra K_m signala uzrokuje pojavu parazitne amplitudske modulacije koja se u postupku demodulacije (DM) uklanja limiterima (realni DM), i djeliteljem (kompleksni DM).

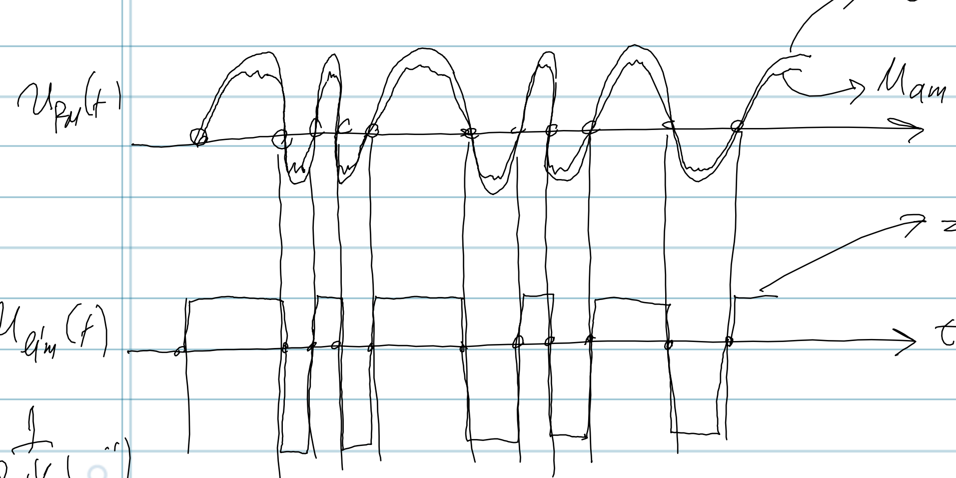
FM signal



R. V. – red veličine

U postupku DM





$U_0 \cos\left(\omega_0 t + K_\omega \int_{-\infty}^{t} u_m(t)\,dt\right)$

$u_{am}(t) \cdot \cos\left(\omega_0 t + K_a \int_{-\infty}^{t} u_m(t)\,dt\right)$

$= U_{PP}\ \text{square}\left(\omega_0 t + K_\omega \int_{-\infty}^{t} u_m(t)\,dt\right)$

limiter

$T = \frac{1}{f \ldots}(\ldots)$

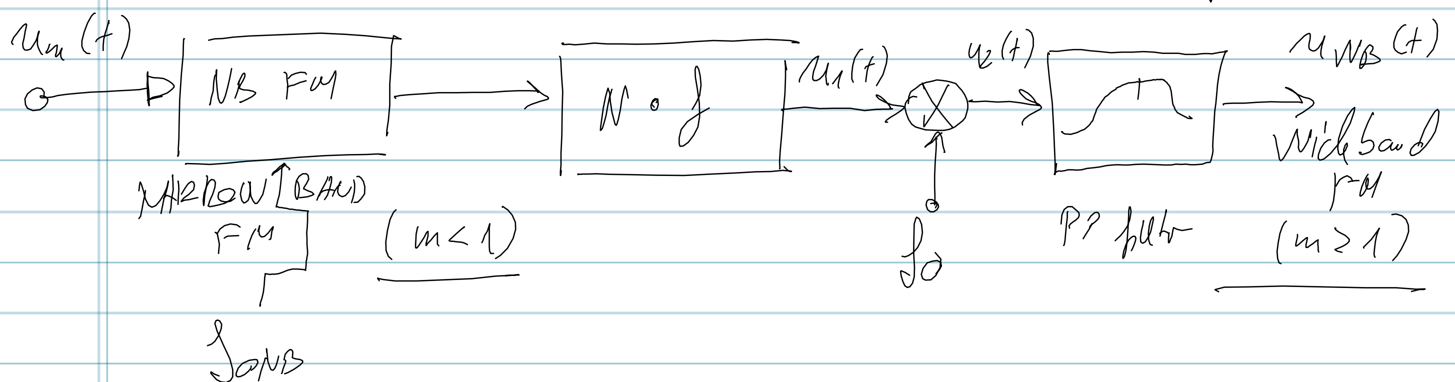
$K_\omega = 2\pi K_f$

$u_{FM}(t)$ je FM signal kod kojeg je signal vršitca promjenljivog oblika, a ne više sinusnog.

velikog

⑩ Indirektni FM odašiljač

KAGS



$u_m(t) \;\hat{=}\; f_M = 15\ kHz$

$u_{NB}(t) \;\hat{=}\; f_{NB} = f_{0NB} + \underbrace{k_f \cdot u_m(t)}_{max}$, $\quad \Delta f_{NB} = k_f\, |u_m(t)|_{max} = 3k \cdot 0,5 = 1,5\ kHz$

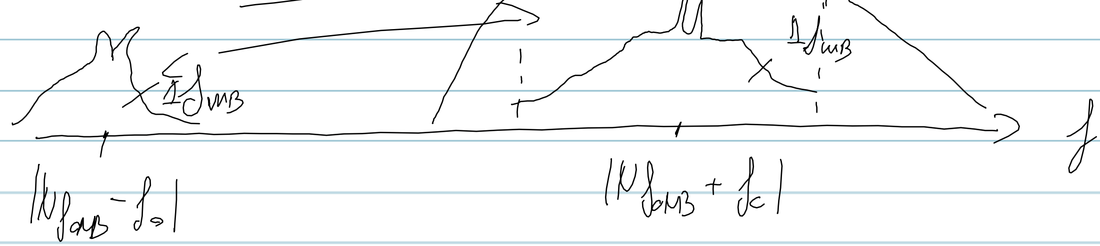
$u_1(t) : f_1 = N \cdot f_{NB} = N f_{0NB} + N \cdot k_f\, u_m(t)$

$u_2(t) : f_2 = |f_1 \pm f_0| = |N f_{0NB} \pm f_0| + N k_f\, u_m(t)$

MIXER
|2| i |5|
dodaju |3| i |7|

$\Rightarrow$ dobivamo 2 FM signala

ali su isti iako slika govori drugo

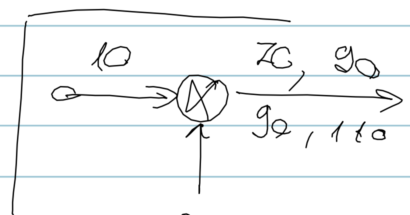


$$\Delta f_{WB} = \underbrace{N K_f |u_m(t)|_{max}}_{\Delta f_{NB}} = N \Delta f_{NB}$$

$$\Rightarrow N = \frac{\Delta f_{WB}}{\Delta f_{NB}} = \frac{75k}{1{,}5k} = \underline{\underline{50}}$$

$$|N f_{0NB} \pm f_0| = f_{0WB} = 90\,MHz$$

$$50 \cdot 200k = 10\,MHz$$



$\underline{f_0 = 80}$ ← uzimamo manji

$= 100$

$$f_0 = 80\,MHz$$

$$u_{WB}(t) : f_{WB} = N f_{0NB} + f_0 + N K_f u_m(t)$$

Pa Carsonovim pravilom određujemo širinu BPF

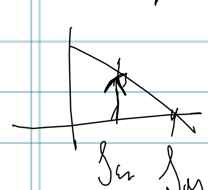
BPF:

$$B = 2 f_M (m+1) = 2 \cdot (\Delta f + f_M) = \underline{180\,kHz}$$

Δf: 75k

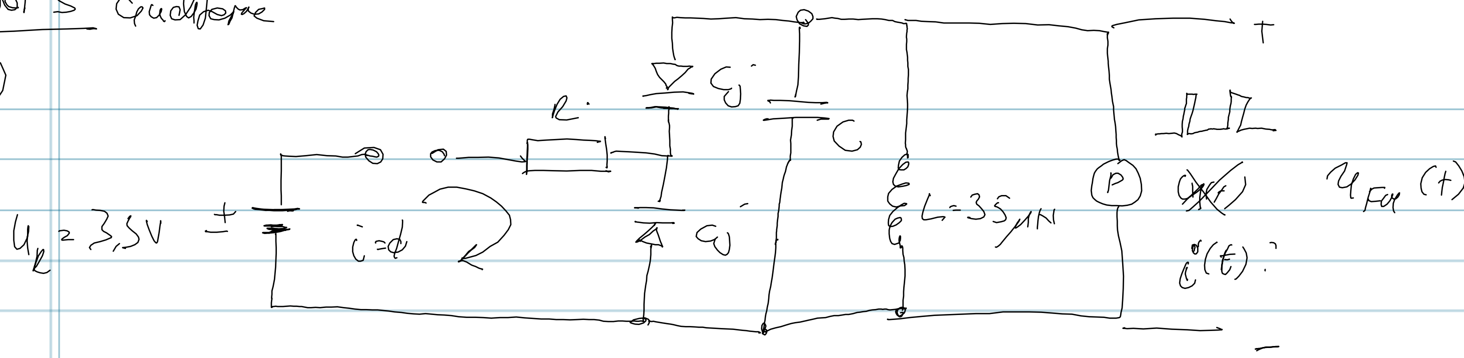
f_M: 15k

$$\underline{f_c = 90\,MHz}$$



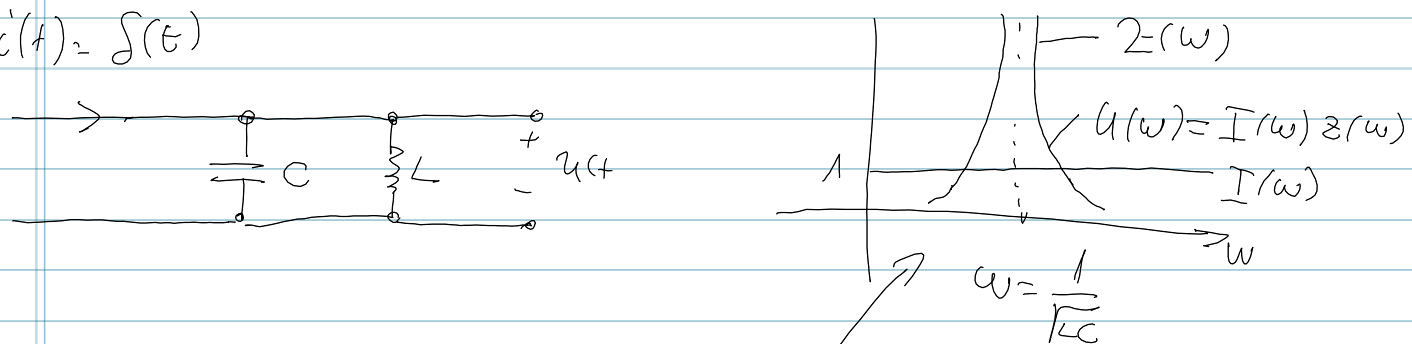
GSK vol 3 oscilatore

11



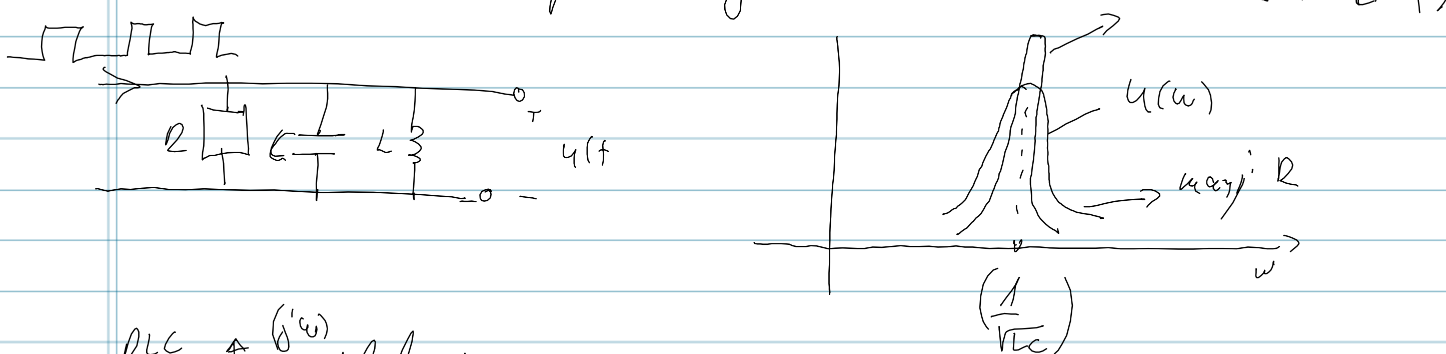
Idealni oscilator

$i(t) = \delta(t)$

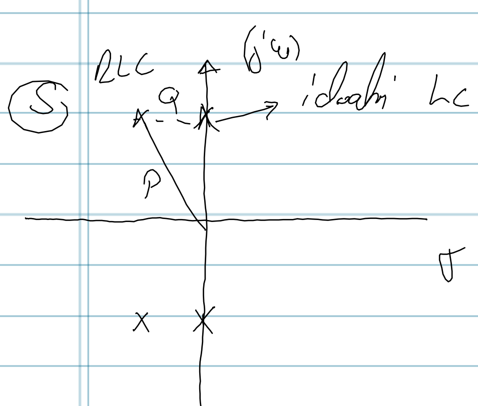


ovako izgleda spektar oscilatora

Praktični oscilator - imamo otporničke gubitke



5



$$Q = \frac{|p|}{2\sigma} = R \cdot \sqrt{\frac{C}{L}}$$

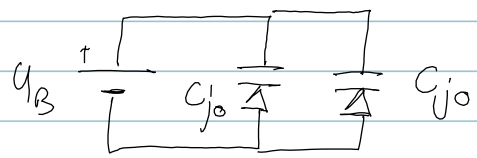
Za LC oscilatore $Q \approx 100$ ~~reda~~ red veličine

Za kvarcni oscilator $Q = 1000$ r.v.

Vratimo se na zadatak

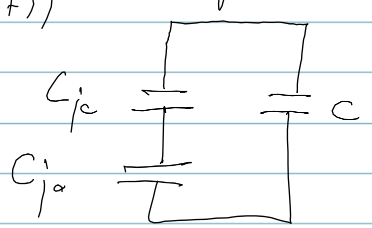
$U_B + u_m(t) > 0$ na diode budu reverzno polarizirane
na otporniku zanemariv pad napona zbog
reverzne struje zasićenja dioda

<u>DC analiza</u> ($u_m(t) = 0$)

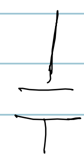


$$C_{j0} \approx \frac{120}{\sqrt{U_B}} = \frac{120}{\sqrt{3{,}3}} = 66\,pF$$

Strujni izvor vidi kapacitet
(ovaj $i(t)$)



$\Rightarrow$



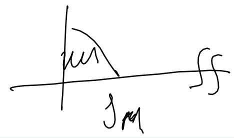
$$C_0 = C + \frac{C_{j0}C_{j0}}{2C_{j0}} = C + \frac{C_{j0}}{2}$$

$$\omega_0 = \frac{1}{\sqrt{LC_0}} \Rightarrow C_0 = \frac{1}{4\pi^2 f_0^2 L} \approx 181\,pF$$

$$C = C_0 - \frac{C_{j0}}{2} = 148\,pF$$

Sad odredimo širinu pojasa

AC analiza

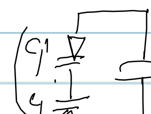


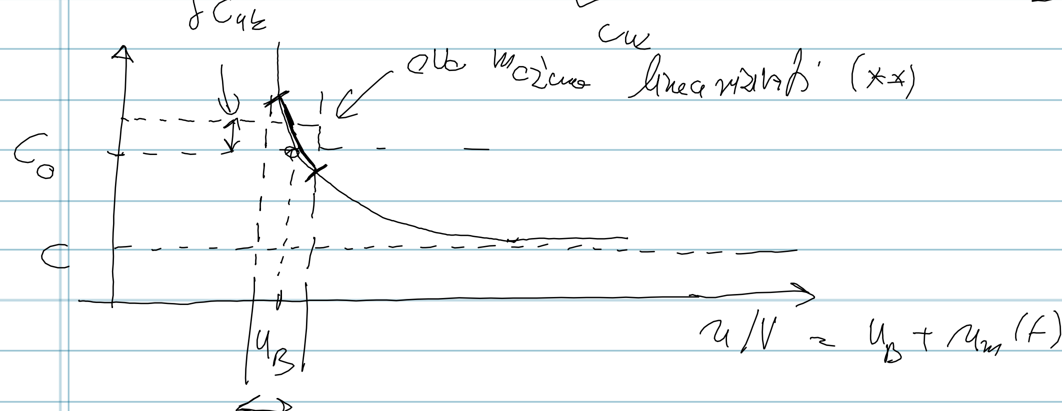
I) Iznos otpora R mora biti što veći zbog visokog Q faktora LC kruga. S druge strane, ne prevelik zbog atenuacije $u_m(t)$!

II) Na varikap diodama je prednapon $U_B + u_m(t)$, jer za niske frekvencije f_M (da je $f_M << f_0$)

L predstavlja vrlo nisku, a C vrlo visoku impedanciju

$$C_{uk} = ? = C + \frac{C_j(t)}{2} = C + \frac{C_{j0} + \delta C_j(t)}{2} = (*)$$





$$(*) = C_0 + \frac{\delta C_j(t)}{2} \Rightarrow \text{devijacija od } C_{uk}\ (\delta C_{uk})$$

Trenutna frekv. $\Rightarrow$ $$\omega_i = \frac{1}{\sqrt{L \cdot C_{uk}}} = \frac{1}{\sqrt{L \cdot (C_0 + \delta C_{uk})}} = \underbrace{\frac{1}{\sqrt{LC_0}}}_{=\omega_0} \cdot \frac{1}{\sqrt{1 + \frac{\delta C_{uk}}{C_0}}}$$

Uz $\delta C_{uk} << C_0$ APROKSIMACIJA $\frac{1}{\sqrt{1+x}} \approx 1 - \frac{x}{2}$

$$\omega_1 = \omega_0 \left(1 - \frac{\delta C_{uk}}{2C_0}\right)$$

$$\omega_1 = \omega_0 - \frac{\omega_0}{2C_0}\cdot \delta C_{ut} \overset{\text{DEF.}}{=} \omega_c + k_\omega \cdot u_m(t)$$

$$\Rightarrow k_\omega = -\frac{\omega_0}{2C_0}\underbrace{\frac{\delta C_{ut}}{u_m(t)}}_{=k}$$

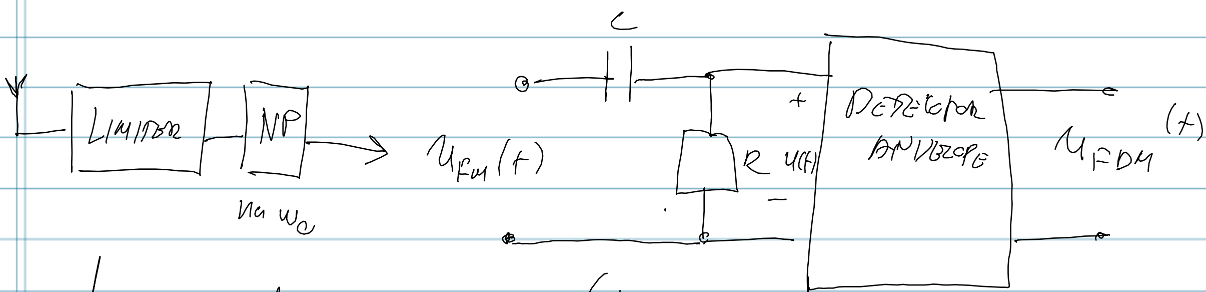
$$(**) \quad \delta C_{ut} = k \cdot u_m(t)$$

k je derivacija $= \left.\frac{dC_{ut}}{du}\right|_{u=U_B}$ $\rightarrow C + \frac{C_j}{2}$ $= \frac{1}{2}\left.\frac{dC_j}{du}\right|_{u=U_B} = \frac{-30}{\sqrt{U_B^3}}$

$$k_\omega \Rightarrow k_f = -\frac{f_c}{2C_0}\frac{-30}{\sqrt{U_B^3}} = \frac{2\cdot 10^6}{2\cdot 181}\frac{30}{\sqrt{3{,}3^3}} = 27{,}6 \text{ kHz/V}$$ osjetljivost

$$B = 2\Delta f + 2f_M = 2\cdot k_f\cdot \underbrace{|u_m(t)|_{max}}_{50\,mV} + 2\underbrace{f_M}_{\text{zadano}} = 22{,}8 \text{ kHz}$$ uskopojasni

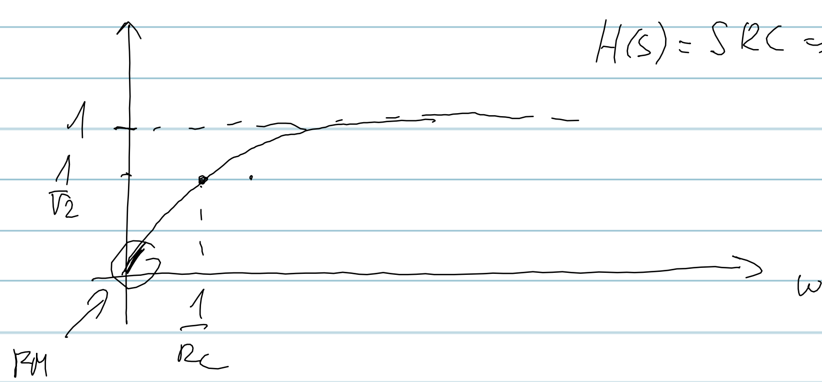
(12)



$R << \frac{1}{\omega C}$ u području FM signala (tj. $\omega_0 - \frac{B_{FM}}{2} \le \omega \le \omega_0 + \frac{B_{FM}}{2}$)

$$\omega << \frac{1}{RC} = \omega_{-3dB}$$

$$H(\omega) = \frac{R}{\cancel{R} + \frac{1}{j\omega C}} = j\omega RC$$



$H(s) = sRC \Rightarrow$ DERIVATOR u području GUŠENJA

$$u(t) = RC \frac{d u_{FM}(t)}{dt}$$

$$u_{FM}(t) = U_0 \cos\left(w_0 t + k_w \int_{-\infty}^{t} u_m(t)\, dt\right)$$

$$\Rightarrow u(t) = -RCU_0 \underbrace{\sin\left(w_0 t + k_w \int_{-\infty}^{t} u_m(t)\,dt\right)}_{FM} \cdot \underbrace{\left(w_0 + k_w \cdot u_m(t)\right)}_{AM}$$

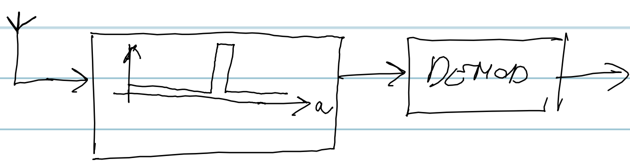
FM DISKRIMINATOR per FM $\Rightarrow$ AM

u_2 idealan detektor anvelope $\Rightarrow u_{FDM}(t) = RCU_0 w_0 \cdot \left(\left(w_0 + k_w \cdot u_m(t)\right) + \frac{1}{w_0}\right)$

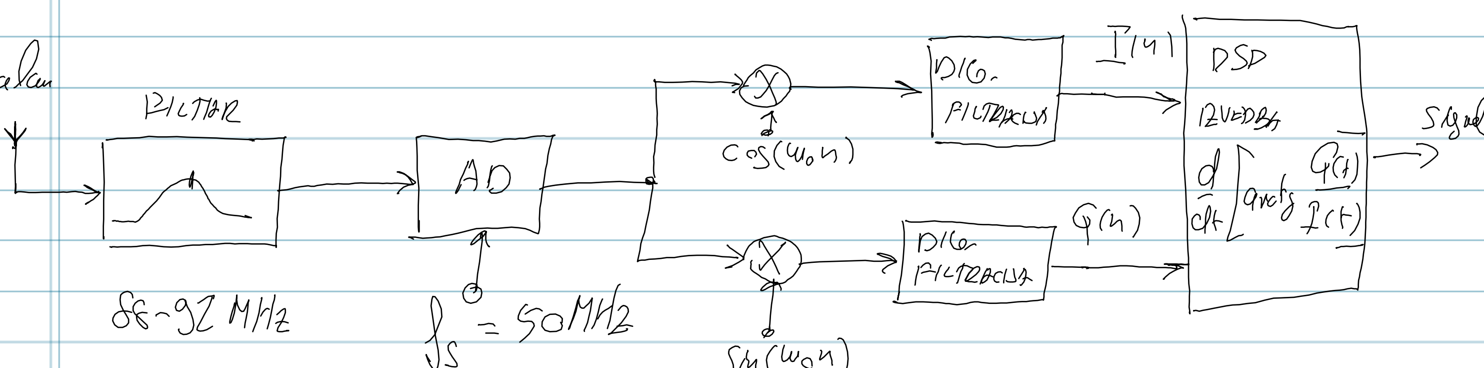
$$RCU_0 w_0 + RCU_0 k_w \cdot u_m(t)$$

(13) Direktna pretvorba i poduzorkovanje

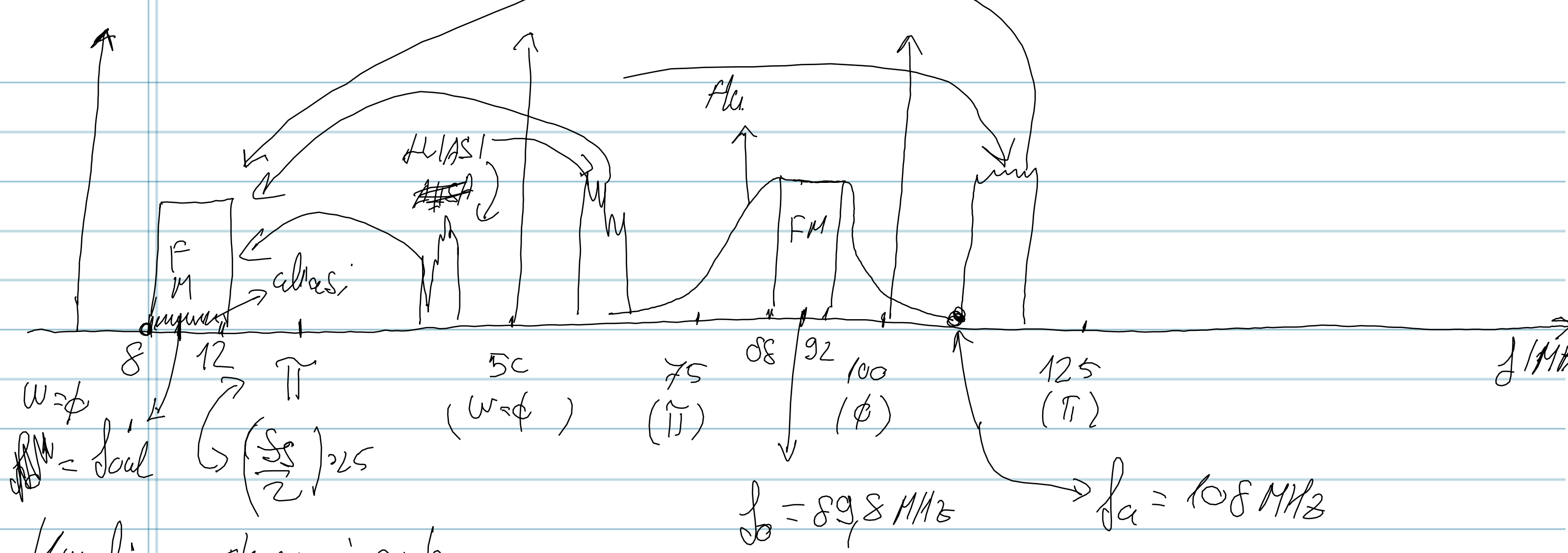
a) IDEALNI PRIJEMNIK



Realan



b) ω_0 – numerički ulaz kanal



Kanali se okrenu i prebace

f_{0ul} nam odgovara $f'_{0ul} = 100 - 89,8 = 10,2$ MHz

Budući da se radi o direktnoj pretvorbi, digitalni oscilator mora odgovarati toj freq. tj.

$$\omega_D = \frac{10,2}{25}\cdot\pi = 0,408\,\pi \text{ rad}$$

c) Butterworth treba znati

H_{ul} = antialiasing filtar (AAF) za AD

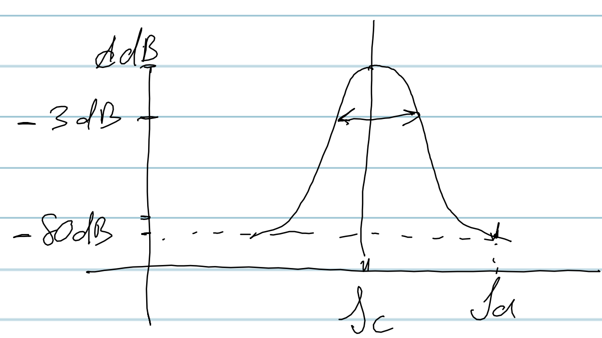
Najbliža alias komponenta kanalima je $f_a = 108$ MHz

$f_c = \sqrt{88\cdot 92} = 90$ MHz

$B = 4$ MHz

BP Butterworthov filtar reda N

$$|H(f)| = \frac{1}{\sqrt{1+\left(\frac{f^2-f_c^2}{B\cdot f}\right)^{2N}}}$$



$20\log|H(f_a)| \le -80\,dB$ GRBOVDA xD

$$-10\log\underbrace{\left|1+\left(\frac{f_a^2-f_c^2}{f_a\cdot B}\right)^{2N}\right|}_{\ge 10^8} \le -80 \quad / : (-10)$$

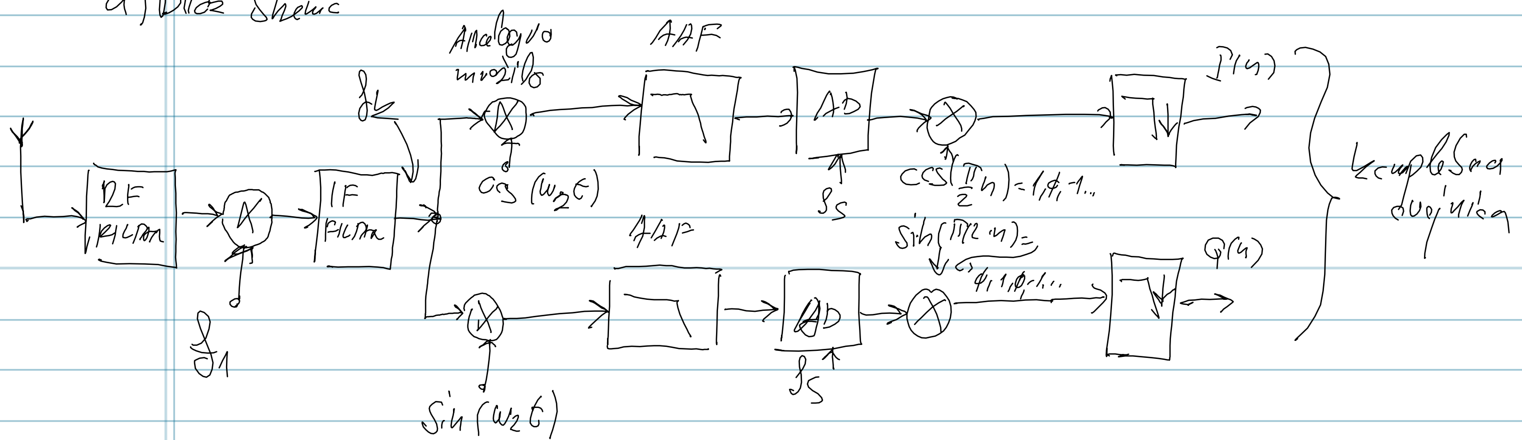
$$2N\cdot\log\left|\frac{f_a^2-f_c^2}{f_a\cdot B}\right| \ge 8$$

$$N \ge \frac{4}{\log\left|\frac{108^2-90^2}{4\cdot 108}\right|} = 4{,}3 \Rightarrow \underline{\underline{N=5}}$$

(u praksi se koristi eliptični filtar)

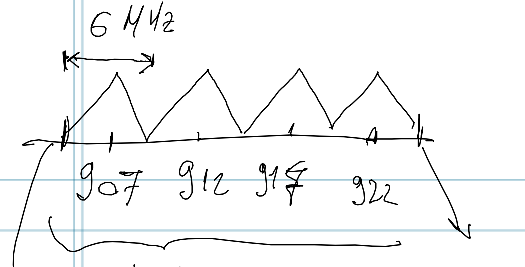
14) Bla Bla

a) Blok shema



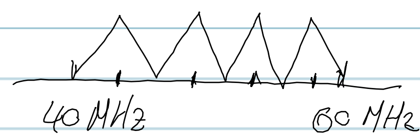
b) druga stranica buahahaha ... haha ...

b)



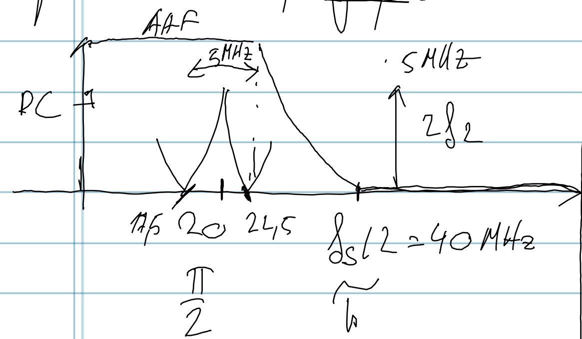
904,5 Hz — 924,5 MHz

(Poslije IF-a)



f_k

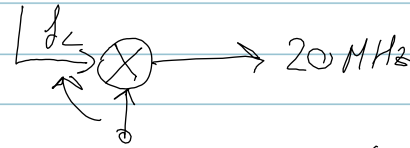
Poslije AAF-a (tj. prije!!)



$f_1 = 904{,}5\,M - 40\,M = 864{,}5\,MHz$

$f_2 = ?$

$f_k = \{42{,}5,\ 47{,}5,\ 52{,}5,\ 57{,}5\}$ MHz

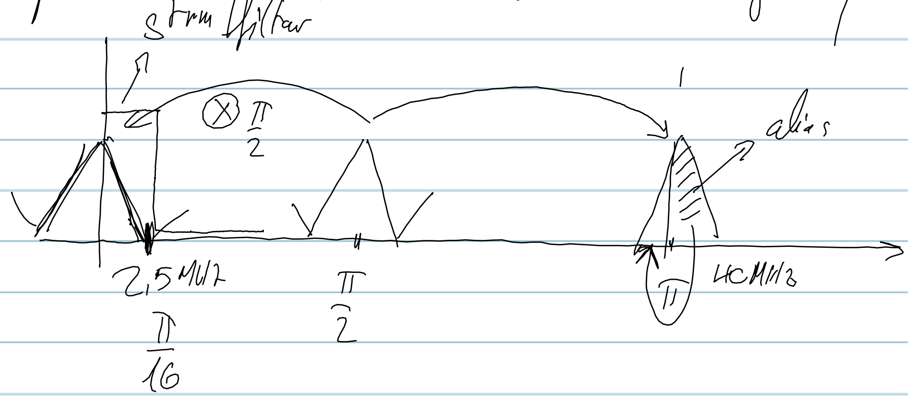


$f_2 = f_k - 20 = \{22{,}5,\ 27{,}5,\ 32{,}5,\ 37{,}5\}$ MHz

Zbog analognog množila dolazi do preslikavanja f_2 na signal na ulazu (f_k). Pri čemu se pojavljuju komponente $2f_2$ i ϕ koje u našem slučaju ne upadaju u kanal.

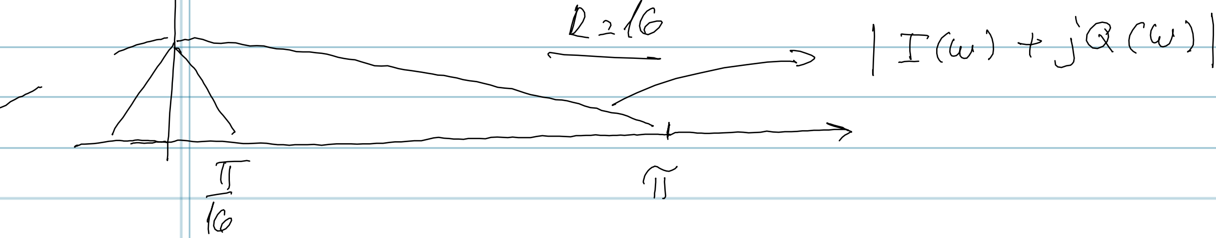
Zato se radi uzorkovanje s f_c i $\frac{\pi}{2}$! (problem analognog množila)

Dobivamo kompleksne ovojnice ($I + jQ$) u digitalnoj domeni.



SMEĆE ČE SUSJEDI FTW!

↓R, izbacujem svaki R-ti uzorak

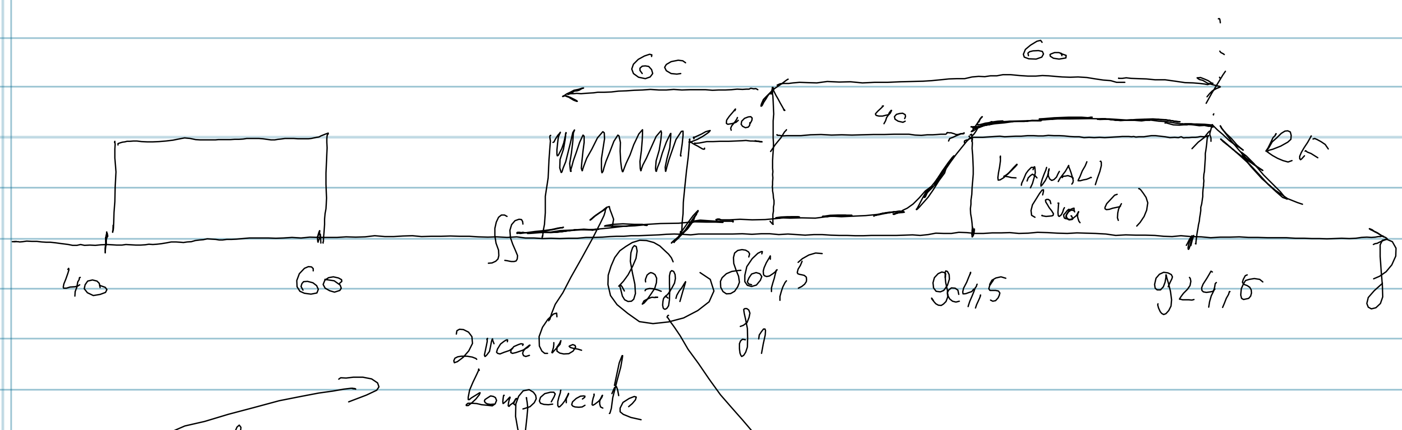


$$f_{s_{Low}} = \frac{f_s}{R} = \frac{80}{16} = 5\,MHz$$

c) odrediti gušenje zrcalnih freq

Zrcalne freq. se pojavljuju kod svake transpozicije freq (ali da nije 0)
nije direktna pretvorba

Mi imamo transpoziciju s f_1 i f_2 (kod miješanja)

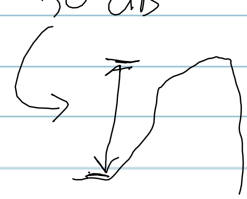


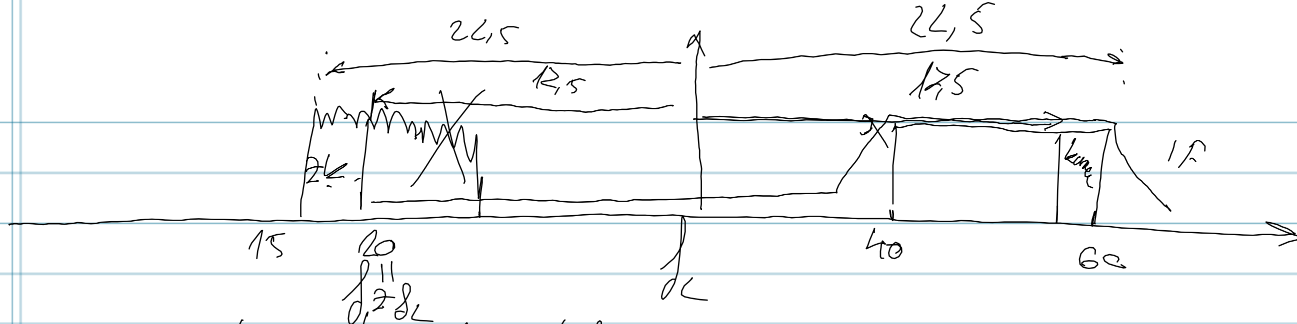
RF guši te frekvencije.

= 824,5 MHz (864,5 − 40)
(najbliža zrcalna freq kanalima)

Od područja propuštanja do područja gušenja

Očitavanjem amp. karakteristike filtra (RF) dobivamo da je gušenje komponenti na ulazu veće od 50 dB





Najgori slučaj kad kanal desno (desni kanal)

koji daje najbliži zrcalnu komponentu kanala

PASS BAND

Kad se predita sa papira (IF karakteristika)

STOP BAND

gušenje kod 2. transpozicije mora > (1b

Veće od 70 dB

NAPOMENA

OSK auditorne Vol 2

Lol

(15) – mjere A/D pretvarača obzirom na šum i distorziju

1.) SINAD (signal to noise and distortion)

{ukupan/total SNR}

$$SINAD = 10 \log \frac{P_S}{P_N + P_D}$$

2) SNR (signal to noise ratio)

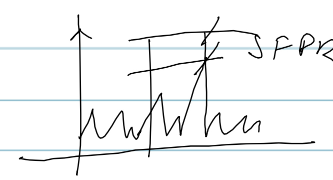
$$SNR = 10 \log \frac{P_S}{P_N}$$

3) THD (total harmonic distorsion)

$$THD = 10 \log \frac{P_S}{P_D}$$ (obično se izražava u dBc)
(i mjeri se na prvih 10 harmonika)

4) SFRD (~~signal~~ spurious free dynamic range)

$$SFDR = 10 \log \frac{P_S}{\max(P_N + P_D)}$$



– efektivni broj bitova (effective number of bits ENoB)

Određuje se iz

$$SINAD = 1,76 + 6,02 \cdot ENOB$$ ⇒ model šuma kvantizacije s ENOB bitova

$$ENOB = \frac{SINAD - 1,76}{6,02}$$

- Ulazna dinamika obično (uvijek) se izražava u dBFs (decibel relative to full scale)

$$U = 10^{\frac{U_{dBFS}}{20}} \cdot U_{FS} \; [V_{PP}]$$

Normirana vrijednost šuma izlaznog se izračunava:

$$U_{n,LSB} = \frac{U_n}{U_{LSB,rms}} = \frac{U_n}{\frac{U_{LSB}}{2}} = \frac{2U_n}{\frac{U_{FS}}{2^N}} =$$

$$= \frac{U_n}{U_{FS}} \cdot 2^{N+1} \; [LSB]$$

U našem slučaju je:

$N = 14$

$U_{FS} = 3 \; V_{PP}$

$U_{n,LSB} = 0,6 \; LSB$

$THD = 82 \; dB_C$

$U_{dBFS} = -1 \; dBFs \implies U = 10^{\frac{-1}{20}} \cdot 3 = 2,67 \; V_{PP}$

$ENOB = ?$

Amplituda sin. sig:

$$U_m = \frac{2,67}{2} = 1,34V$$

Snaga:

$$P_S = \left(\frac{U_m}{\sqrt{2}}\right)^2 = 0,89 \, W$$

$$THD = 10 \log \frac{P_S}{P_D} \Rightarrow P_D = 10^{\frac{-THD}{10}} \cdot P_S = 5{,}64 \cdot 10^{-9}\ W$$

$$U_n = \frac{U_{M,LSB} \cdot U_{FS}}{2^{N+1}} = \frac{0{,}6 \cdot 3}{2^{15}} = 5{,}49 \cdot 10^{-5}\ V$$

$$P_n = U_n^2 = 3{,}02 \cdot 10^{-9}\ W$$

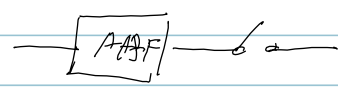
$$SINAD = 10 \log \frac{P_S}{P_n + P_D} = 80{,}14\ dB$$

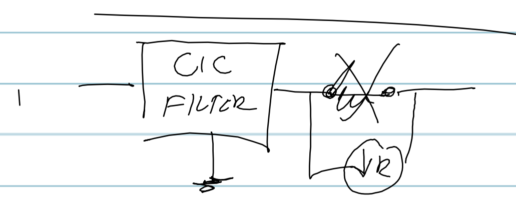
{ Puno ladica od CIC-a }

$$\Rightarrow ENOB = \frac{80{,}14 - 1{,}76}{6{,}02} = 13{,}02$$

Uočiti: A/D pretvorač ima 14 bitova, a njegovi šumovi i distorzija pojeli su 1 bit.

(16) CIC decimator





$f_{SH} = 1{,}2\ MHz$

$\omega_c = 0{,}005\pi$

$f_{SL} = 25\ kHz$

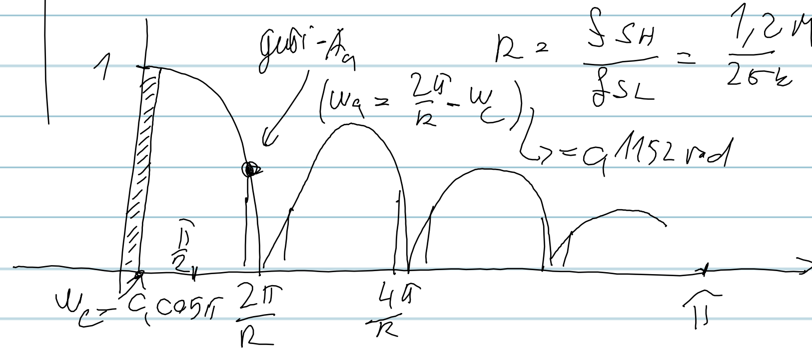
$A_a = 80\ dB$

$B_{in} = 18$

$N = ?,\ B_{max} = ?$

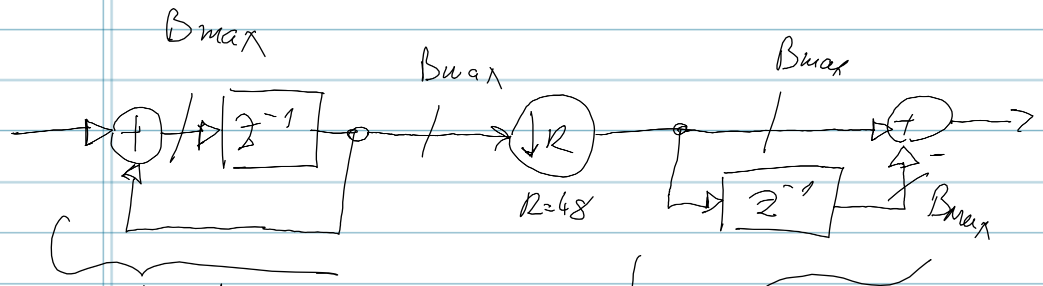
$$|H(\omega)| = \left| \frac{1}{R} \cdot \frac{\sin\left(\frac{\omega R}{2}\right)}{\sin\left(\frac{\omega}{2}\right)} \right|^N$$

$$R = \frac{f_{SH}}{f_{SL}} = \frac{1{,}2M}{25k} = 48$$



$$20\log|H(\omega_a)| = -A_a \Rightarrow N \geq \frac{-A_a}{20\log\left|\frac{1}{R}\frac{\sin\left(\frac{\omega_a R}{2}\right)}{\sin\left(\frac{\omega_a}{2}\right)}\right|} = 4{,}57 \Downarrow 5$$

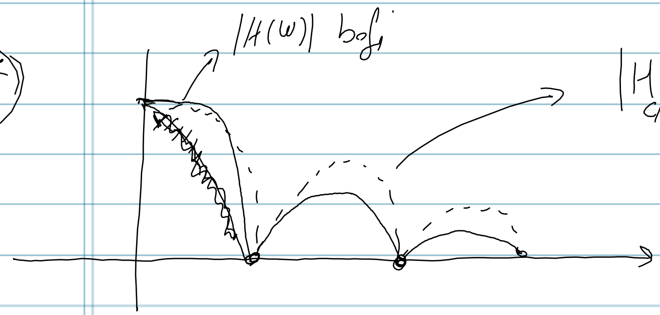
ovaj $H(\omega_a)$ sa prošle str.



$$B_{max} = \lceil N\log_2(R) + B_{in} \rceil = 46 \text{ bitova}$$

$N = 5$, $R = 48$, $B_{in} = 18$

17



$$|H_{cic}(\omega)| = \left|\frac{1}{R}\cdot\frac{\sin\left(\frac{\omega R}{2}\right)}{\sin\left(\frac{\omega}{2}\right)}\right|^N$$

→ značajan propad u pass bandu

→ nedovoljna atenuacija stop banda

Kako odrediti $H(z)$ koristeći $H_{cic}(z) = \left(\frac{1}{R}\cdot\frac{1-z^{-R}}{1-z^{-1}}\right)^N$?

Moramo uvesti faznu karakteristiku u izraz za $|H(\omega)|$.

$$|H(\omega)| = 3|H_{cic}(\omega)|^2 - 2|H_{cic}(\omega)|^3 \quad / \cdot e^{j3\varphi_{cic}(\omega)}$$

$$\varphi_{cic}(\omega) = -D\omega$$

$$\underbrace{e^{j\varphi_{cic}(\omega)\cdot 3}\cdot|H(\omega)|}=3\cdot\underbrace{|H_{cic}(\omega)|^2\cdot e^{j2\varphi_{cic}(\omega)}}\cdot\underbrace{e^{j\varphi_{cic}(\omega)}}-2|H_{cic}(\omega)|^3\cdot e^{j3\varphi_{cic}(\omega)}$$

$$\{H(z)\}=3\cdot H_{cic}^2(z)\cdot z^{-D}-2H_{cic}^3(z)$$

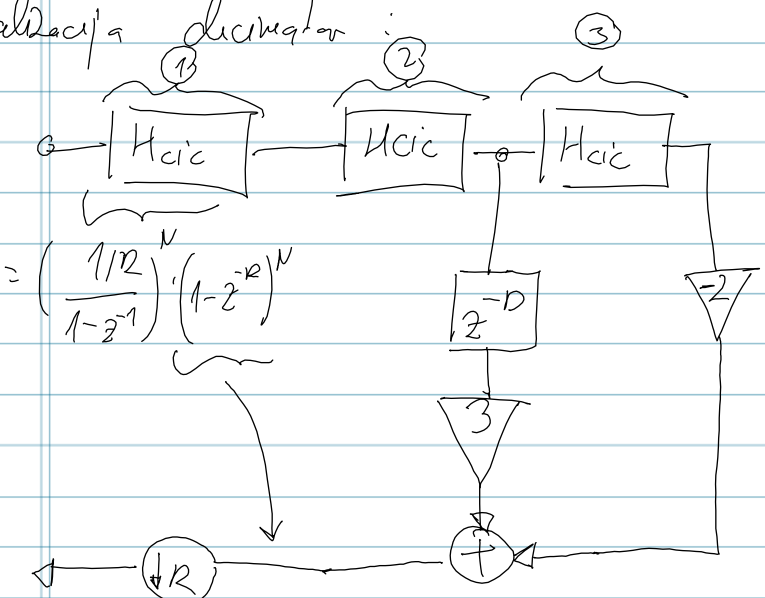
Duljina impulsnog odziva od $H_{cic}(z)$ je

$$L=N(R-1)+1$$

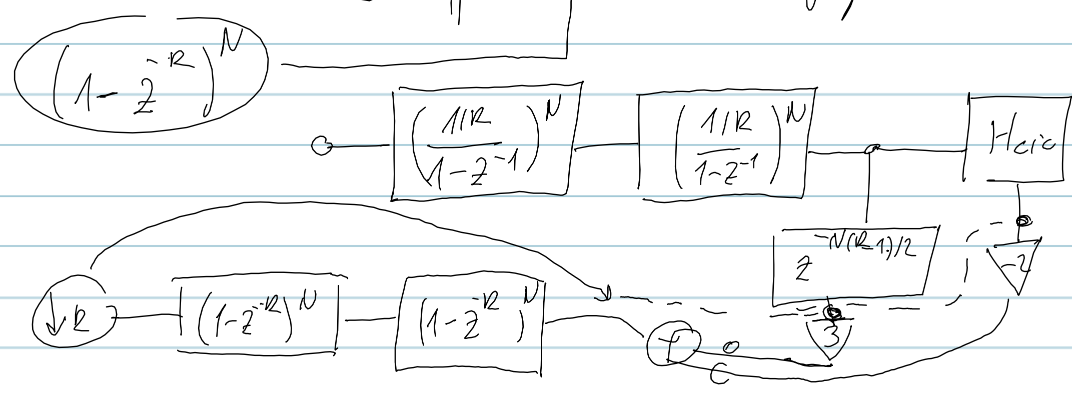
Budući je $H_{cic}(z)$ FIR filter s linearnom fazom njegovo kašnjenje je

$$D=\frac{L-1}{2}\qquad\left(D=\frac{N(R-1)}{2}\right)$$

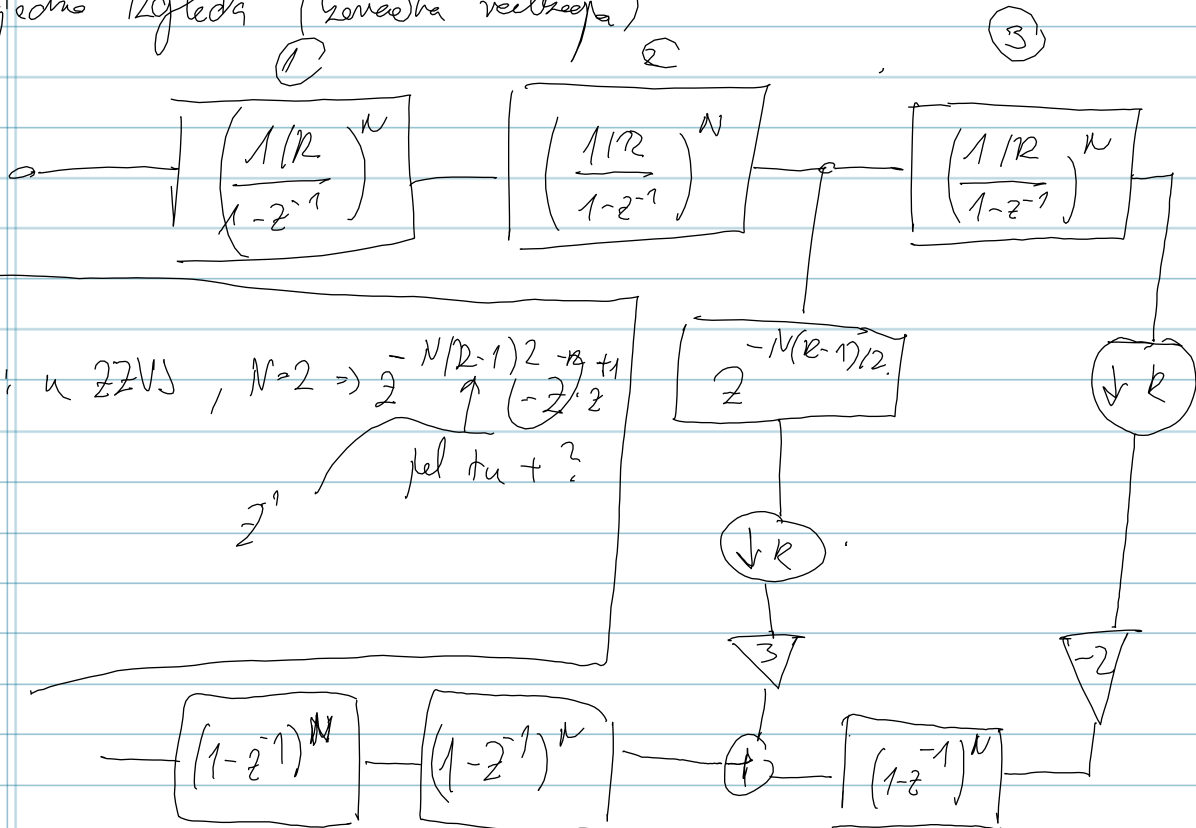
Realizacija decimator:



Filter je kaskada 1 2 i 3 pa se može staviti poslije downsamplera



Sve zajedno izgleda (konačna realizacija)



Napomena: u ZZVJ, $N=2 \Rightarrow z^{-N(R-1)2 - R + 1}$ $(-z^{-1} \cdot z)$

z^{1} jel tu + ?

Divno je biti rekao nešto

wtf

Divno je biti dobi sve...

podatak od prošlog puta

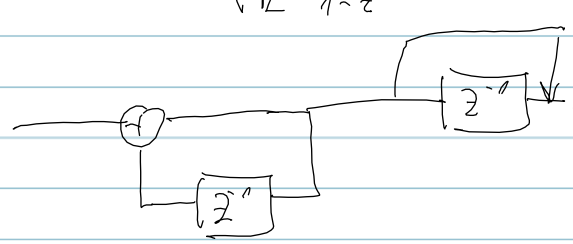
Sad kompenzacija... jeee...

$$H_{cic}(z) = \left(\frac{1}{R}\frac{1-z^{-R}}{1-z^{-1}}\right)^N \longrightarrow L(z) = \left(\frac{1}{R}\frac{1-z^{-R}}{1-z^{-1}} \cdot z^{-1}\right)^N$$

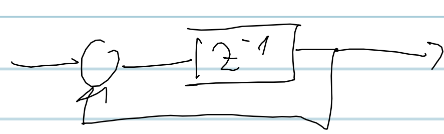
$$\hookrightarrow D = \frac{N(R-1)}{2} + N = \frac{N(R+1)}{2}$$

$N=2$

$D=R+1$



$$\longrightarrow I(z) = \frac{1/R}{1-z^{-1}}$$

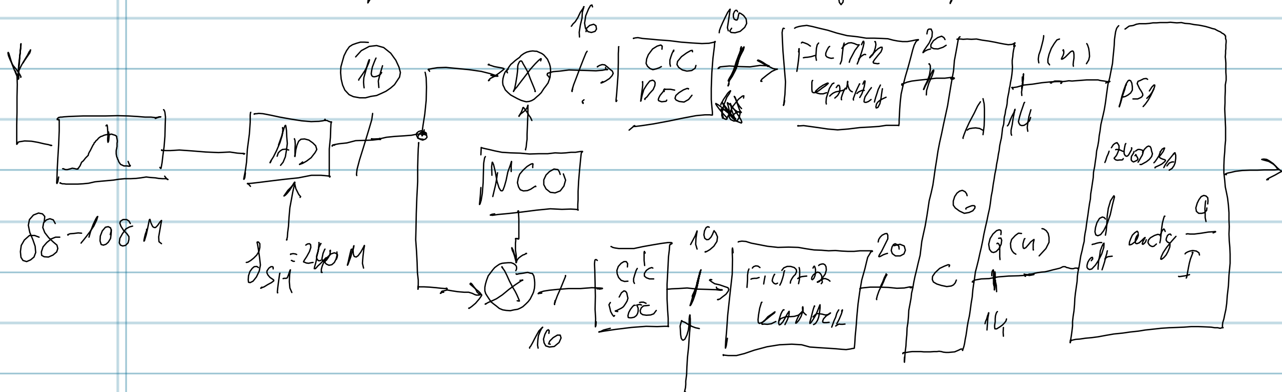


$$I(z) = \frac{1/R \cdot z^{-1}}{1+z^{-1}}$$

18) 2 bile teksta:

a) blok šema:

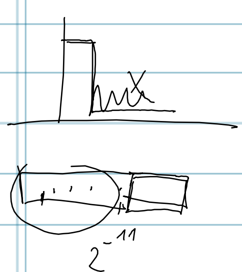
Prijemnik s uzorkovanjem u osnovnom freq. području



$f_{SL} = 300 kHz$ (poslije CIC-a)

perverzije na sve strane ...

b)



Processing gain

$N \times N \to 2N$ unosi -3 dB SNR

$N \times N \to N$ -6 dB

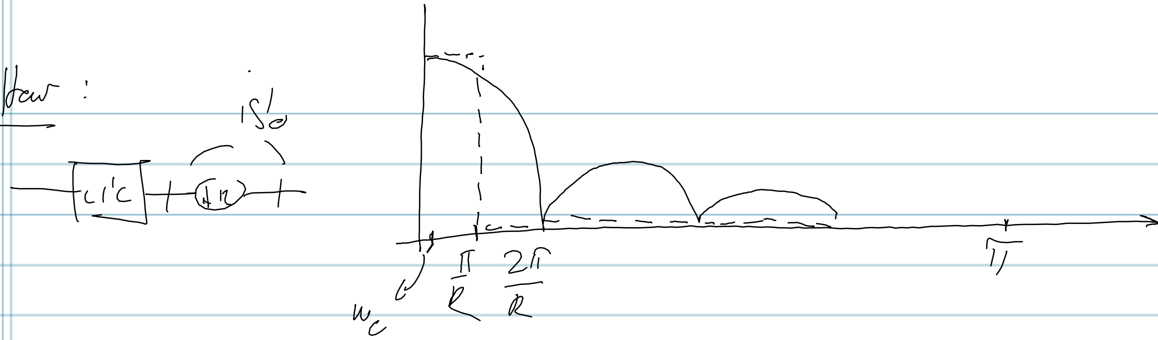
$N \times N \to N+1$ -4 dB

$N \times N \to N+2$ $-3,1$ dB ← do k+B

Na izlazu miješala uzimamo 2 bita više kako bi osigurali min. gubitak od SNR-a od -3 dB?!

Na izlazu CIC dec. i filtra kanala broj bitova odgovara se s obzirom (dodatnu) processing (PG) gaina

CIC filter :



Pretpostavimo da je ovo (- - -) LP karakteristika koju aproksimira CIC filter
U tom slučaju je PG estimiran izrazom:

$$PG_{cic} = 10\log\frac{\text{cijeli band}}{\text{propusni band}} = 10\log\frac{\pi}{\pi/R} = \underline{\underline{10\log R}}$$

{Sve puno CICa}

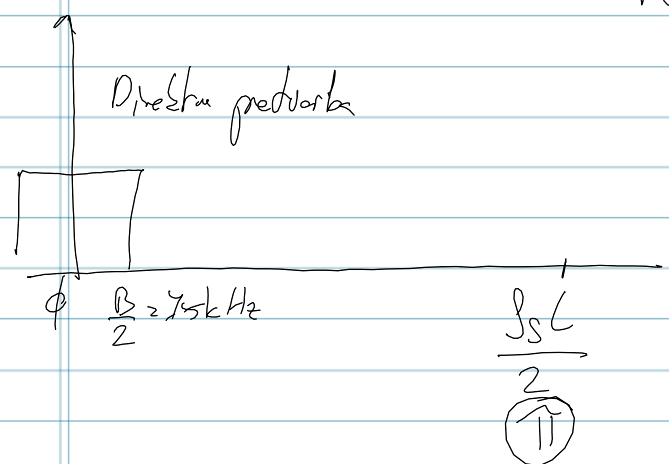
$$R = \frac{f_{s4}}{f_{sL}} = 800 \Rightarrow PG_{cic} = 29\,dB$$

Broj bitova koji treba dodati na ulazni broj bitova kako bi se osiguralo

<u>dani PG</u> iznosi: $\frac{PG_{cic}}{6\,dB} = 4{,}8 \Rightarrow 5$ bitova

Na izlazu CIC decimatora imamo $14+5=19$. Uočiti da kao referentni broj bitova uzimamo broj bitova AD pretvornika.
Razlog – mješalo smanjuje SNR za razliku od filtara koji ga povećavaju PG-om.

Filtar kanala



$$PG_{FK} = 10\log\left(\frac{f_{SC}/2}{B/2}\right) = 10\log\frac{150k}{75k} = 3\,dB$$

$$\frac{PG_{FK}}{6dB} = 0,5 \Rightarrow 1\,bit$$

c) AAAAAAAAA ... AAAAA...!

$$SNR_{OUT} = SNR_{AD} + SNR_{Mix} + PG_{c/c} + PG_{FK}$$

$$= 70 + (-3) + 29 + 3 = 99\,dB$$ (točno našeg banda kojeg slušamo)

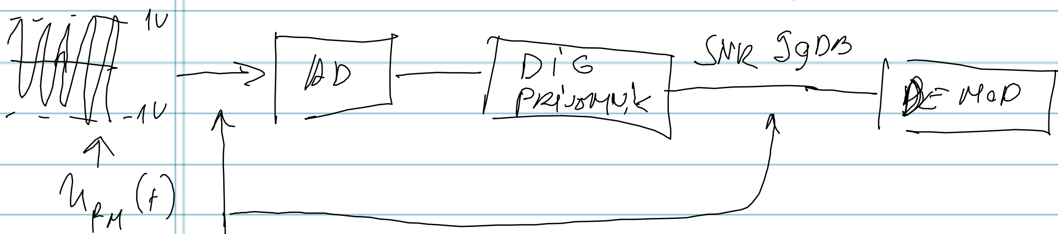
d) 17:22 h/sati

Ako na izlazu filtra kanala ne bi uzeli 1 bit kanala više tada bi izgubili njegov PG od 3 dB. Budući da i miješalo unosi gubitak od 3 dB ukupno bi bilo 6 dB (u kodnom kanalu 1 bit) ⇒ na izlazu prijemnika mogu za 1 bit. U tom slučaju, prijemnik bi se povećao tako da ima 15 bita na ulazu, a ne 14.

e) Ludilo brate...

Kada na izlazu imamo SNR 98 dB?

Kada je na AD pretvarač doveden fm signal maksimalne dinamike, a s tim da na ulazu u pretvarač nema šuma (nema popodala...)



Snaga u tim točkama je ista $P_S = \left(\frac{1}{\sqrt{2}}\right)^2 = \frac{1}{2}$ V, a $SNR = 10 \lg \frac{P_S}{P_N}$

$$\Downarrow$$

$$P_N = P_S \cdot 10^{-\frac{SNR}{10}} = \underline{\underline{6{,}3 \cdot 10^{-11}\ W}}$$

Ako je SNR = 10 dB tada je na ulazu snaga signala

$$P_S = P_N \cdot 10^{\frac{SNR}{10}} = 6{,}3 \cdot 10^{-11} \cdot 10^{\frac{10}{10}} = \underline{6{,}3 \cdot 10^{-10}\ W}$$

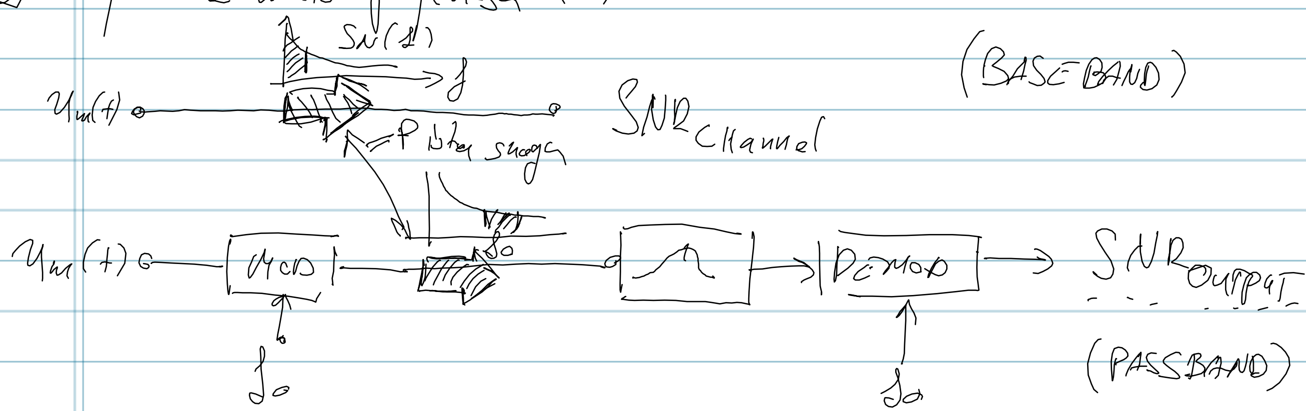
Efektivna vrijednost FM signala koji se još može čuti je u rms

$$U_{RMS} = \sqrt{P_S} = 26\ \mu V$$

KAOS!

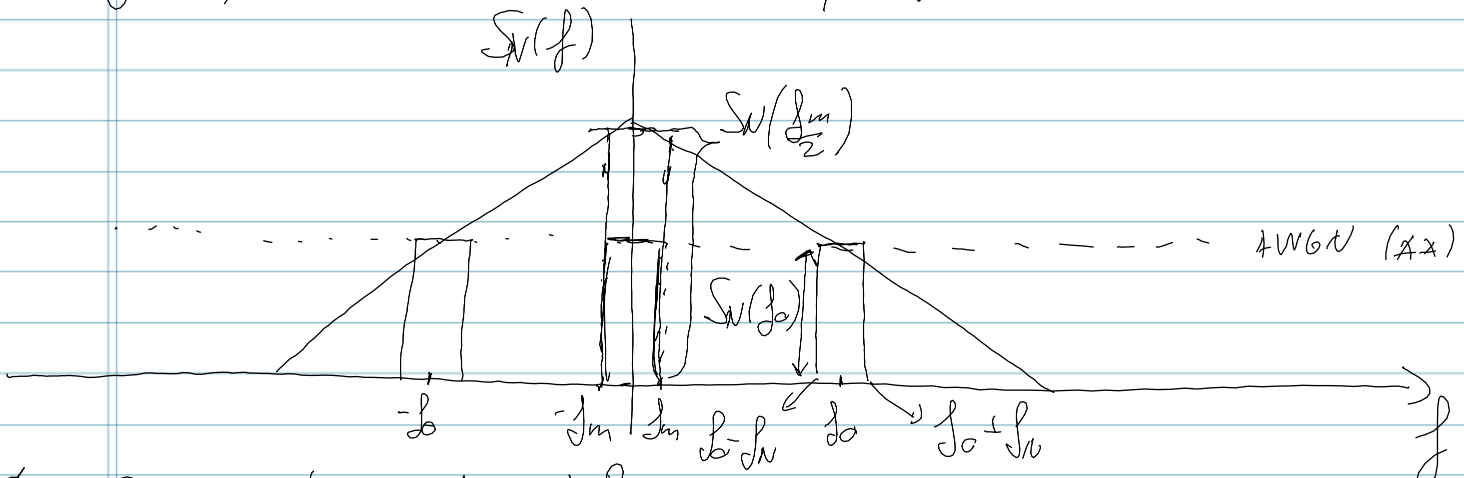
OSK aud. Vol. 2-2

(19) Mjera kvalitete prijenosa (*)



$$\boxed{M = \frac{SNR_O}{SNR_C}} \quad (*)$$

Ideja: svesti M za dani šum na M_{AWGN} na način $M = k \cdot M_{AWGN}$ jer je M_{AWGN} poznat za modulacijske postupke.

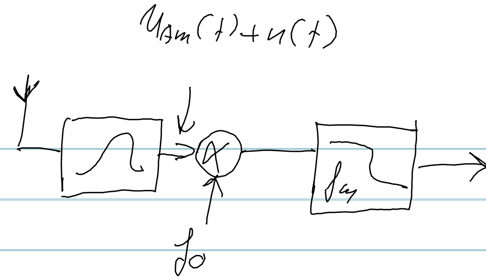


~~SNRO~~ SNR_O je isti za ovako postavljen AWGN.

Ovo (**) odabiremo za AWGN jer je tada SNR_O isti za dani šum i AWGN.

$$M = \frac{SNR_O}{SNR_C} = \frac{\overset{= SNR_{O,AWGN}}{SNR_O}}{\frac{P_{SC}}{P_{NC}}} = \frac{SNR_O}{\underbrace{\frac{P_{SC}}{2 f_m \cdot S_N(\frac{f_m}{2})} \cdot \frac{S_N(f_0)}{S_N(f_0)}}_{SNR_{C,AWGN}}} = \boxed{\frac{S_N(\frac{f_m}{2})}{S_N(f_0)} \cdot M_{AWGN}}$$

$M_{AWGN} = ?$ Za koherentni prijemnik oblika



odredimo M_{AWGN}.

$$u_{AM} = \underbrace{U_0 \cos(\omega_0 t)}_{TC} + \underbrace{k_a u_m(t) \cos(\omega_0 t)}_{DSB}$$

$$P_0 = \frac{U_0^2}{2}, \quad P_{DSB} = E\left[k_a^2 u_m^2(t) \cos^2 \omega_0 t\right]$$

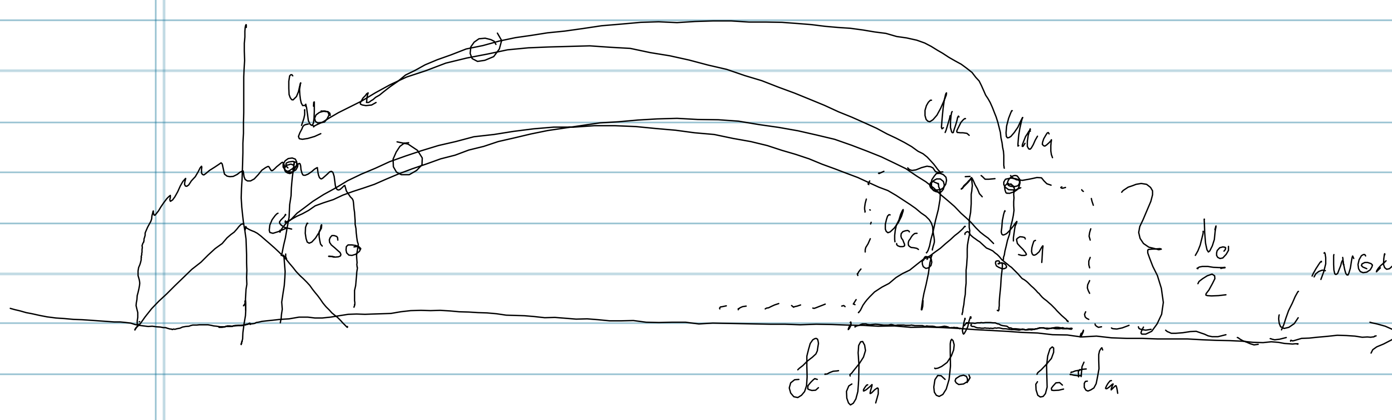
$$= E\left[k_a^2 u_m^2(t)\right] \cdot E\left[\cos^2 \omega_0 t\right]$$

$$= k_a^2 \cdot P \cdot \left(\frac{1}{\sqrt{2}}\right)^2 = \frac{k_a^2 P}{2}$$

Snaga od $u_m(t)$

- Passband, $SNR_{0,AWGN} = ?$

U - rms, efektivne vrijednosti u band širine f_m
L - lower, U - upper



u_{SL} i u_{SU} su korelirane sekvence. Imaju takve faze da nakon KOHERENTNE DEMODULACIJE daju iste sekvence koje se zbrajaju i daju jednu duplo veću.

u_{NL} i u_{NU} su NEkorelirane sekvence. Imaju stohastičke faze pa „ne znamo" što dobivamo nakon demodulacije.

SNAGA ŠUMA na IZLAZU prijemnika (u_{No})

$$P_{NL} = P_{NU} = 2 f_m \cdot \frac{N_o}{2} = N_o f_m \Rightarrow u_{NL} = u_{NU} = \underset{\text{konstanta demodulacije}}{k} \sqrt{P_{NL}} = k\sqrt{N_o f_m}$$

$$\boxed{u_{No} = \sqrt{u_{NL}^2 + u_{NU}^2}} = \sqrt{2} \cdot k \sqrt{N_o f_m} \Rightarrow P_{No} = u_{No}^2 = 2k^2 N_o f_m$$

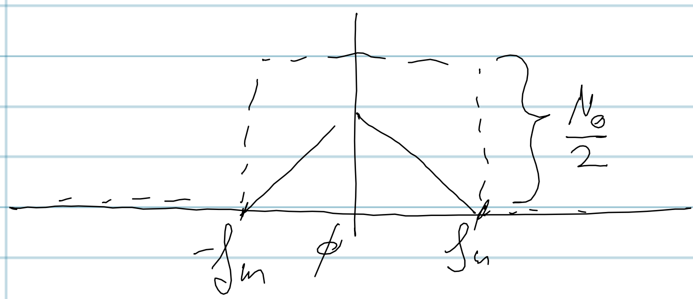
SNAGA SIGNALA na IZLAZU prijemnika

$$P_{SL} = P_{SU} = \underset{\text{snaga 1 banda}}{P_{SSB}} \Rightarrow u_{SL} = u_{SU} = k \cdot \sqrt{P_{SSB}}$$

$$\boxed{u_{SO} = u_{SL} + u_{SU}} = 2k\sqrt{P_{SSB}} \Rightarrow P_{SO} = u_{SO}^2 = 4k^2 \cdot P_{SSB} = 2k^2 \underset{\text{snaga 2 banda}}{P_{DSB}}$$

$$\Rightarrow SNR_o = \frac{P_{So}}{P_{No}} = \frac{\cancel{2k^2} P_{DSB}}{\cancel{2k^2} N_o f_m} = \frac{P_{DSB}}{N_o f_m} = \frac{k_a^2 P}{2 N_o f_m}$$

• BASEBAND prijenos, SNR_c - ?



Snaga šuma u kanalu poruke:

$$P_{NC} = 2 f_m \cdot \frac{N_0}{2} = N_0 f_m$$

Snaga signala u kanalu poruke:

$$P_{SC} = P_{AM} = \frac{U_0^2}{2} + \frac{k_a^2 P}{2} \quad \text{(uvjet za mjeru)}$$

$$\Rightarrow SNR_c = \frac{P_{SC}}{P_{NC}} = \frac{\cancel{N_0 f_m}\, U_0^2 + k_a^2 P}{2 N_0 f_m}$$

Napokon naša mjera:

$$M_{PSBTC-AM, AWGN} = \frac{SNR_0}{SNR_C} = \frac{k_a^2 P}{U_0^2 + k_a^2 P} = \left| m = \frac{k_a |u_m(t)|_{max}}{U_0} \right| =$$

$$= \frac{m^2 P}{|u_m(t)|_{max}^2 + m^2 P} < 1$$

ne isplati se za AWGN

U zadatku $f_0 = 360\,kHz$, $P_0 = 50\,W$, $f_m = 3\,kHz$ $P_{SSB} = 5\,W$

$$S_N(f) = -\frac{10^{-6}}{400}\cdot|f| + 10^{-6}, \quad |f| < 400 \quad kHz$$

$$S_N(f_c) = 10^{-7}\ W/Hz, \quad S_N\left(\frac{f_m}{2}\right) = 9{,}96\cdot 10^{-7}\ W/Hz$$

$$\left.\begin{aligned} P_{DSB} = 2P_{SSB} = \frac{k_a^2 P}{2} &\Rightarrow k_a^2 P = 20 \\ P_0 = \frac{u_0^2}{2} &\Rightarrow u_0^2 = 100 \end{aligned}\right\} \Rightarrow M_{AWGN} = \frac{20}{100+20} = \frac{1}{6}$$

$$M = 9{,}96\cdot\frac{1}{6} = 1{,}66$$ (bolji AM od Baseband)

$$SNR_0 = \frac{P_{DSB}}{N_0 f_m} = \frac{P_{DSB}}{2S_N(f_0)\cdot f_m} = 1{,}67\cdot 10^4 = 42\ dB$$

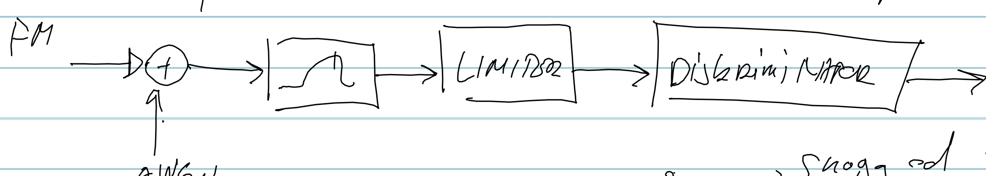
▷

odgovarajućih ~~odgoj~~

(20) Usporedba 2 tipa modulacije obzirom na SNR podrazumijeva usporedbu mjera

$M_{FM} > M_{DSB-TC-AM}$

Za općeniti modulacijski signal, AWGN kanal i direktan prijemnik s BPF-om:



mjera prijenosa FM signala je $M_{FM} = \frac{3k_f^2\cdot P}{f_m^2}$ → snaga od $u_m(t)$

$$\mu_{DSB-TK-AM} = \frac{\frac{m_{AM}^2}{2} P}{|u_m|_{max} + u_{AM}^2 P} = \frac{0,9^2 \cdot 0,08}{0,5^2 + 0,9^2 \cdot 0,08} = 0,2$$

$$\frac{3 k_f^2 P}{f_m^2} > 0,2 \Rightarrow k_f > \sqrt{\frac{0,2 (3 \cdot 10^3)^2}{3 \cdot 0,08}} = 2,78 \text{ kHz/V}$$

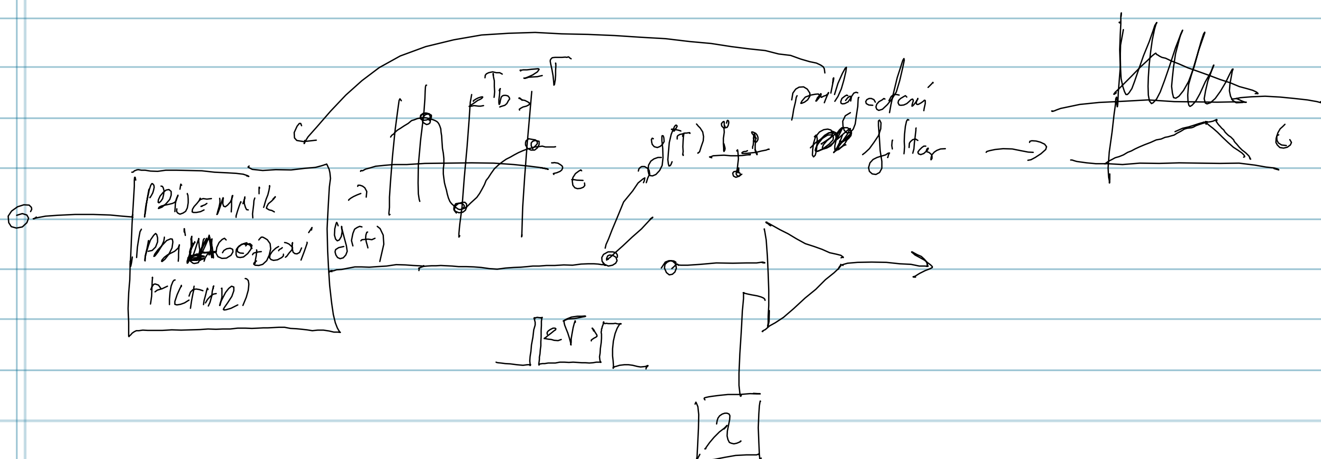
$$m_{fm} = \frac{\Delta f}{f_m} = \frac{k_f \cdot |u_m(t)|_{max}}{f_m}$$

$$> 2,78 \cdot 0,5$$

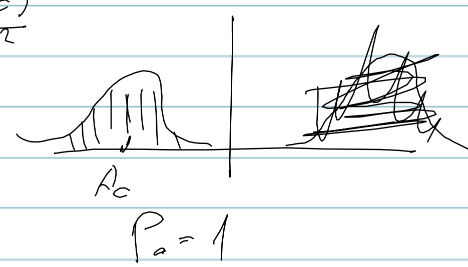
$$m_{FM} > 0,46$$

sad digitalni dio...

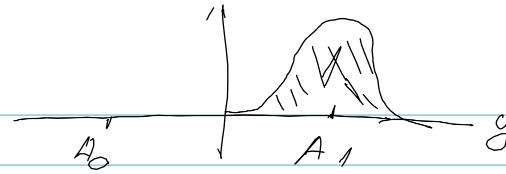
(21)



Neka je Y - slučajni proces koji opisuje signal $y \equiv y(t)$. U našem slučaju imamo binarni prijenos $(M=2)$ s amplitudama $A_0 = -1V$ i $A_1 = 1V$. F-ja gustoće (pdf) vjerojatnosti amplituda su: $f_Y(y|A) = \frac{1}{\sqrt{2\pi}\,\sigma} \cdot e^{-\frac{(y-A)^2}{2\sigma^2}}$



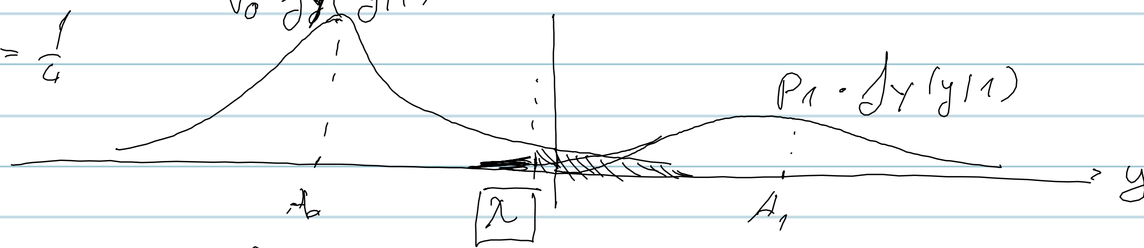
$$f_Y(y|1) = \frac{1}{\sqrt{2\pi}\,\sigma} \cdot e^{-\frac{(y-A_1)^2}{2\sigma^2}}$$



$P_1 = 1$ cijela vjer.. složeno 1.

Vjerojatnost pogreške detekcije bitova (Probability of error detection)

$P_0 = \frac{3}{4}, \; P_1 = \frac{1}{4}$



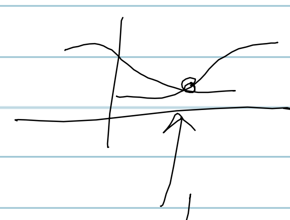
$$P_e = \int_{\lambda}^{\infty} P_0 \cdot f_Y(y|0)\,dy \; \underset{\text{ili}}{+} \int_{-\infty}^{\lambda} P_1 \cdot f_Y(y|1)\,dy$$

$P_e = P_e(\lambda)$

Optimalni λ je onaj koji minimizira P_e.

$$\frac{dP_e}{d\lambda} = 0$$

$$P_0 \underbrace{\frac{d}{d\lambda}\int_{\lambda}^{\infty} f_Y(y|0)\,dy}_{= -f_Y(\lambda|0)} + P_1 \underbrace{\frac{d}{d\lambda}\int_{-\infty}^{\lambda} f_Y(y|1)\,dy}_{= f_Y(\lambda|1)}$$



$$P_0\, f_Y(\lambda|0) = P_1\, f_Y(\lambda|1)$$ ← sjecište

$$\frac{\cancel{\frac{1}{\sqrt{2\pi}\sigma}} \cdot e^{-\frac{(\lambda-A_0)^2}{2\sigma^2}}}{\cancel{\frac{1}{\sqrt{2\pi}\sigma}} \cdot e^{-\frac{(\lambda-A_1)^2}{2\sigma^2}}} = \frac{P_1}{P_0} \quad \Big|\ln \quad \Big| 2\sigma^2$$

$$2\lambda(A_0 - A_1) + A_1^2 - A_0^2 = 2\sigma^2 \ln\frac{P_1}{P_0} \quad \Big/ \text{div } (A_1 - A_0)$$

$$\hookrightarrow = (A_1 - A_0)(A_1 + A_0)$$

$$\lambda = \frac{A_0 + A_1}{2} - \frac{\sigma^2}{A_1 - A_0}\ln\left(\frac{P_1}{P_0}\right) = \frac{-1+1}{2} - \frac{0{,}2^2}{1-(-1)}\ln\frac{1/4}{3/4} = \underline{\underline{0{,}11\,V}}$$

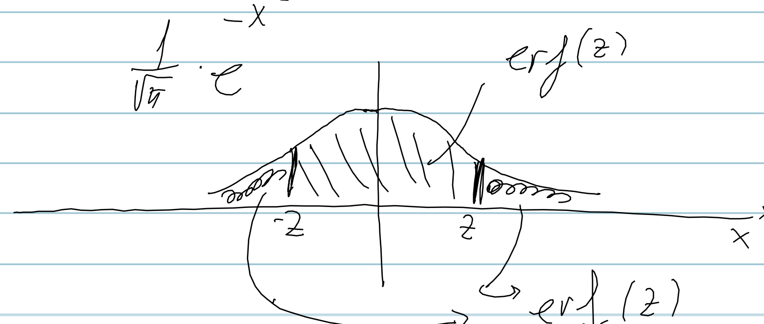
Vraćamo se u Pe

$$P_e = P_0 \int_{\lambda}^{\infty} \frac{1}{\sqrt{2\pi}\,\sigma}\cdot e^{-\frac{(y-A_0)^2}{2\sigma^2}}\,dy + P_1 \int_{-\infty}^{\lambda} \frac{1}{\sqrt{2\pi}\,\sigma}\cdot e^{-\frac{(y-A_1)^2}{2\sigma^2}}\,dy$$

$$= P_0 \cdot \int_{\frac{\lambda - A_0}{\sqrt{2}\,\sigma}}^{\infty} \frac{1}{\sqrt{\pi}}\, e^{-\left(\frac{y-A_0}{\sqrt{2}\,\sigma}\right)^2} d\left(\frac{y-A_0}{\sqrt{2}\,\sigma}\right) + P_1 \int_{-\infty}^{\frac{\lambda - A_1}{\sqrt{2}\,\sigma}} \frac{1}{\sqrt{\pi}}\, e^{-\left(\frac{y-A_1}{\sqrt{2}\,\sigma}\right)^2} d\left(\frac{y-A_1}{\sqrt{2}\,\sigma}\right)$$

(integrali za ERFC fju)

$$\frac{1}{\sqrt{\pi}}\cdot e^{-x^2}$$



$$\text{erf}(z) + \text{erfc}(z) = 1$$

$$P_e = \underset{3/4}{P_0}\cdot\frac{1}{2}\cdot\text{erfc}\Big(\overset{1{,}76}{\frac{\lambda - A_0}{\sqrt{2}\,\sigma}}\Big) + \underset{1/4}{P_1}\cdot\frac{1}{2}\cdot\text{erfc}\Big(\overset{-1{,}41}{\frac{\lambda - A_1}{\sqrt{2}\,\sigma}}\Big) = \underline{\underline{10^{-2}}}$$

(izvod sigurno na ispitu ...)

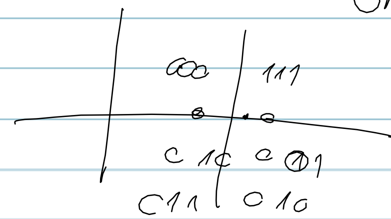
Lakiša!

(22) ASK - binarni prijenos, MASK - M-arni prijenos

$M = 8$ 3 bita po simbolu

Grayev kod

$\sigma^2 = 0{,}07\ V^2$



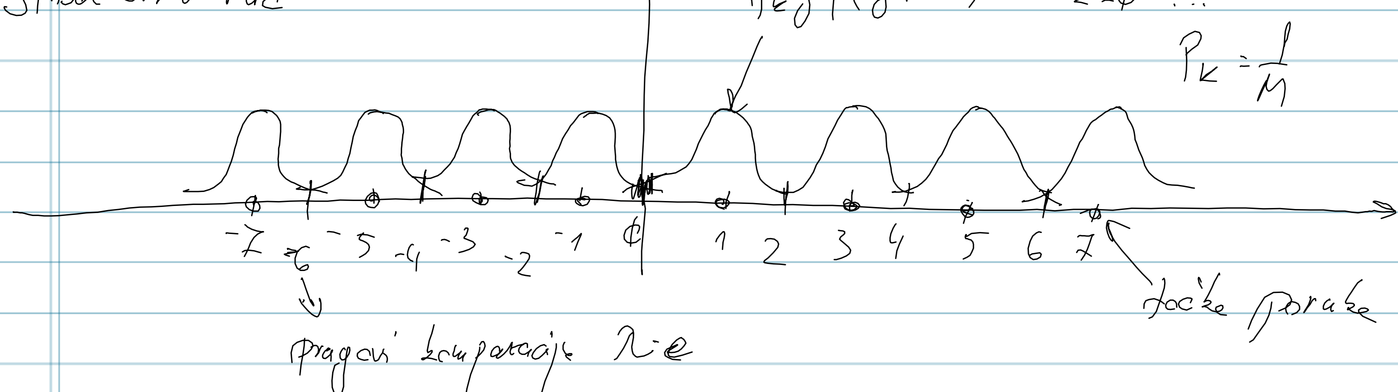
a) Grayev kod

SYB	AMP
000	-7
001	-5
011	-3
010	-1
110	1
111	3
101	5
100	7

b) Simbol error rate

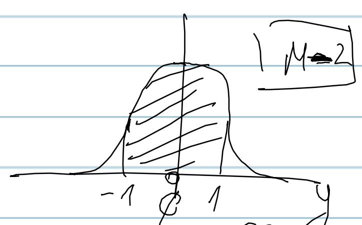
$P_k f_Y(y|x_k)$ $k = 0 \ldots M$

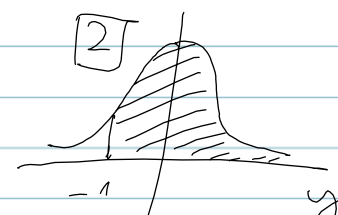
$P_k = \frac{1}{M}$



Vjerojatnost ispravne detekcije simbola (probability of correct detection - P_c, SER)

Translatacija pdf-a ne mijenja SER.





$$P_C = (M-2)\cdot\frac{1}{M}\int_{-1}^{1}\frac{1}{\sqrt{2\pi}\sigma}\cdot e^{\frac{-y^2}{2\sigma^2}}dy + 2\cdot\frac{1}{M}\int_{-1}^{\infty}\frac{1}{\sqrt{2\pi}\sigma}e^{\frac{-y^2}{2\sigma^2}}dy$$

$$P_c = \underbrace{(M-2)\frac{1}{M}}_{\left(1-\frac{2}{M}\right)} \underbrace{\int_{\sigma\sqrt{2}}^{-\frac{1}{\sigma\sqrt{2}}} \frac{1}{\sqrt{\pi}} \cdot e^{-\left(\frac{y}{\sqrt{2}\sigma^2}\right)^2} d\left(\frac{y}{\sqrt{2}\sigma}\right)}_{1-\mathrm{erfc}\left(\frac{1}{\sigma\sqrt{2}}\right)} + \frac{2}{M} \underbrace{\int_{-\frac{\cancel{1}}{\sigma\sqrt{2}}}^{+\infty} \frac{1}{\sqrt{\pi}} \cdot e^{-\left(\frac{y}{\sqrt{2}\sigma^2}\right)^2} d\left(\frac{y}{\sqrt{2}\sigma}\right)}_{1-\frac{1}{2}\mathrm{erfc}\left(\frac{1}{\sigma\sqrt{2}}\right)} =$$

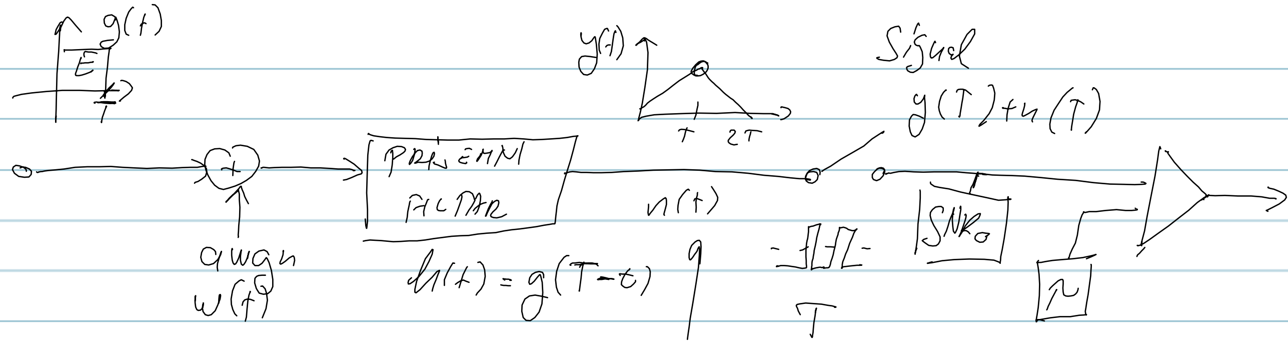
$$P_c = 1 - \frac{M-1}{M}\mathrm{erfc}\left(\frac{1}{\sigma\sqrt{2}}\right)$$

$$P_e \equiv SER = 1 - P_c = \frac{M-1}{M}\mathrm{erfc}\left(\frac{1}{\sigma\sqrt{2}}\right) = \frac{7}{8}\mathrm{erfc}(2{,}67)$$

$$= 1{,}4 \cdot 10^{-4}$$

OSk - Zadnji dio auditornih

23)



SNR ne računamo odmah iza prijemnog filtra već nakon uzorkovanja. Razlog tome je taj što nas ne zanima valni oblik signala između uzorkovanja.

$SNR_{0max} = ?$

$SNR_0 = \frac{P_S}{P_N}$

$P_S = y^2(T)$

$y(t) =$ idemo u frekv. domenu $= \frac{1}{2\pi}\int_{-\infty}^{\infty} G(\omega)\cdot H(\omega) e^{j\omega t}\, d\omega$ IFT.

$$P_S = \frac{1}{(2\pi)^2}\left[\int_{-\infty}^{\infty} G(\omega)H(\omega)\cdot e^{j\omega T}\, d\omega\right]^2$$

Primijenimo Schwartzovu nejednakost

$$\left|\int_{-\infty}^{\infty} f_1(\omega)\cdot f_2(\omega)\, d\omega\right|^2 \leq \int_{-\infty}^{\infty} |f_1(\omega)|^2 d\omega \cdot \int_{-\infty}^{\infty} |f_2(\omega)|^2 d\omega$$

uz uvjet $f_1(\omega) = f_2^*(\omega)$

Označimo $f_1(\omega) = H(\omega)$, $f_2(\omega) = G(\omega)e^{j\omega T}$

Provjerimo uvjet: (sad u vremensku domenu)

$$h(t) = g(T-t) = g[-(t-T)]$$

$$H(s) = G(-s)\cdot e^{-sT}$$

$$H(\omega) = G(-\omega)\cdot e^{-j\omega T} = \left[G(\omega)\cdot e^{j\omega T}\right]^*$$

vrijedi jer je $Re[G(\omega)]$ parna f-ja od ω, a $Im[G(\omega)]$ neparna f-ja od ω.

$$P_S \leq \frac{1}{(2\pi)^2} \int_{-\infty}^{\infty} \underbrace{|G(\omega) e^{j\omega T}|^2}_{|G(\omega)|^2 \cdot \underbrace{|e^{j\omega T}|^2}_{=1}} d\omega \cdot \int_{-\infty}^{\infty} |H(\omega)| d\omega$$

Energija signala (simbola) $g(t)$ se može izraziti pomoću Parsevalove jednadžbe kao

$$E = \frac{1}{2\pi} \int_{-\infty}^{\infty} |G(\omega)|^2 d\omega$$

$$P_S \leq \frac{1}{2\pi} \cdot E \cdot \int_{-\infty}^{\infty} |H(\omega)|^2 d\omega$$

Sad snaga šuma: (snaga obojenog i konačnog signala je jednaka)

$$P_N = \frac{1}{2\pi} \int_{-\infty}^{\infty} S_V(\omega) d\omega = \frac{1}{2\pi} \cdot \int_{-\infty}^{\infty} \underset{\uparrow \text{ulaz}}{\frac{N_0}{2}} \cdot \underset{\uparrow (\text{amp. karakteristika})^2}{|H(\omega)|^2} d\omega = \frac{N_0}{4\pi} \int_{-\infty}^{\infty} |H(\omega)|^2 d\omega$$

$$SNR_0 \leq \frac{P_S}{P_N} \leq \frac{\frac{1}{2\pi} \cdot E \cancel{\int_{-\infty}^{\infty} |H(\omega)|^2 d\omega}}{\frac{N_0}{4\pi} \cdot \cancel{\int_{-\infty}^{\infty} |H(\omega)|^2 d\omega}} = \frac{2E}{N_0}$$

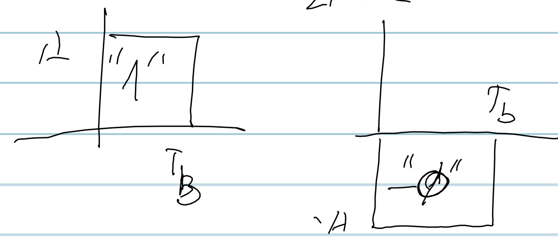
$$SNR_{0MAX} = \frac{2E}{N_0} = \frac{2 \cdot 2 \cdot 10^{-3}}{2 \cdot 10^{-6}} = 2000 = 3\ldots$$

$$= 33\,dB$$

$$\frac{N_0}{2}!$$

Malo o ispitu:

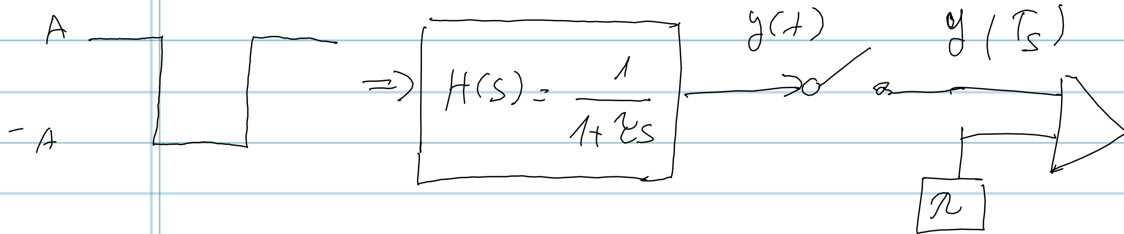
2A i 2 ZVS

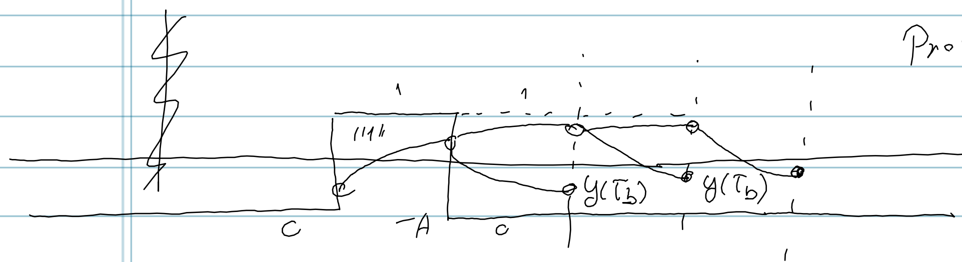


(24) $A = 5\,V$ (nrz $+5 - (-5)$)

$$T_b = \frac{1}{19210} = 52\,\mu s$$

$\tau = 60\,\mu s$ (RC član)





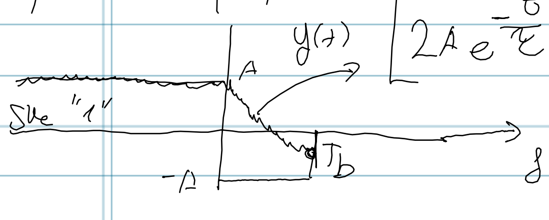
Problem detekcije "0"

$\lambda = 0$ prag komparacije

Smanjuje se vrijednost $y(T_b)$ što je više uzastopnih "1" pa prijelaz u "0".

Ova pojava se zove ISI (Inter Symbol Interference)

Najgori slučaj je beskonačno "1" pa potom "0"



$$y(t) \left[2A e^{-\frac{t}{\tau}} - A\right] \Rightarrow y(T_b) = 2\cdot 5\cdot e^{-\frac{1}{60\cdot 10^{-6}}\cdot 52\cdot 10^{-6}} - 5 = -0{,}8\,V$$

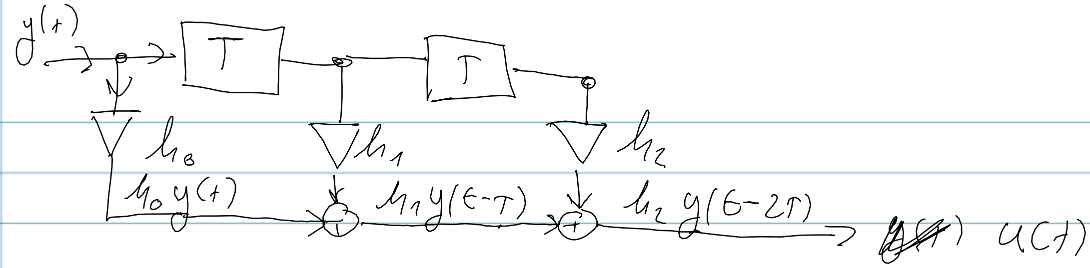
$$\lambda_{min} = -0{,}8\,V$$

$y(T_b) < \lambda_{min}$ detektovano kao "0"

Ista analiza vrijedi za gornji prag $\Rightarrow \lambda_{max} = +0{,}8\,V$

$y(T_b) > \lambda_{max}$ detektovano "1"

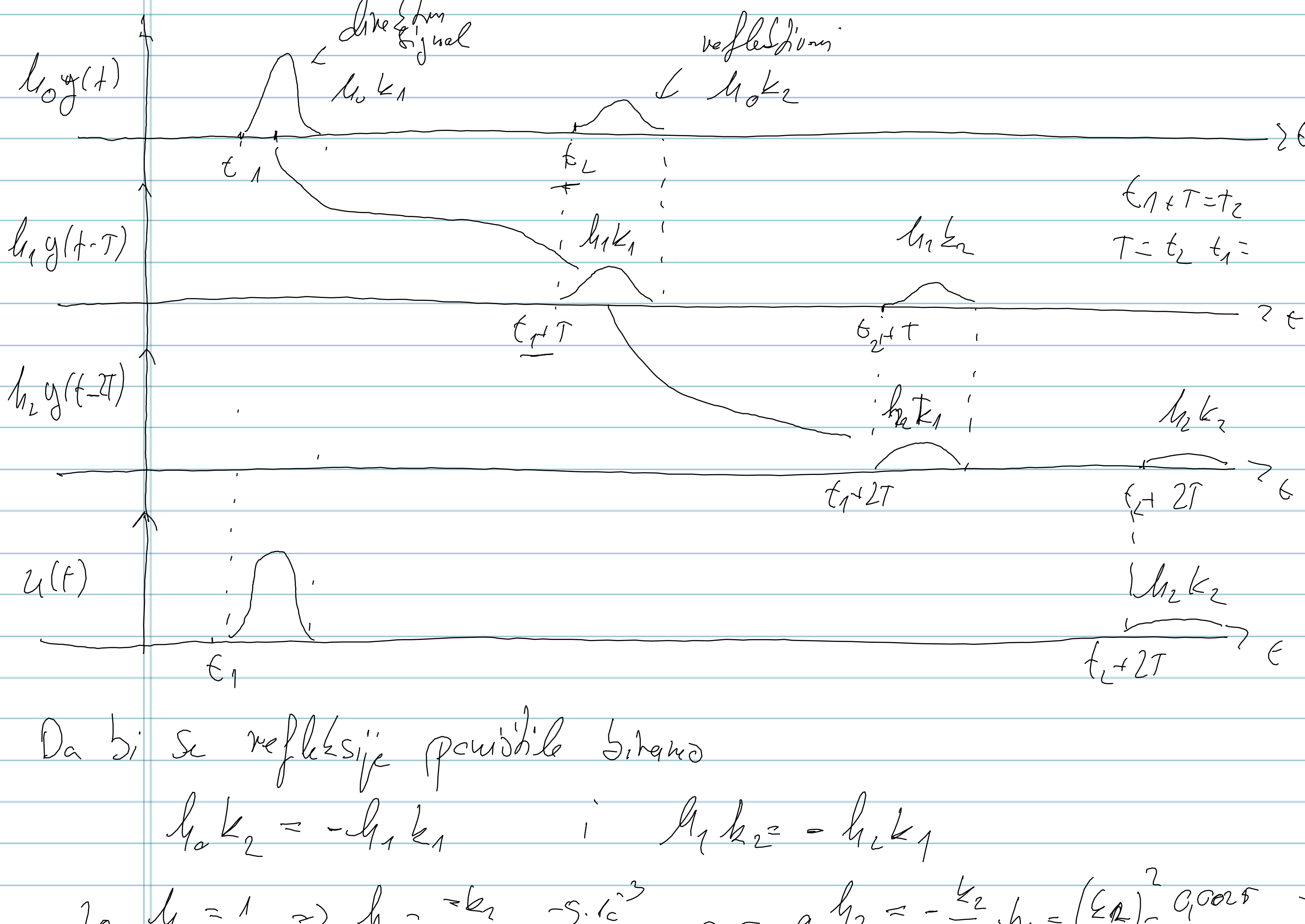
25



$$y(t) = k_1 x(t-t_1) + k_2 x(t-t_2)$$

$k_1 = 0,1$, $k_2 = 5 \cdot 10^{-3}$ $\Rightarrow$ $k_2 << k_1$

$t_1 = 2ms$, $t_2 = 6 ms$



Da bi se refleksije poništile biramo

$h_0 k_2 = -h_1 k_1$ i $h_1 k_2 = -h_2 k_1$

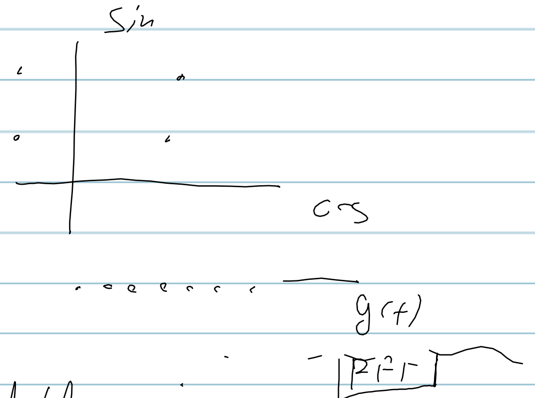
Za $h_0 = 1$ $\Rightarrow$ $h_1 = \frac{-k_2}{k_1} = \frac{-5 \cdot 10^{-3}}{0,1} = -0,05$, a $h_2 = -\frac{k_2}{k_1} \cdot h_1 = \left(\frac{k_2}{k_1}\right)^2 = 0,0025$,

$$\Rightarrow u(t) = k_1 \cdot x(t-T_1) + \left(\frac{k_2}{k_1}\right)^2 \cdot k_2\, x(t-\tau_1)$$

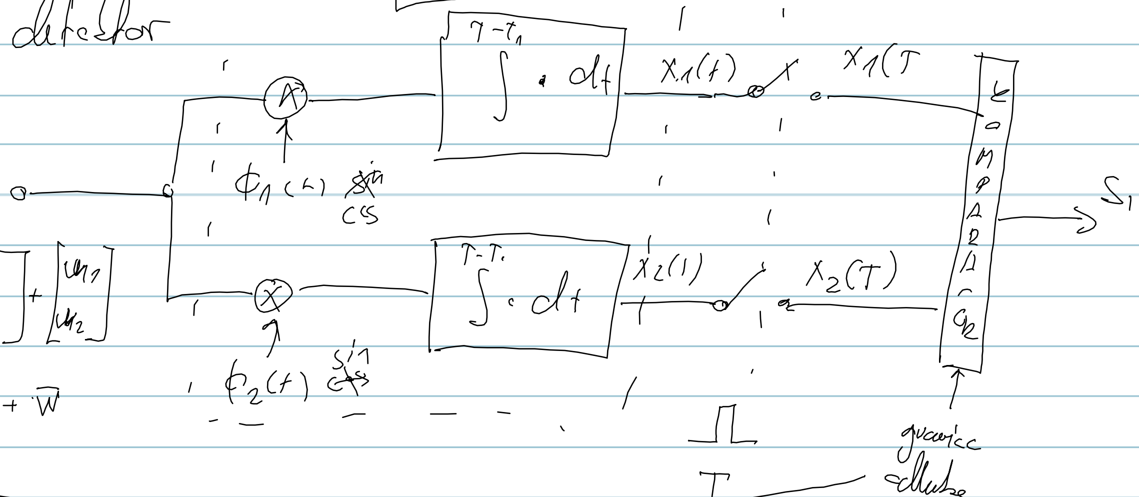
Korektor je smanjio utjecaj refleksije $\frac{1}{0{,}0025} \Rightarrow$ 400 puta

Smanjenje je veće što je veći red korektora.

(26)

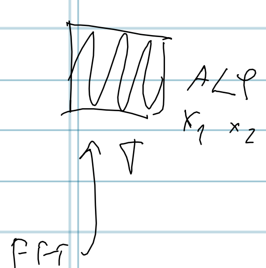


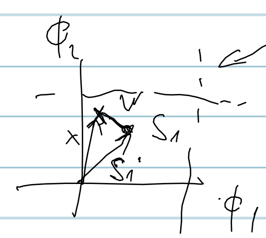
QAM detektor



$$\begin{bmatrix}x_1\\x_2\end{bmatrix} = \begin{bmatrix}s_{i1}\\s_{i2}\end{bmatrix} + \begin{bmatrix}w_1\\w_2\end{bmatrix}$$

$$\bar{X} = \bar{S} + \bar{W}$$



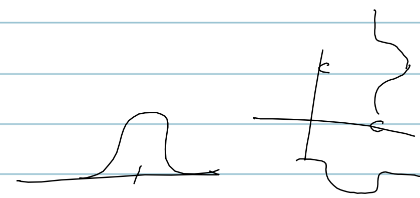


Neka je $\underline{X} = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$ 2D proces (slučajni) koji opisuje signal

$\underline{X} = \underline{x}(T) = \begin{bmatrix} x_1(T) \\ x_2(T) \end{bmatrix}$. Kod koherentne detekcije varijanca šuma u signalima $x_1(T)$ i $x_2(T)$ su: $\sigma_{x_1}^2 = \sigma_{x_2}^2 = \frac{N_0}{2}$ (bez izvoda)

F-je gustoća vj. amplituda su:

$$f_{x_1}(x_1 | S_i) = \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(x_1 - S_{i1})^2}{N_0}}$$

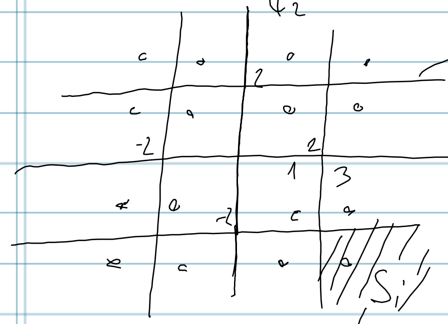


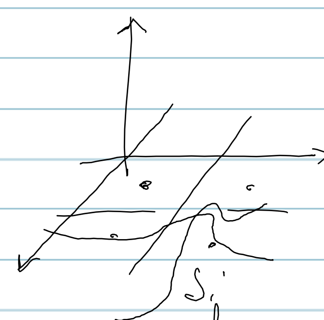
i

$$f_{x_2}(x_2 | S_i) = \frac{1}{\sqrt{\pi N_0}} e^{-\frac{(x_2 - S_{i2})^2}{N_0}}$$

$$f_{\underline{x}}(\underline{x} | S_i) = \underbrace{f_{x_1}}_{(x_1|S_i)} \cdot f_{x_2}(x_2|S_i) = \frac{1}{\pi N_0} e^{-\frac{(x_1 - S_{i1})^2 + (x_2 - S_{i2})^2}{N_0}}$$

Vjerojatnost ispravne detekcije simbola S_i je volumen ispod polja f-je $\phi_i \cdot f_{\underline{x}}(\underline{x} | S_i)$ unutar njegovih granica odluke.

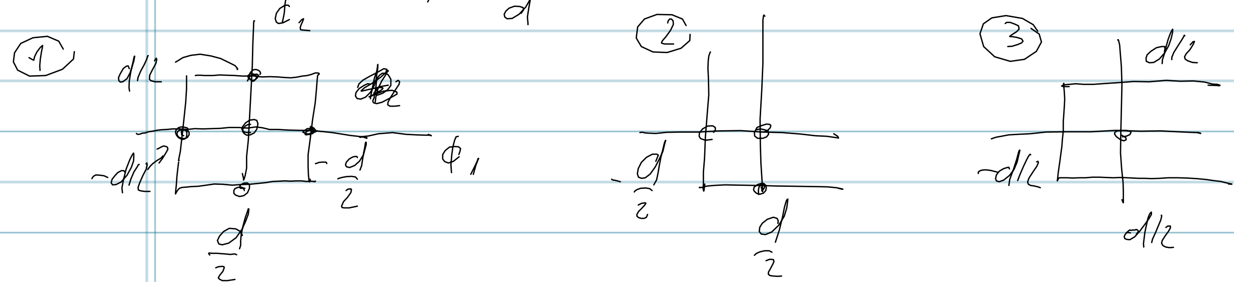




Translatacija i rotacija konstelacije ne mijenjaju SER. Stoga, za lakši račun svaku točku poravnat (odnosno njenu PDF $f_x(x)$) translatiramo u ishodište prostora signala.

Razlikujemo 3 tipa područja integracije

(razmak 2 točke je d)



$$P_C = 4\cdot\frac{1}{16}\cdot\int_{-\frac{d}{2}}^{d/2}\int_{-\frac{d}{2}}^{d/2}\frac{1}{\pi\cdot N_0}\, e^{-\frac{x_1^2+x_2^2}{N_0}}\,dx_1\,dx_2 + 4\cdot\frac{1}{16}\int_{-\frac{d}{2}}^{\infty}\int_{-\frac{d}{2}}^{\infty}\frac{1}{\pi N_0}\, e^{-\frac{x_1^2+x_2^2}{N_0}}\,dx_1\,dx_2 +$$

$$+ 8\cdot\frac{1}{16}\int_{-\frac{d}{2}}^{+\frac{d}{2}}\int_{-\frac{d}{2}}^{+\infty}\frac{1}{\pi N_0}\cdot e^{\frac{-(x_1^2+x_2^2)}{N_0}}\,dx_1\,dx_2$$

Prvi dvostruki integral $\frac{1}{4}\cdot\frac{1}{\pi N_0}\cdot\underbrace{\int_{-\frac{d}{2}}^{d/2} e^{-\frac{x_1^2}{N_0}}\,dx_1}_{\text{Svodim na ERFC}}\cdot\int_{-\frac{d}{2}}^{d/2} e^{-\frac{x_2^2}{N_0}}\,dx_2 = \frac{1}{4}(1-p)^2$

$p = \frac{1}{2}\,\mathrm{erfc}\left(\frac{1}{2N_0}\right.$

Drugi: $\frac{1}{4}(1-p\cdot 2)^2$ Treći: $\frac{1}{2}\,(1-p)\,(1-2p)$

$P_e = \left(1-\frac{3}{2}p\right)^2$, $P_e = 1-P_C = 2,$ [illegible]