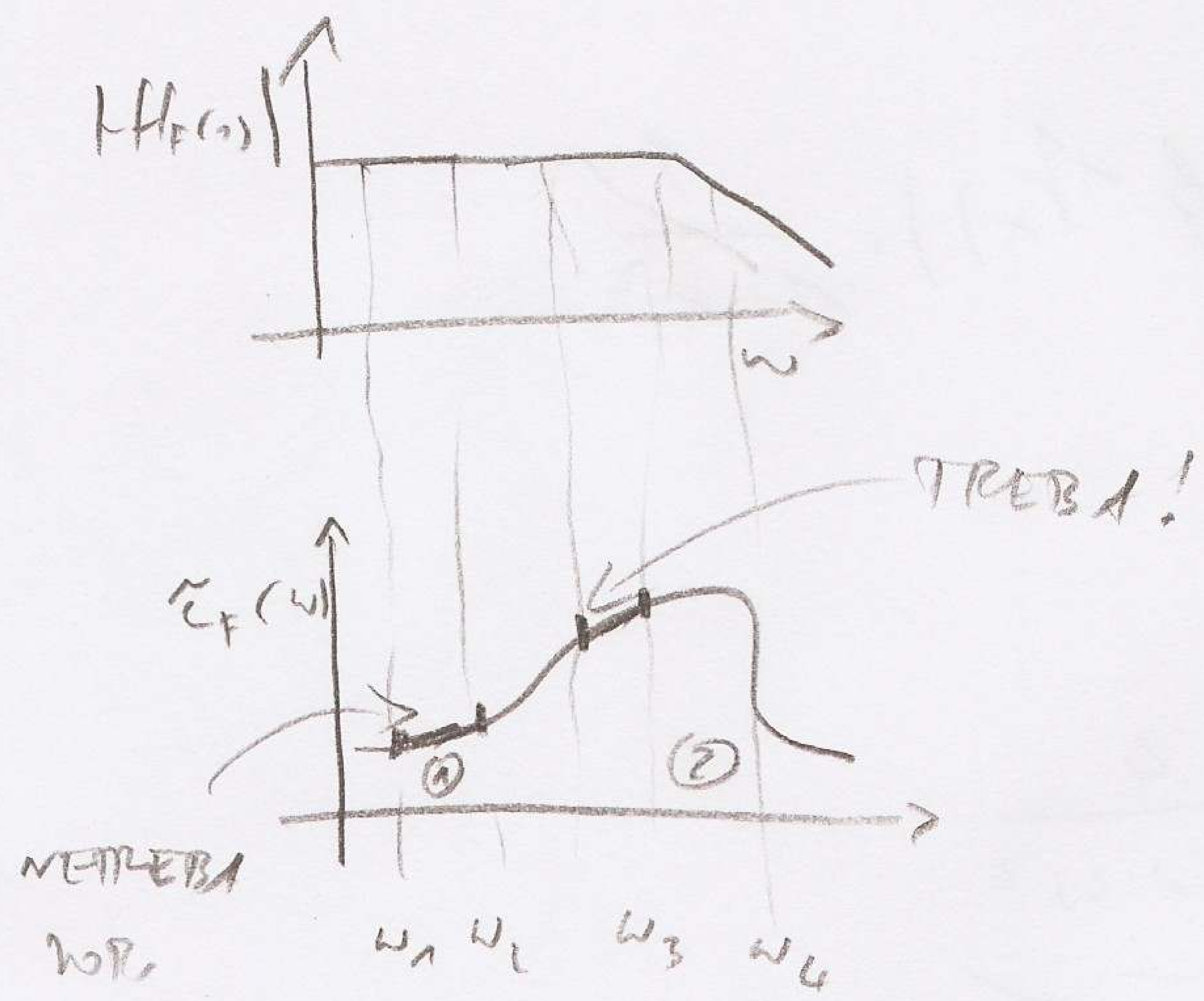
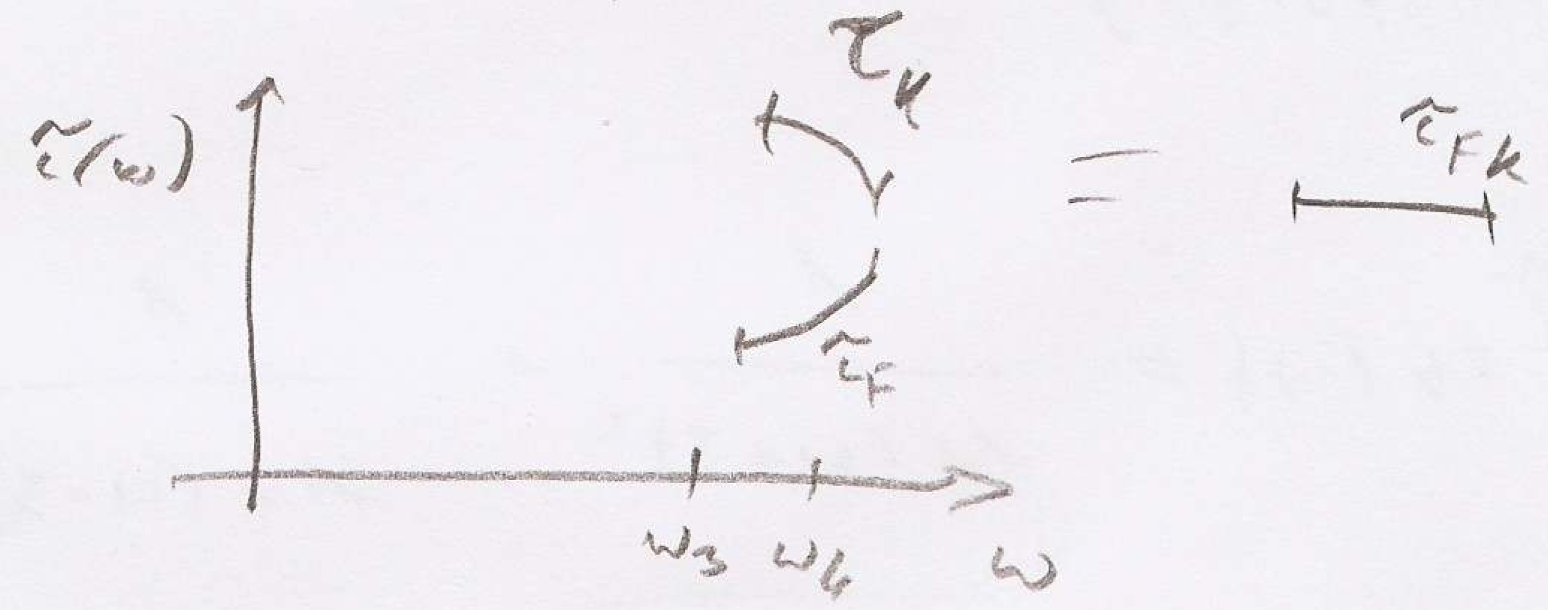
1. NP 2.

$$H_F(s) = \frac{10}{s^2+2s+10}$$

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

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





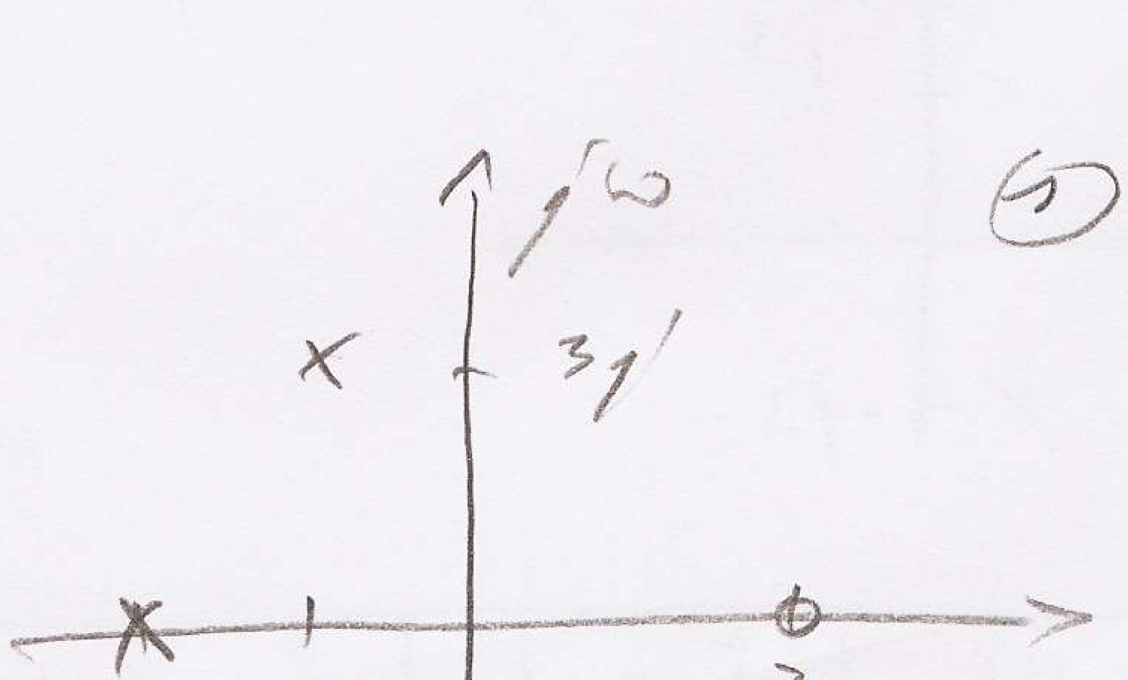
U području 1 nije potrebna korekcija, a području 2 je potrebna.

a) Polovi filtra

kaskada

$s^2+2s+10=0$

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



Polovi korektora

$s+2=0$

$p_K=-2$

Nule korektora

$s-2=0$

$z_K=2$

U digitalnom su #nule = #polovi, nule u ishodištu

b) Grupno kašnjenje

1. faktorizacija!

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

$$s = j\omega$$

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

$$\varphi_{FK}(\omega) = \underbrace{-tg^{-1}(\omega+3) - tg^{-1}(\omega-3)}_{=\varphi_F(\omega)} \underbrace{-2\cdot tg^{-1}\left(\frac{\omega}{2}\right)}_{=\varphi_K(\omega)}$$

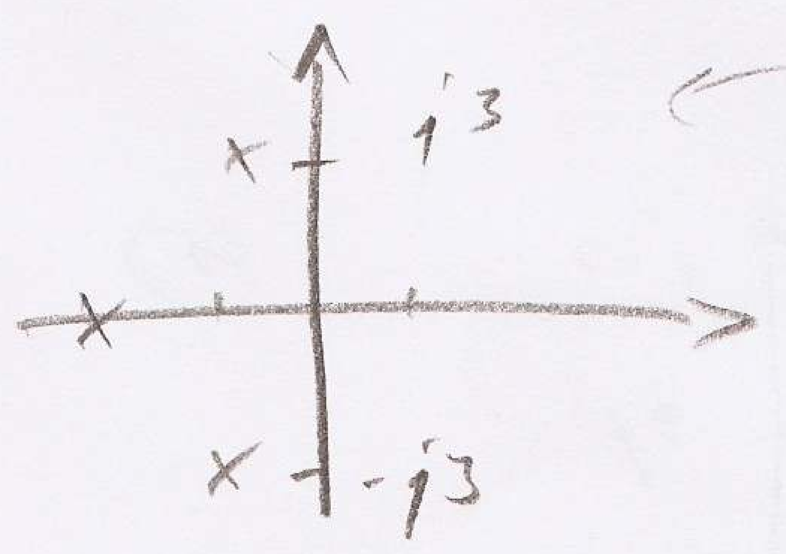
$$\tilde{\tau}_{FK}(\omega) = -\frac{d}{d\omega}\varphi_{FK}(\omega)$$

↳ GRUPA FREKVENCIJA (PODRUČJE)

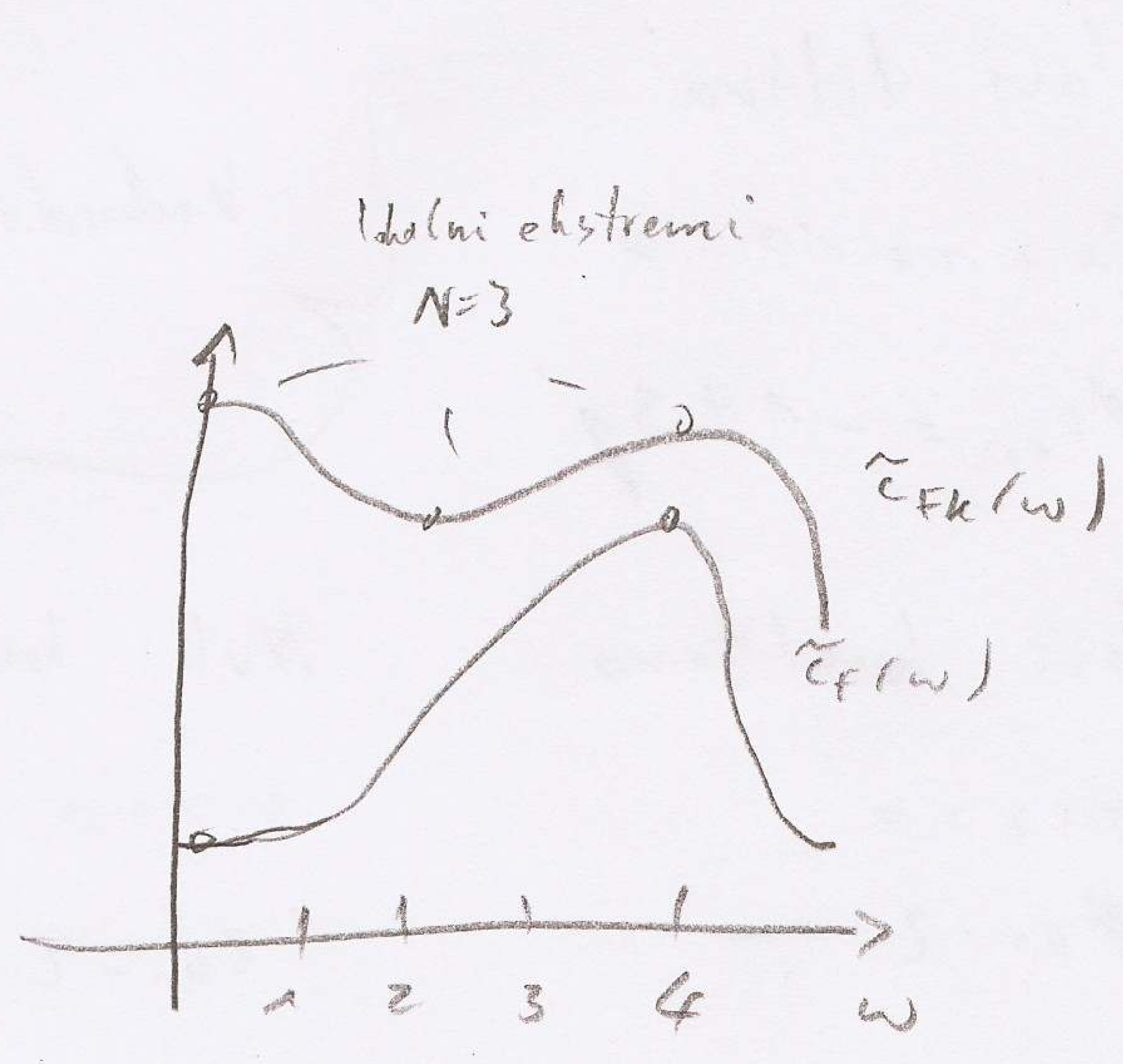
$$\left(tg^{-1}(x)\right)' = \frac{1}{1+x^2}$$

$$\tilde{\tau}_{FK}(\omega) = \underbrace{\frac{1}{1+(\omega+3)^2} + \frac{1}{1+(\omega-3)^2}}_{=\tilde{\tau}_F(\omega)} + \underbrace{\frac{4}{4+\omega^2}}_{=\tilde{\tau}_K(\omega)}$$

Koji ω uzeti? Očitavanjem iz polova.

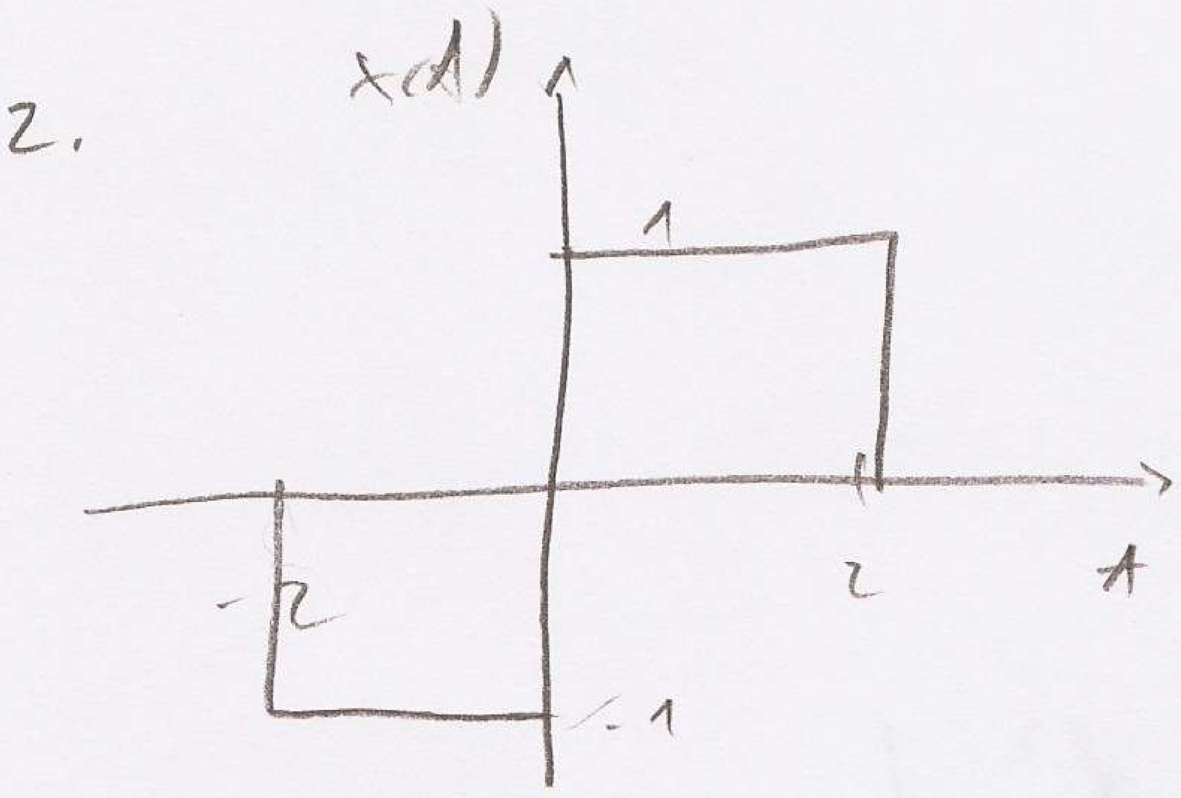


ω	$\tilde{\tau}_F(\omega)$	$\tilde{\tau}_{FK}(\omega)$
0	0,2	1,2
1	0,3	1,1
2	0,5	1
3	1	1,3
4	0,5	0,7
5	0,2	0,4



1. U nekim slučajevima se iz krivulje grupnog kašnjenja (i amplitude) može izravno očitati red sustava. To je broj svih lokalnih ekstrema.

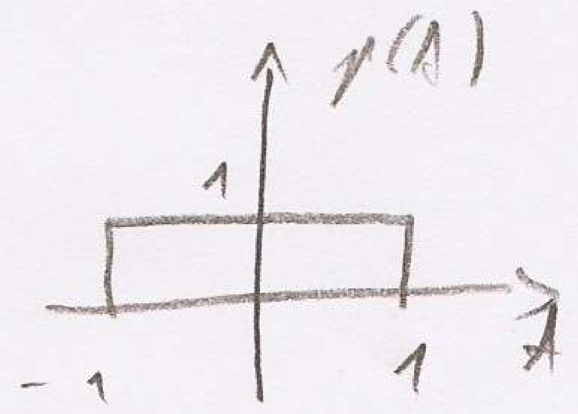
2.



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

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

Uvodimo signal



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

HT je linearan operator.

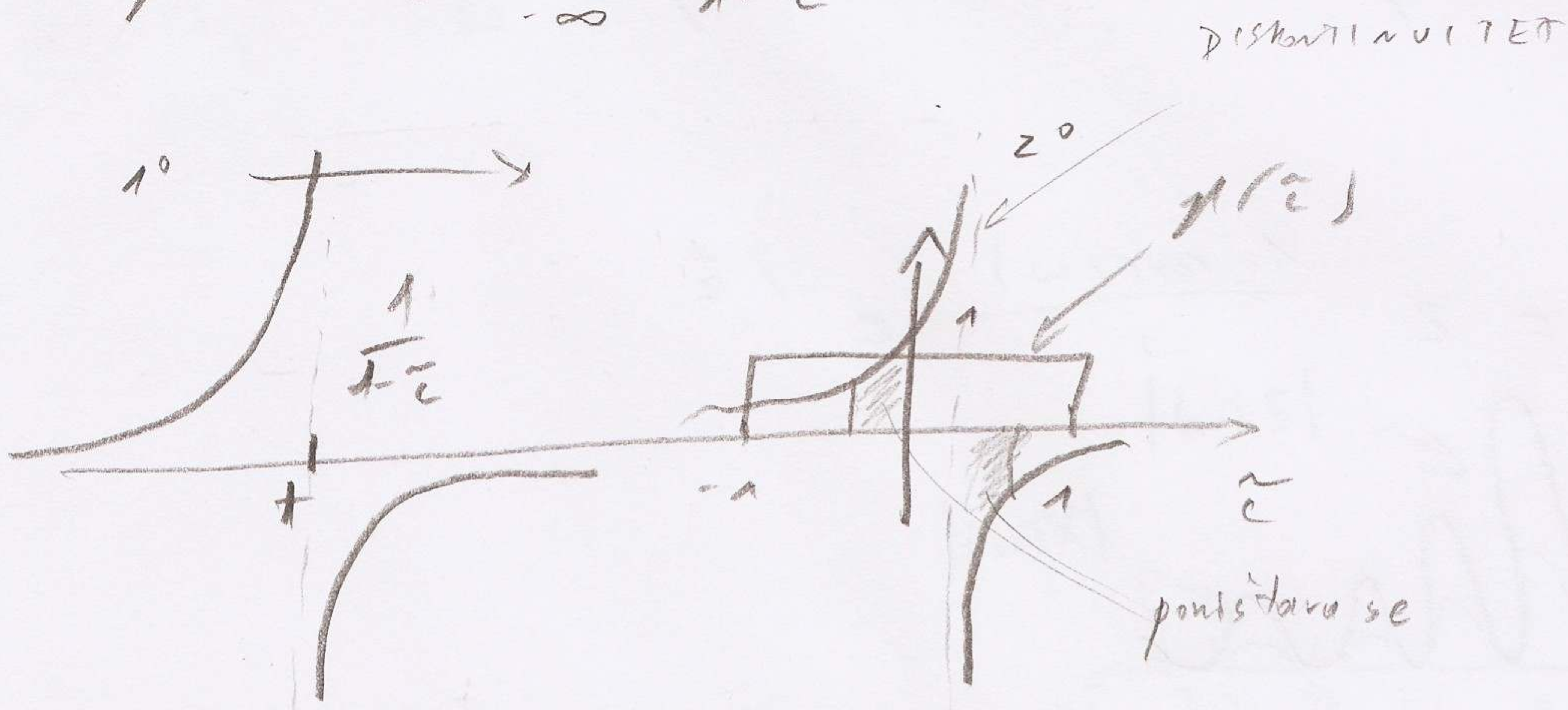
$$\hat{x}(t) = \hat{p}(t-1) - \hat{p}(t+1) \Rightarrow \hat{p}(t) = ?$$

Računanje HT:

1) izravno, računanjem Hilbertovog integrala

2) neizravno, prebacivanjem u FD, a potom računanjem IFT

$$\hat{p}(t) = \frac{1}{\pi} \mathrm{PV} \int_{-\infty}^{\infty} \frac{p(\tau)}{t-\tau} d\tau$$



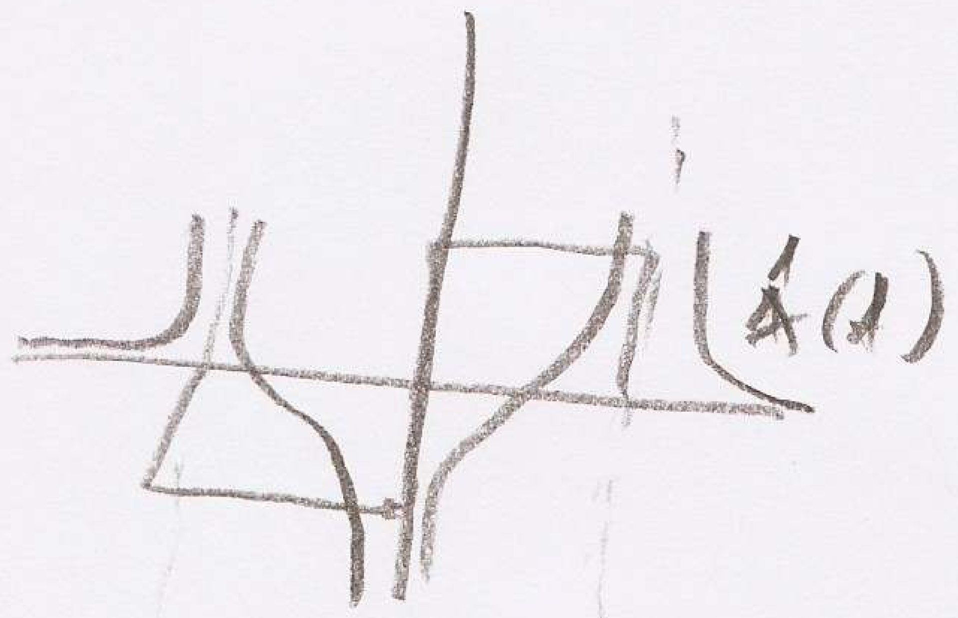
$1^\circ \quad t \le -1, \; t \ge 1$

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

$2^\circ \quad -1 \le t \le 1$

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

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



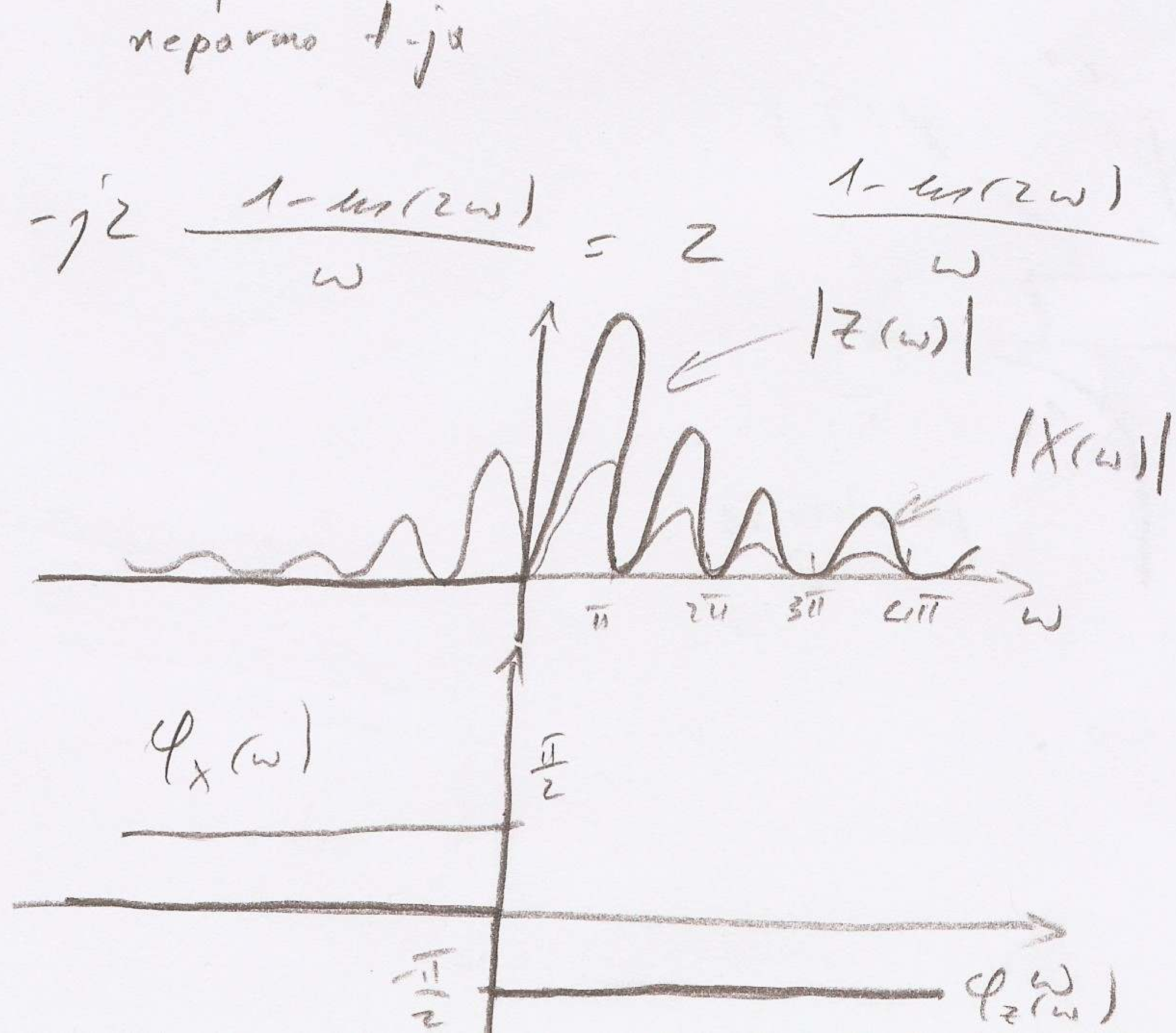
$Z(\omega) = ?$

$$Z(\omega) = \begin{cases} 0, & \omega < 0 \\ X(\omega), & \omega = 0 \\ 2X(\omega), & \omega > 0 \end{cases}$$

$$X(\omega) = \int_{-\infty}^{\infty} x(t) e^{-j\omega t}\, dt = -j2\int_{0}^{2} 1 \cdot \sin(\omega t)\, dt = j2\,\underbrace{\frac{\cos(2\omega)-1}{\omega}}_{\le 0} =$$

neparna f-ja

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



3.

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

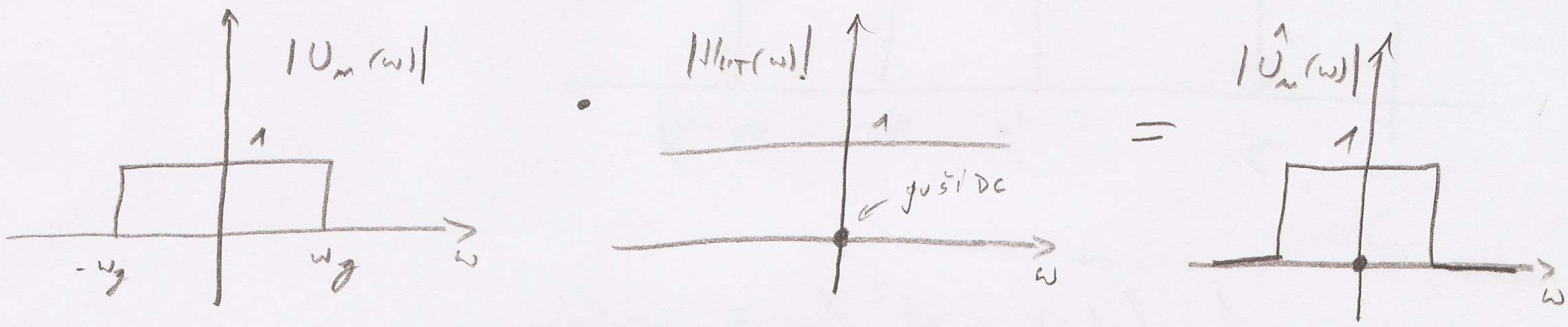
NENORMIRANA – $\frac{\sin(x)}{x}$

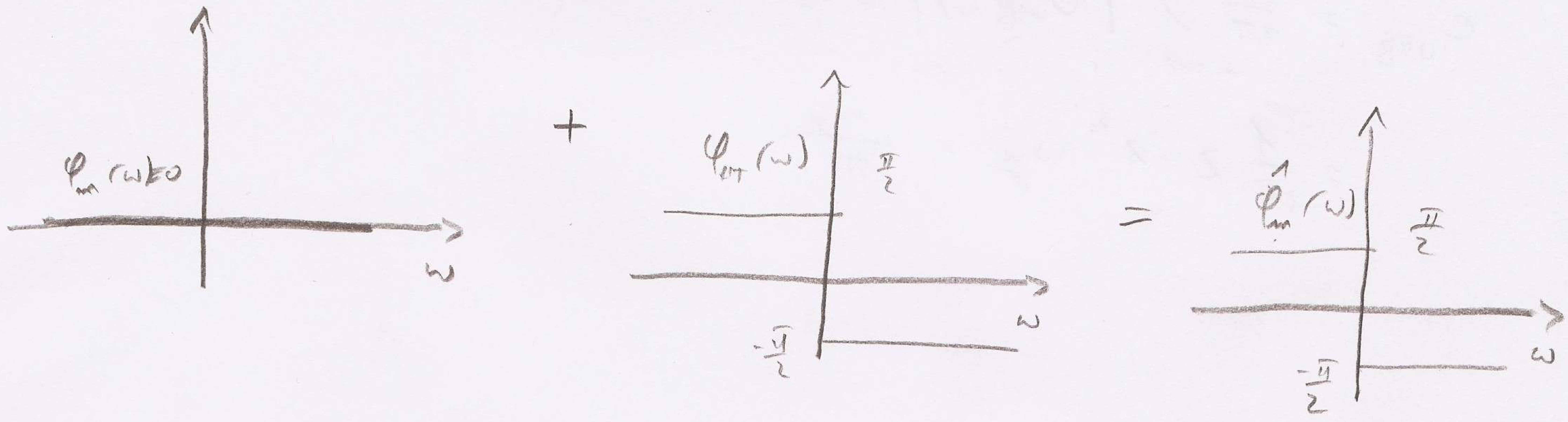
$$u_{SSB}(t) = u_m(t)\cdot\cos(\omega_0 t) \overset{LSB}{\underset{USB}{\pm}} \hat{u}_m(t)\cdot\sin(\omega_0 t)$$

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

$$\hat{U}_m(\omega) = U_m(\omega)\cdot H_{HT}(\omega)$$ (neizravno rač.)

$$H_{HT}(\omega) = -j\,\mathrm{sgn}(\omega)$$

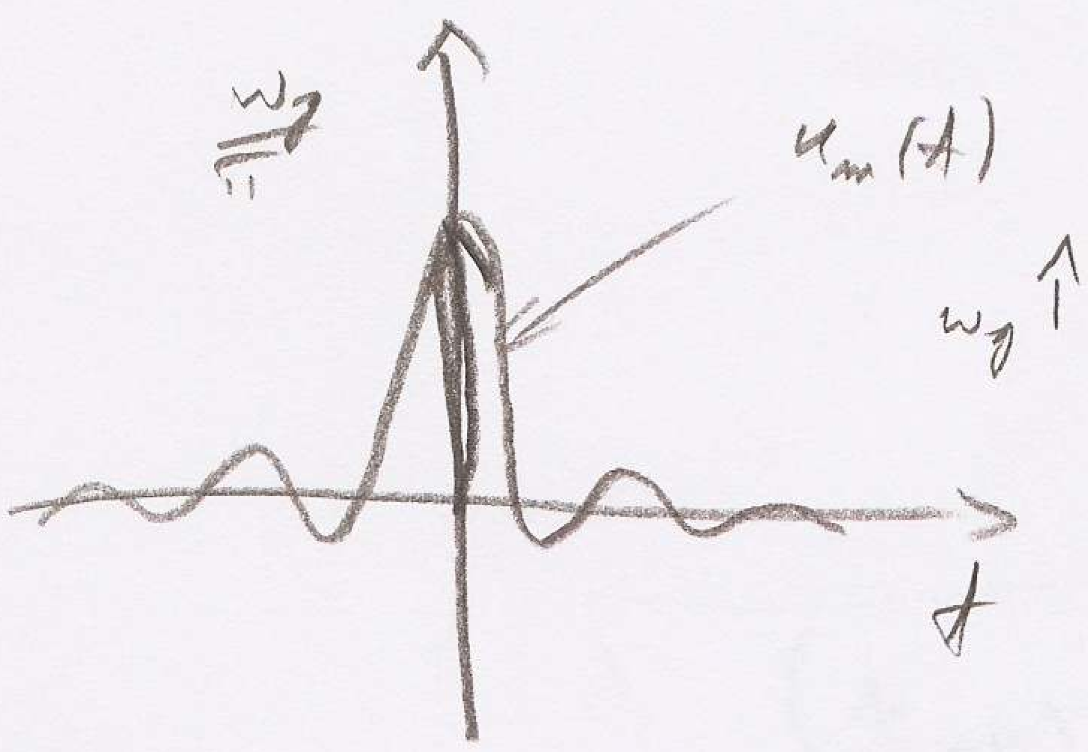


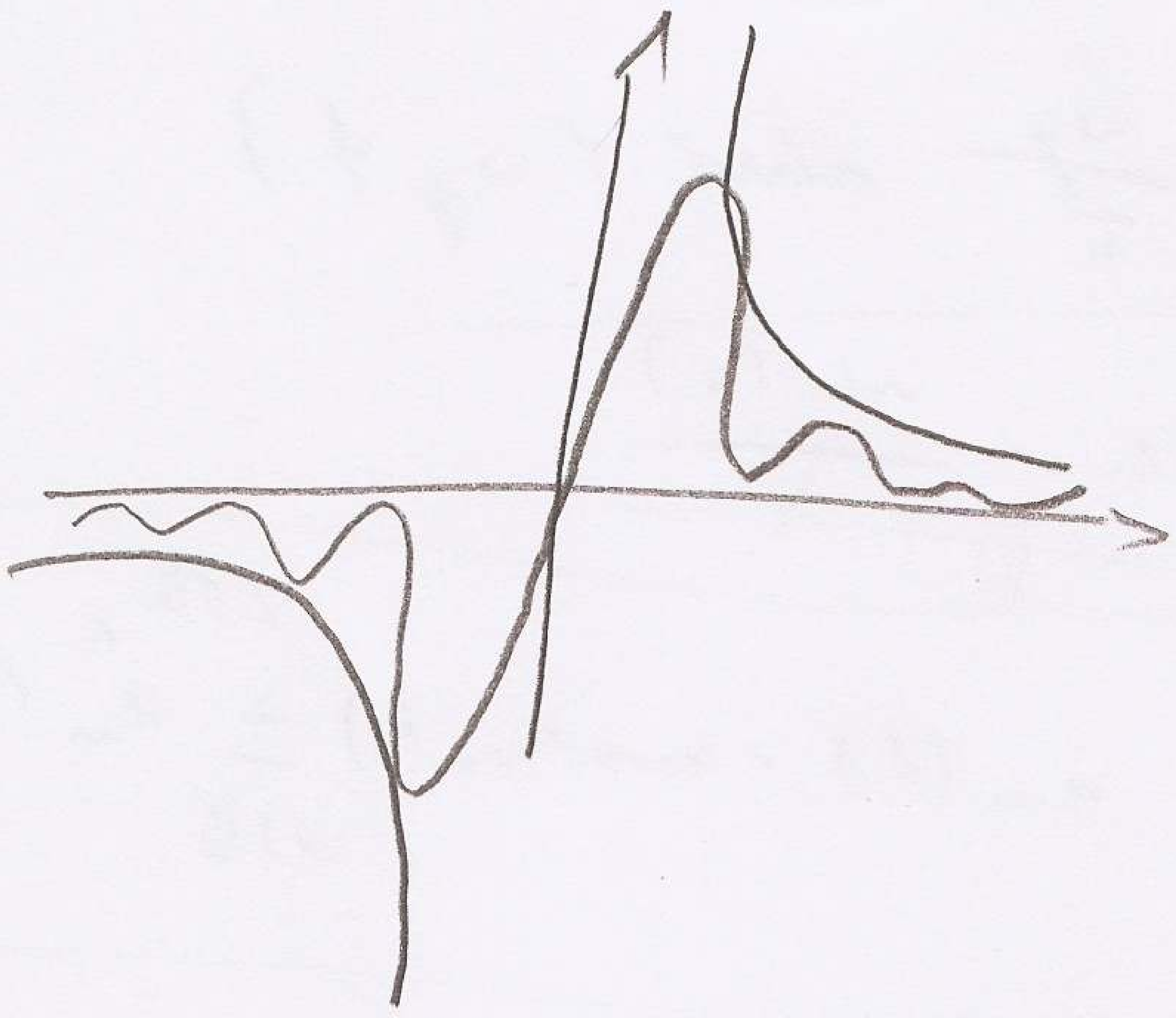


$$\hat{u}_m(t) = \frac{1}{2\pi}\int_{-\infty}^{\infty}\hat{U}_m(\omega)\,e^{j\omega t}\,d\omega =$$

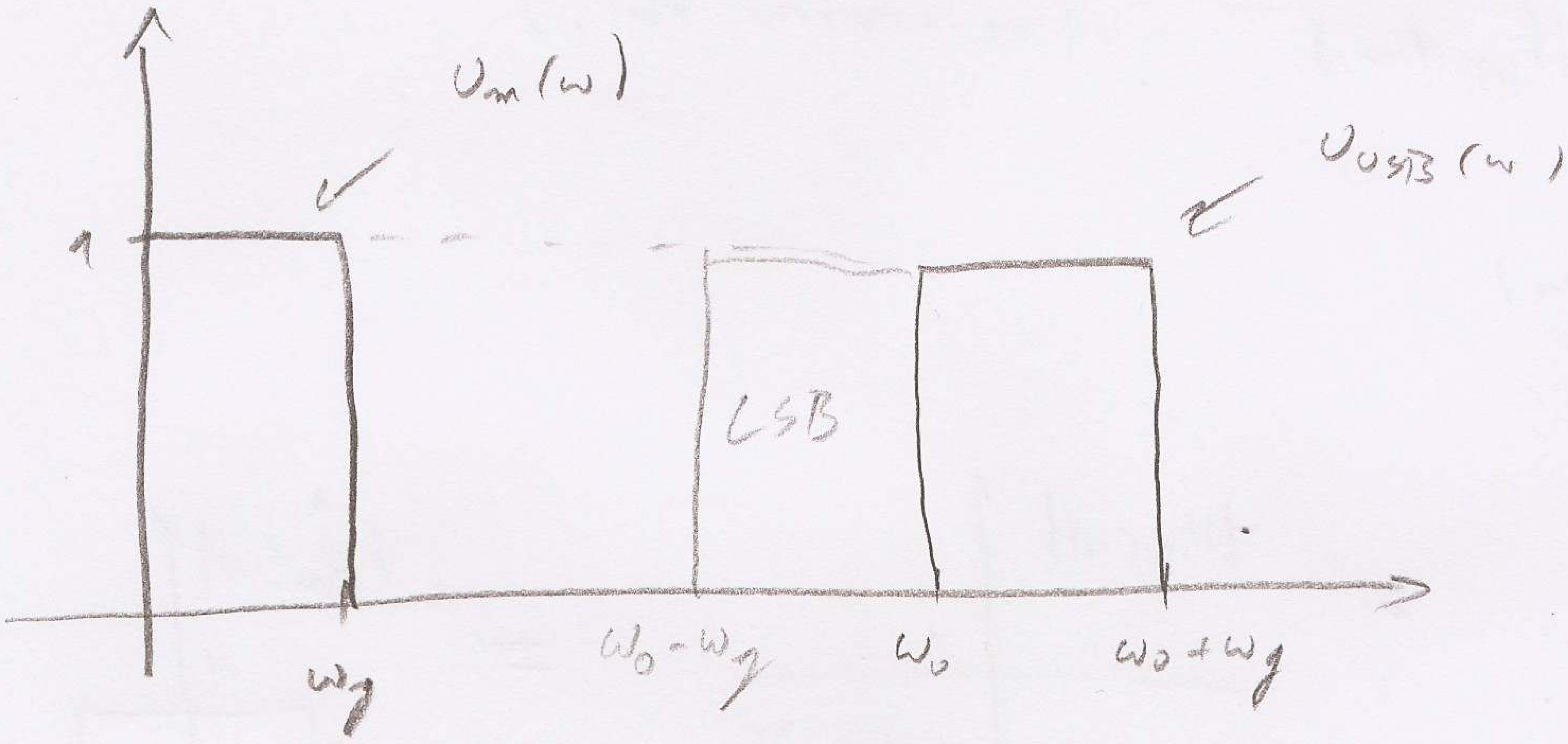
$$= \frac{1}{2\pi}\left\{\int_{-\omega_g}^{0} 1\cdot e^{j\frac{\pi}{2}}\cdot e^{j\omega t}\,d\omega + \int_{0}^{\omega_g} 1\cdot e^{-j\frac{\pi}{2}}\cdot e^{j\omega t}\,d\omega\right\} =$$

$$= \frac{1}{2\pi}\,\frac{1 - e^{-j\omega_g t} - e^{j\omega_g t} + 1}{t} = \frac{1-\cos(\omega_g t)}{\pi t}$$





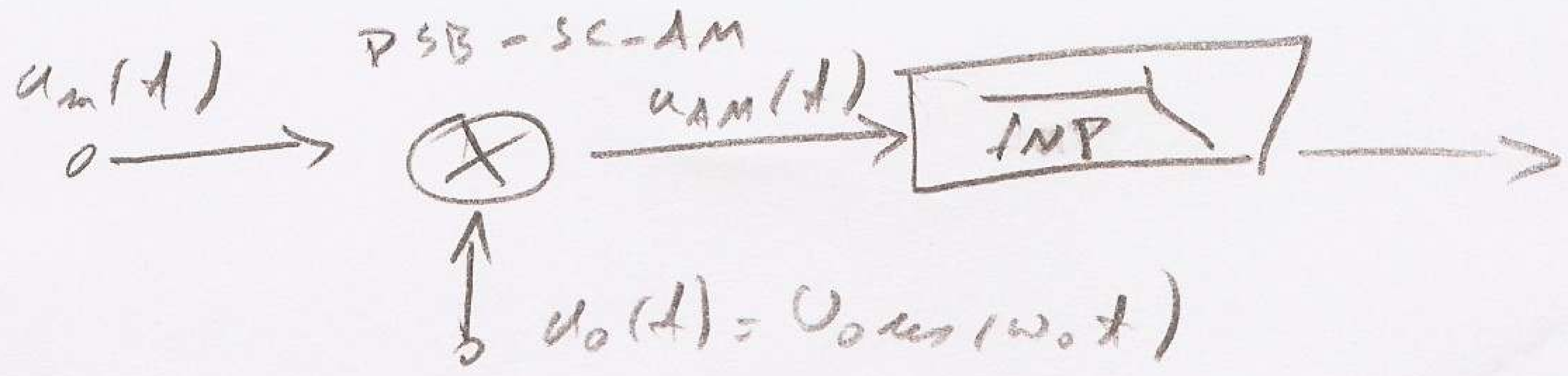
$$u_{USB}(t) = \frac{\omega_g}{\pi} \operatorname{sinc}(\omega_g t) \cos(\omega_0 t) - \frac{1-\cos(\omega_g t)}{\pi t} \sin(\omega_0 t)$$



$$e_{USB} = \frac{1}{2\pi} \int_{-\infty}^{+\infty} |U_{USB}(\omega)|^2 d\omega =$$

$$= \frac{1}{2\pi} 2 \cdot 1^2 \cdot \omega_g = \frac{\omega_g}{\pi}$$

4.



$f_{NP} = 3.4$ kHz $= f_g$

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

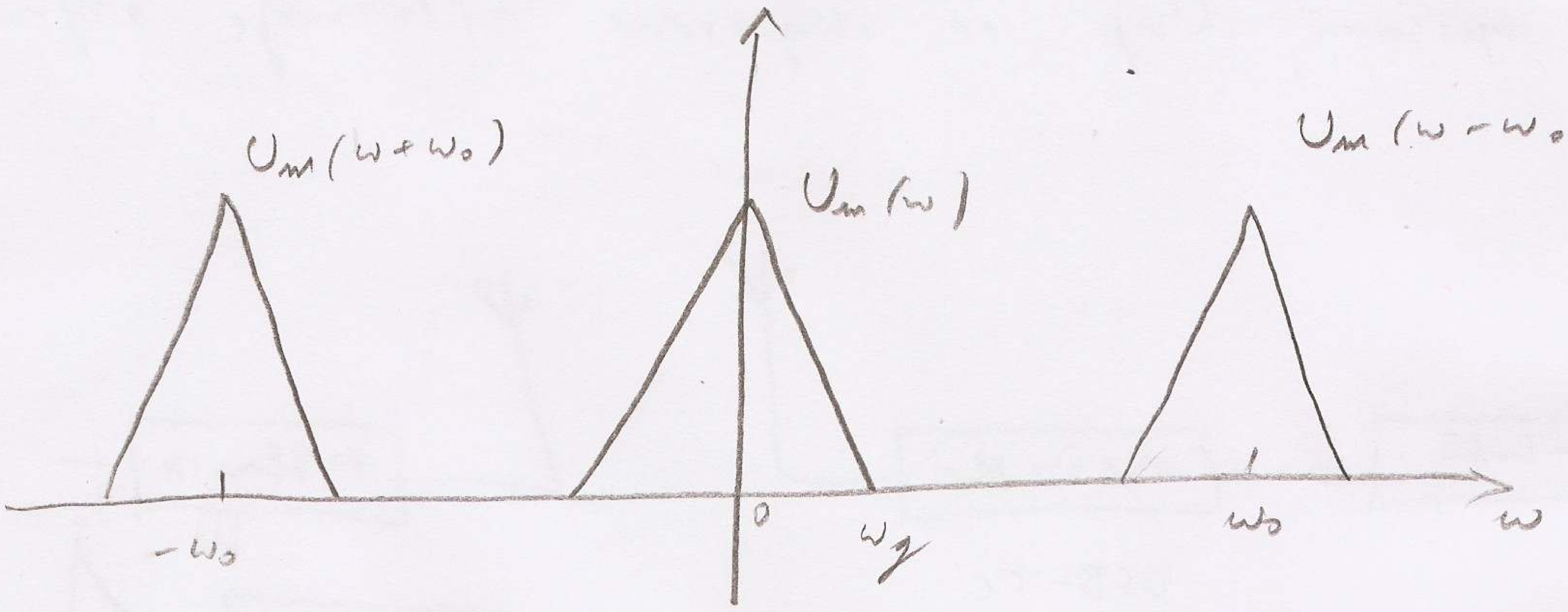
$f_g = 3.4$ kHz

$f_0 = 3.6$ kHz

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

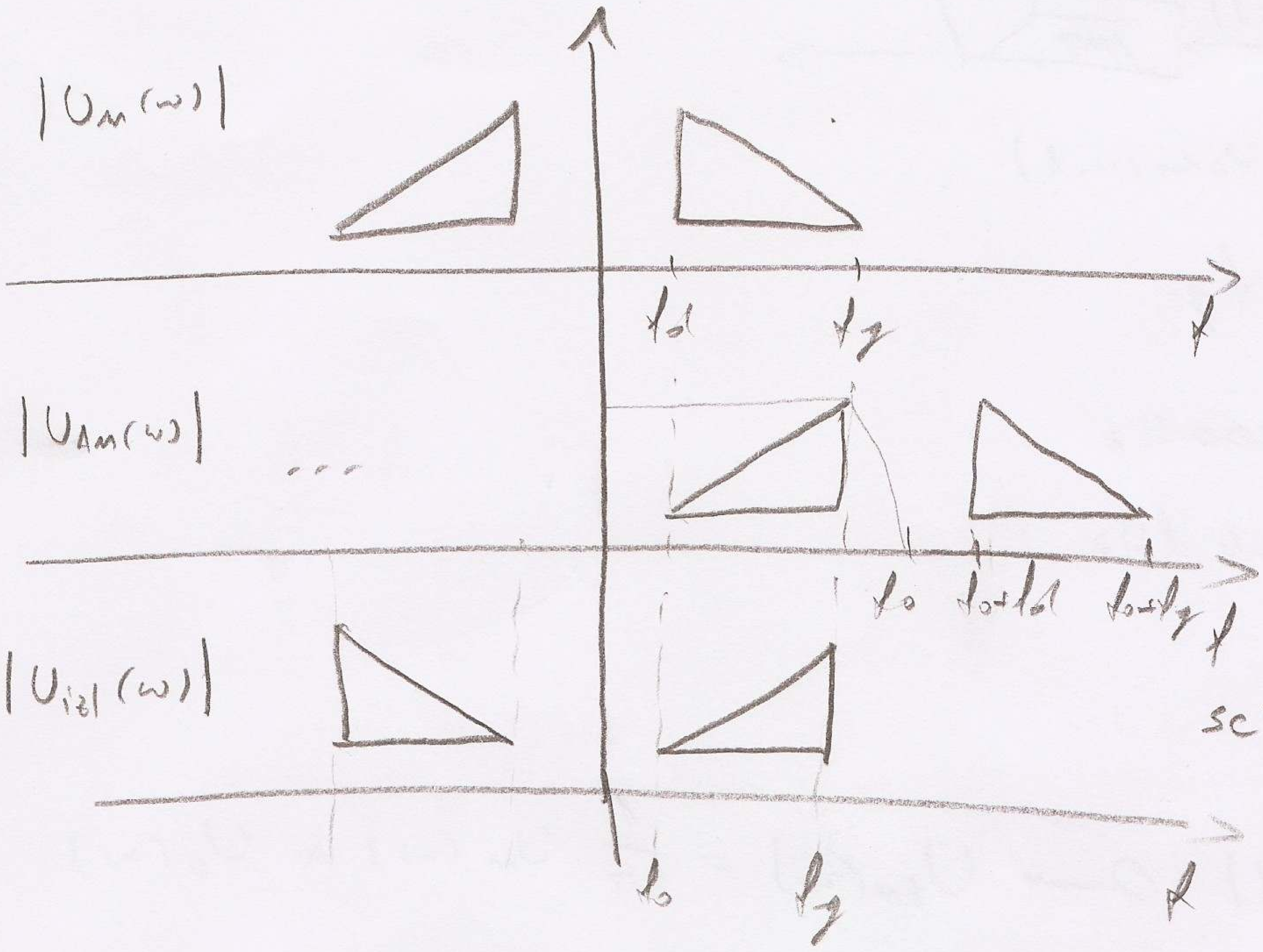
Izvod je na predavanju Pogl. 4.4.2.

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



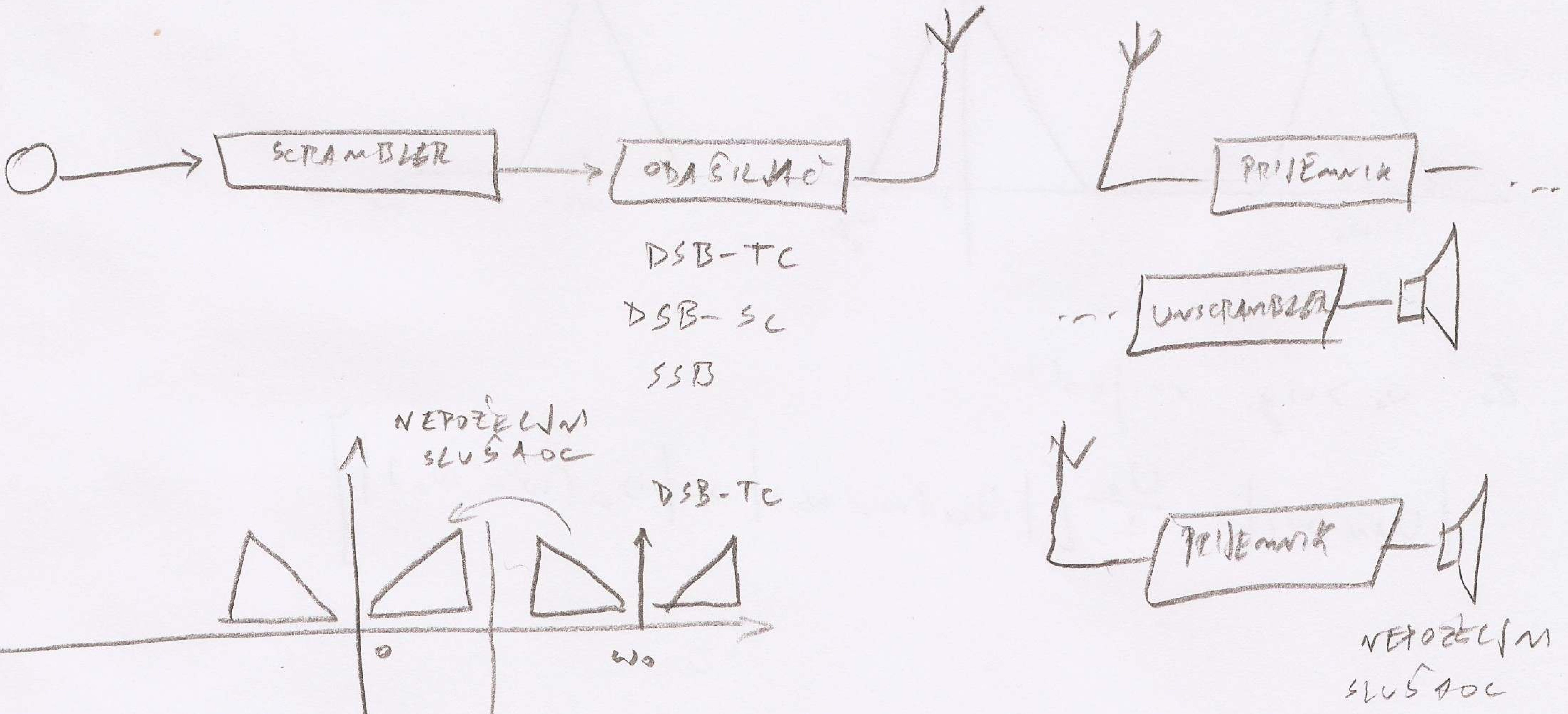
Za $\omega_0 > \omega_g$ vrijedi

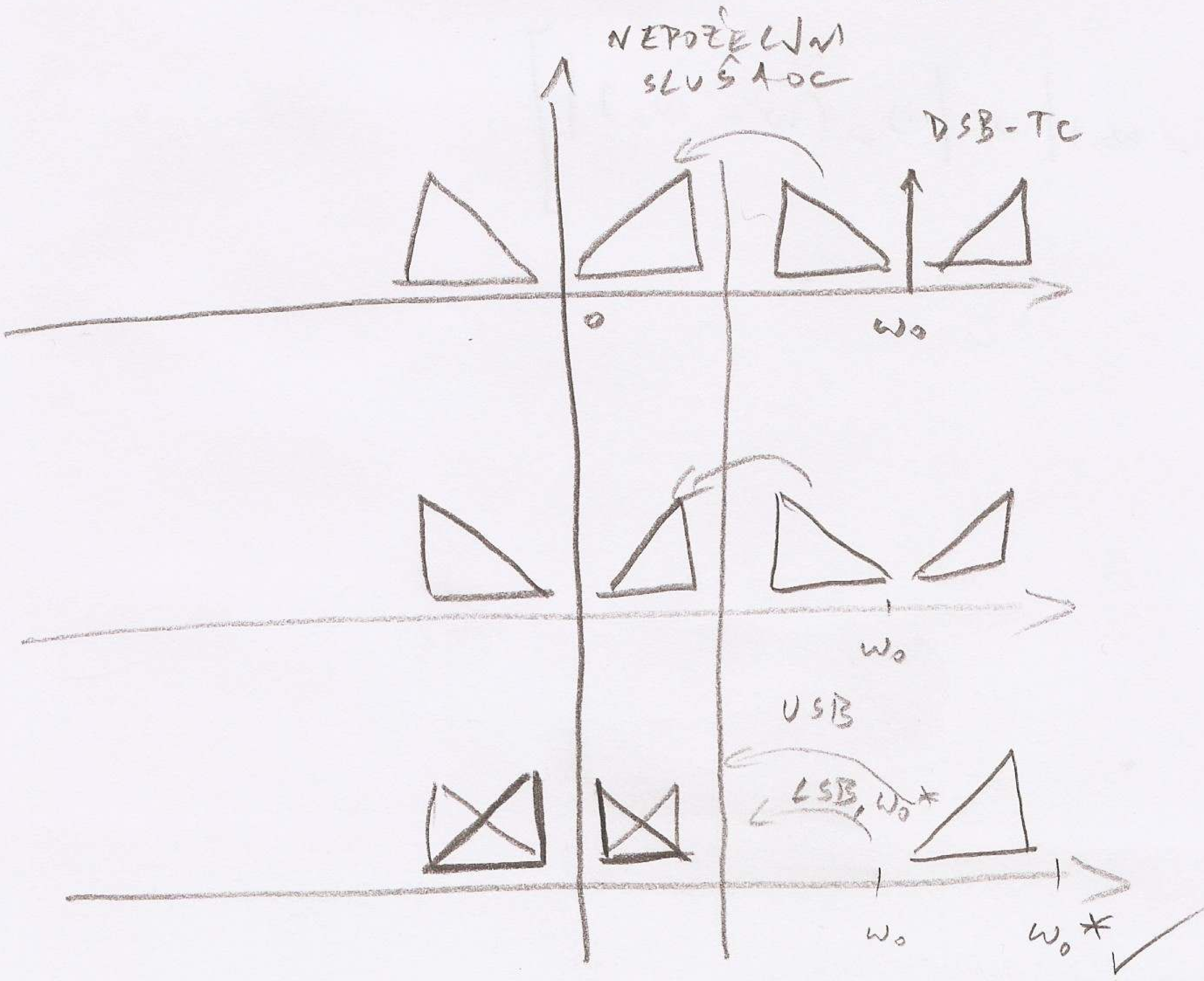
$$|U_{AM}(\omega)| = \frac{U_0}{2}\left[|U_m(\omega + \omega_0)| + |U_m(\omega - \omega_0)|\right]$$



SCRAMBLER
- najjednostavniji oblik šifriranja

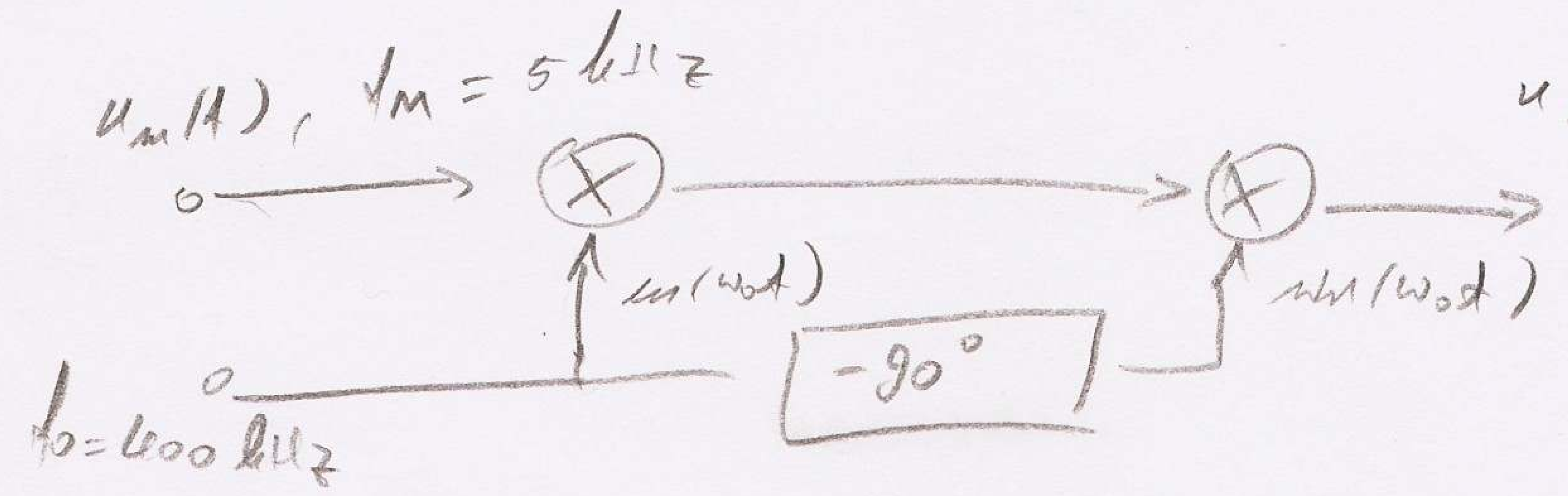
Pretpostavimo da je ovakav sklop postavljen na ulaz odašiljača, te na izlaz prijemnika koji su 3 tipa AM. U kojem slučaju opisani sklop ne osigurava šifriranje signala i zašto?





Ako nep. slo. postavi frekv. nosioca na ω_0^* te postavi primanje LSB kanala tada opisani sklop ne osigurava šifriranje jer prilikom demodulacije dobivamo izvorni signal.

5. Primjer DSB-SC-AM demodulatora na frekv. $2f_0$



Odrediti frekv. područje demod. signala

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

$$= \frac{1}{2} u_m(t) \sin(2\omega_0 t)$$

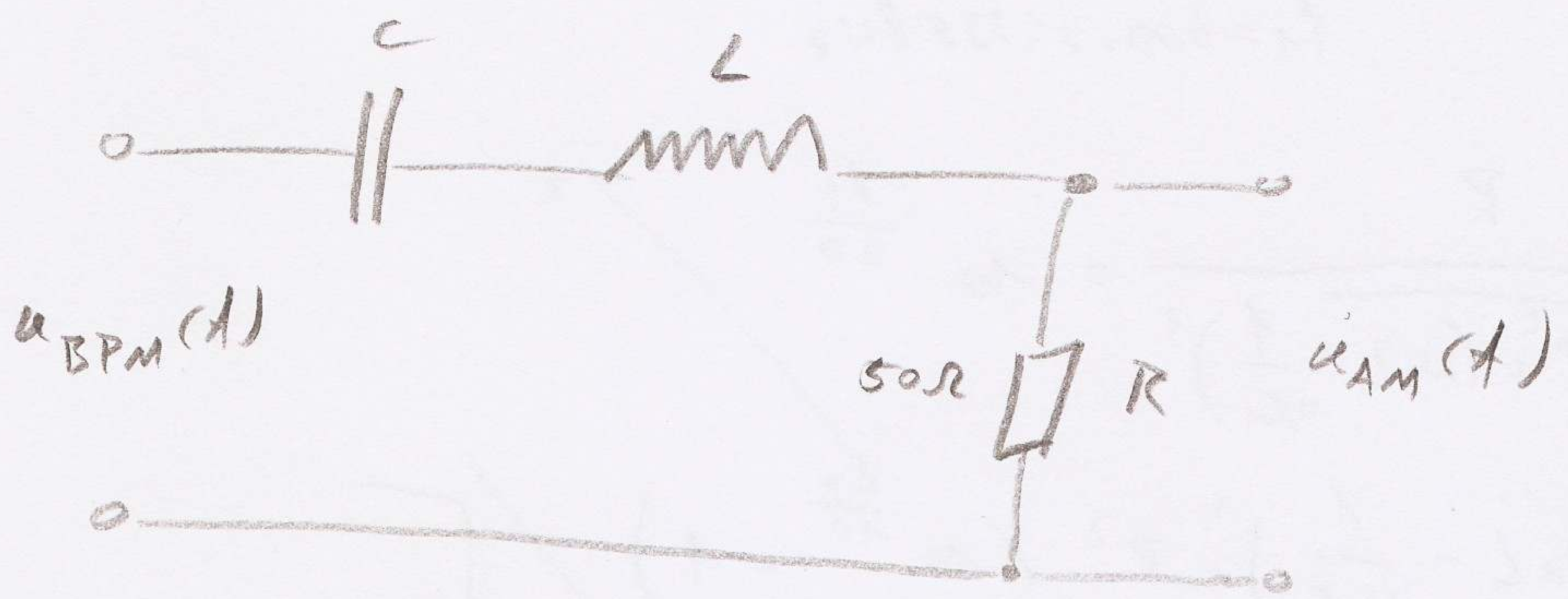
6. $f_m = 5\ \text{kHz}$

$f_0 = 400\ \text{kHz}$

$A_p = 0{,}05\ \text{dB}$

$L, C = ?$

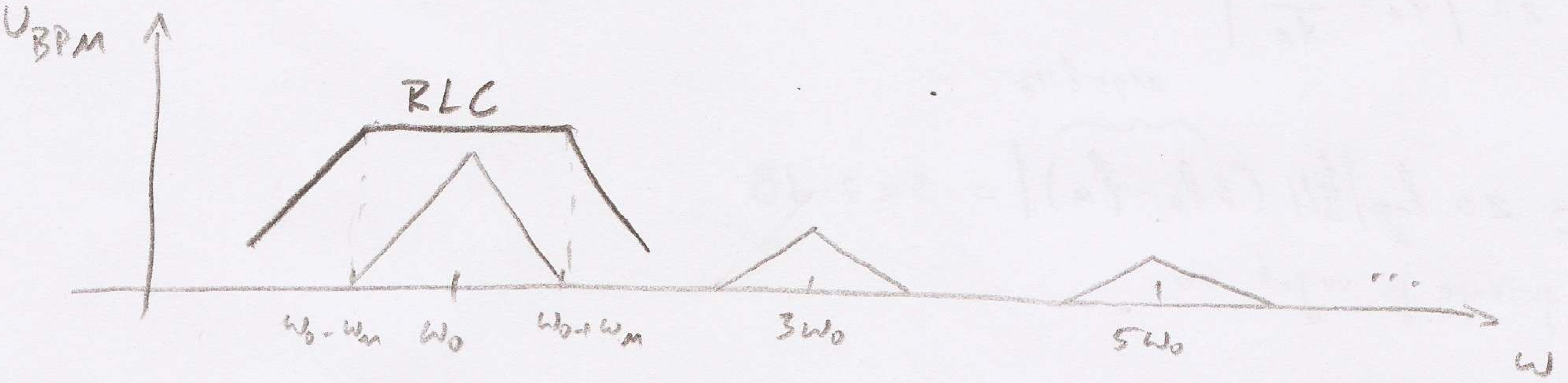
$A_s = ?$



$$u_{BPM}(t) = u_m(t)\cdot \mathrm{sgn}\left[U_0 \cos(\omega_0 t)\right]$$

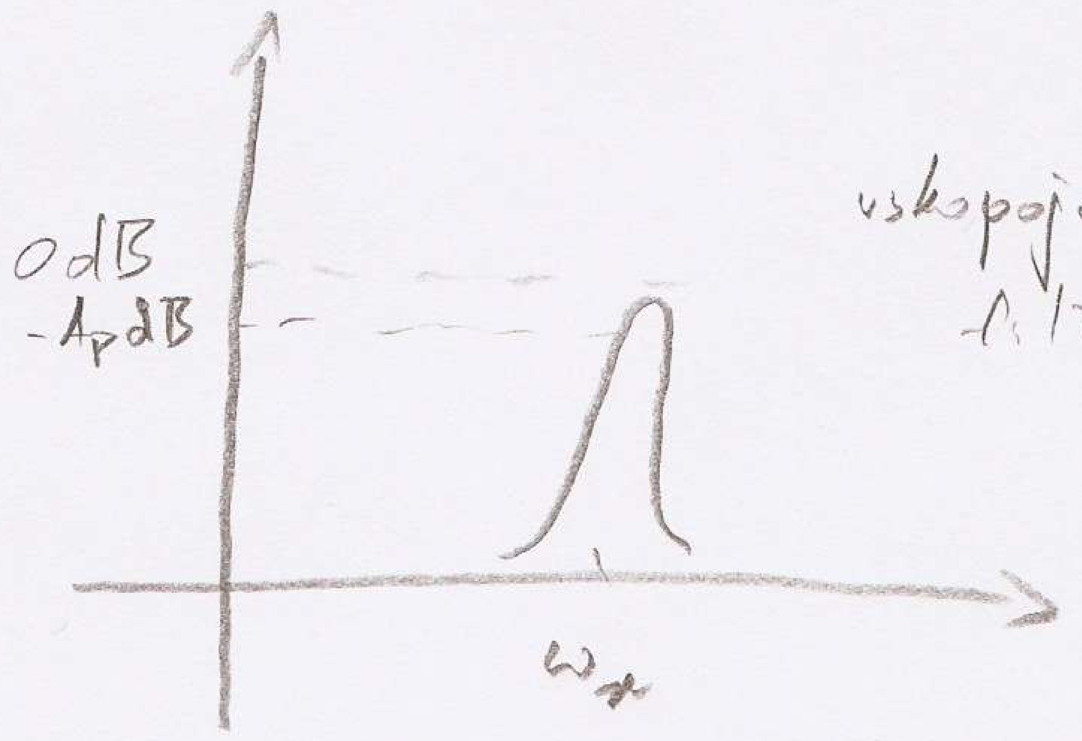
$$= u_m(t)\cdot \mathrm{square}(\omega_0 t)$$

$$= \frac{4}{\pi}\Big[\underbrace{u_m(t)\cdot \cos(\omega_0 t)}_{\text{DSB-SC-AM}} - \frac{1}{3}u_m(t)\cos(3\omega_0 t) + \frac{1}{5}\cos(5\omega_0 t) \pm \dots\Big]$$



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

$$= 0 \Rightarrow \omega_r = \frac{1}{\sqrt{LC}} = \omega_0 \Rightarrow \qquad C = \frac{1}{4\pi^2 f_0^2 L} \ ?$$



uskopojasni filtar => teži simetričnosti

$$20 \lg \left| H(\underbrace{f_0 - f_M}) \right| \geq -A_P$$

$f_1 = 400 - 5 = 395 \, kHz$

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

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

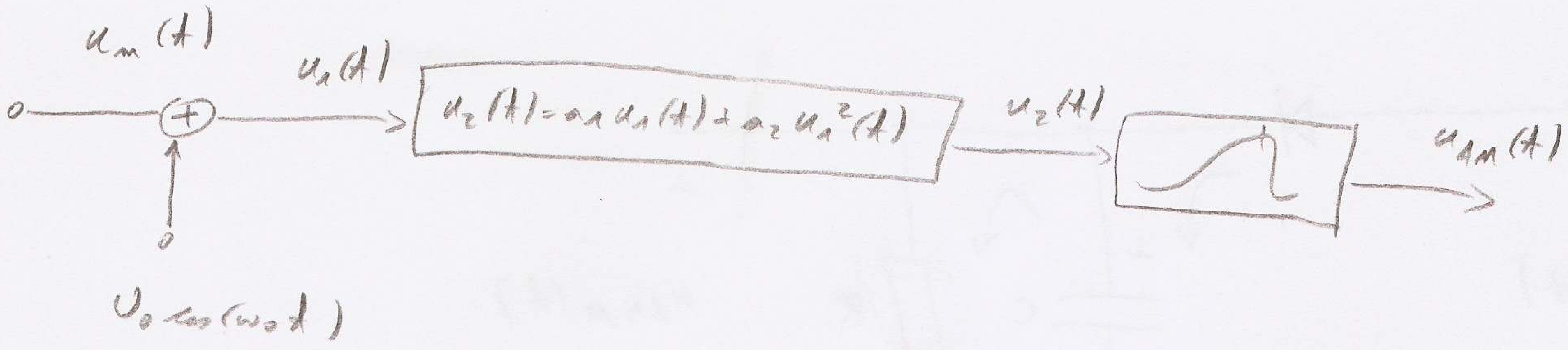
$$L \cdot \left| \omega_1 - \underbrace{\frac{1}{\omega_1 L C}}_{\frac{\omega_0^2}{\omega_1} = 2\pi \frac{f_0^2}{f_1}} \right| = R \sqrt{10^{\frac{A_P}{10}} - 1}$$

$$L = \frac{R\sqrt{10^{\frac{A_P}{10}} - 1}}{2\pi \left| f_1 - \frac{f_0^2}{f_1} \right|} = 85 \, \mu H \implies C = 1.8 \, nF$$

$$A_S = -20 \lg \left| \frac{1}{3} H(\overbrace{3f_0 - f_M}^{1195 \, kHz}) \right| = 30.7 \, dB$$

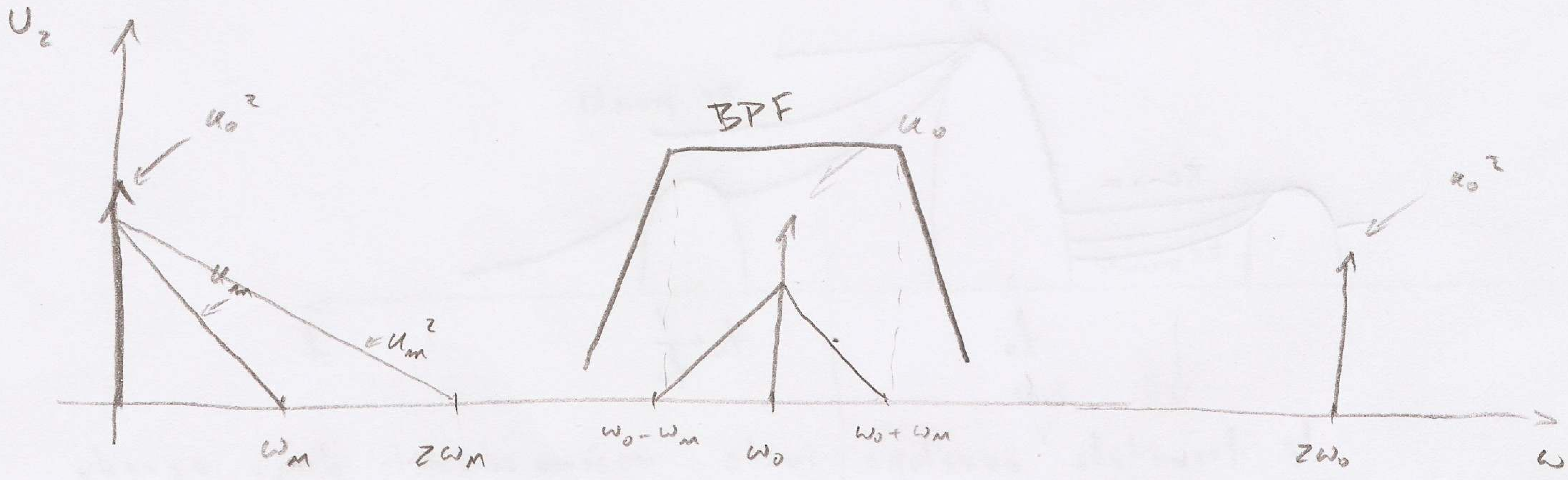
gušenje je uvijek > 0

7.



a) $u_1(t) = u_m(t) + U_0 \cos(\omega_0 t)$

$$u_2(t) = a_1 u_m(t) + a_1 U_0 \cos(\omega_0 t) + a_2 u_m^2(t) + 2 a_2 U_0 u_m(t) \cos(\omega_0 t) + $$
$$+ a_2 U_0^2 \underbrace{\cos^2(\omega_0 t)}_{\frac{1}{2} + \frac{1}{2}\cos(2\omega_0 t)}$$



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

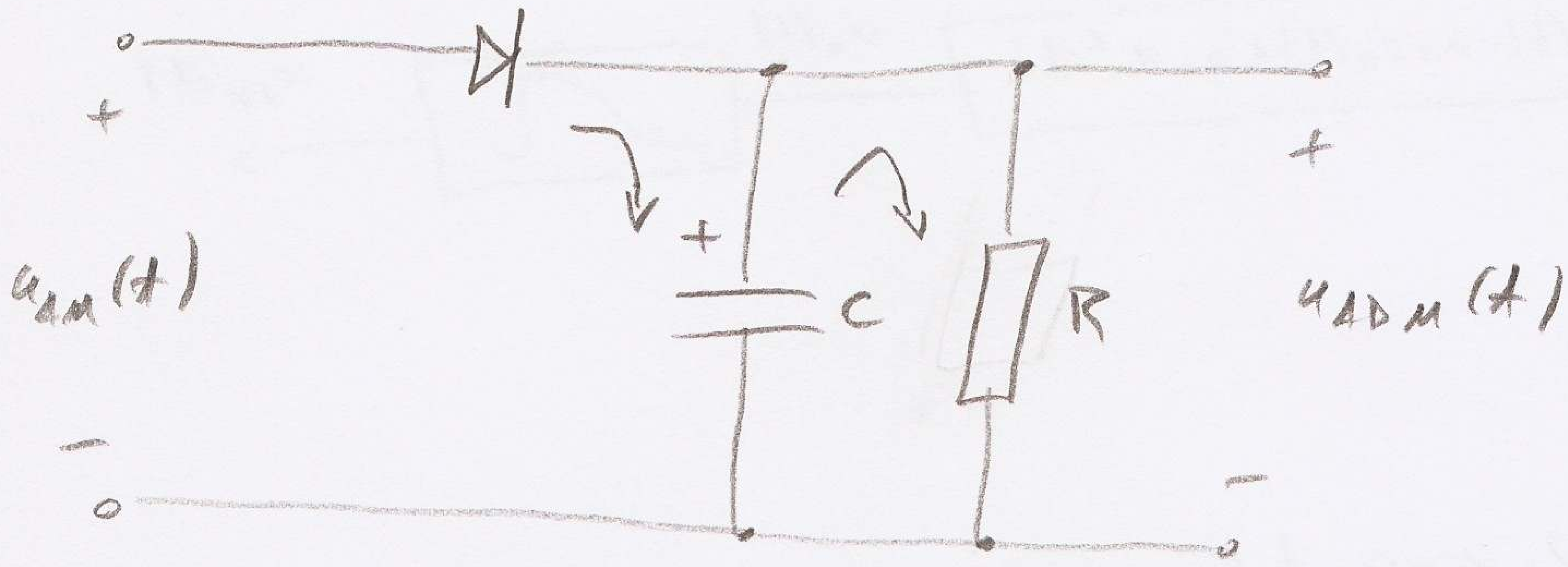
c) $u_{AM}(t) = a_1 U_0 \cos(\omega_0 t) + 2 a_2 U_0 u_m(t) \cos(\omega_0 t)$

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

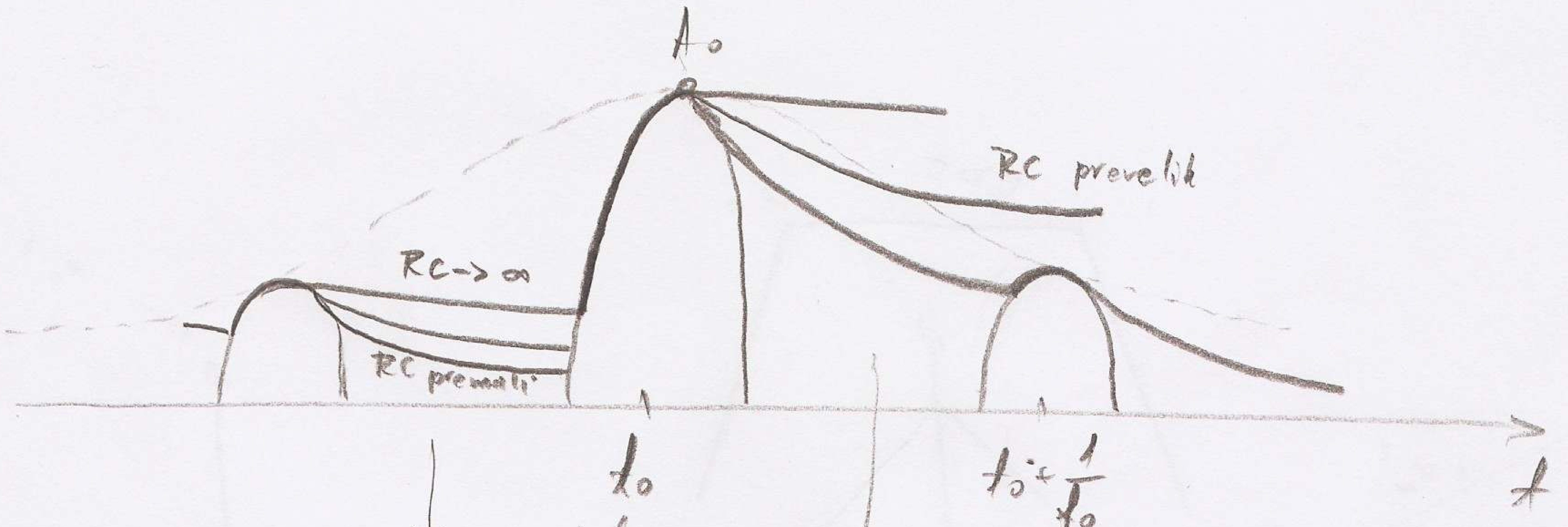
$\Rightarrow U_{0,AM} = a_1 U_0$

$K_a = 2 a_2 U_0$

8.



C se tijekom pozitivne poluperiode od $u_{AM}(t)$ nabija, a vrijek se izbija preko R.

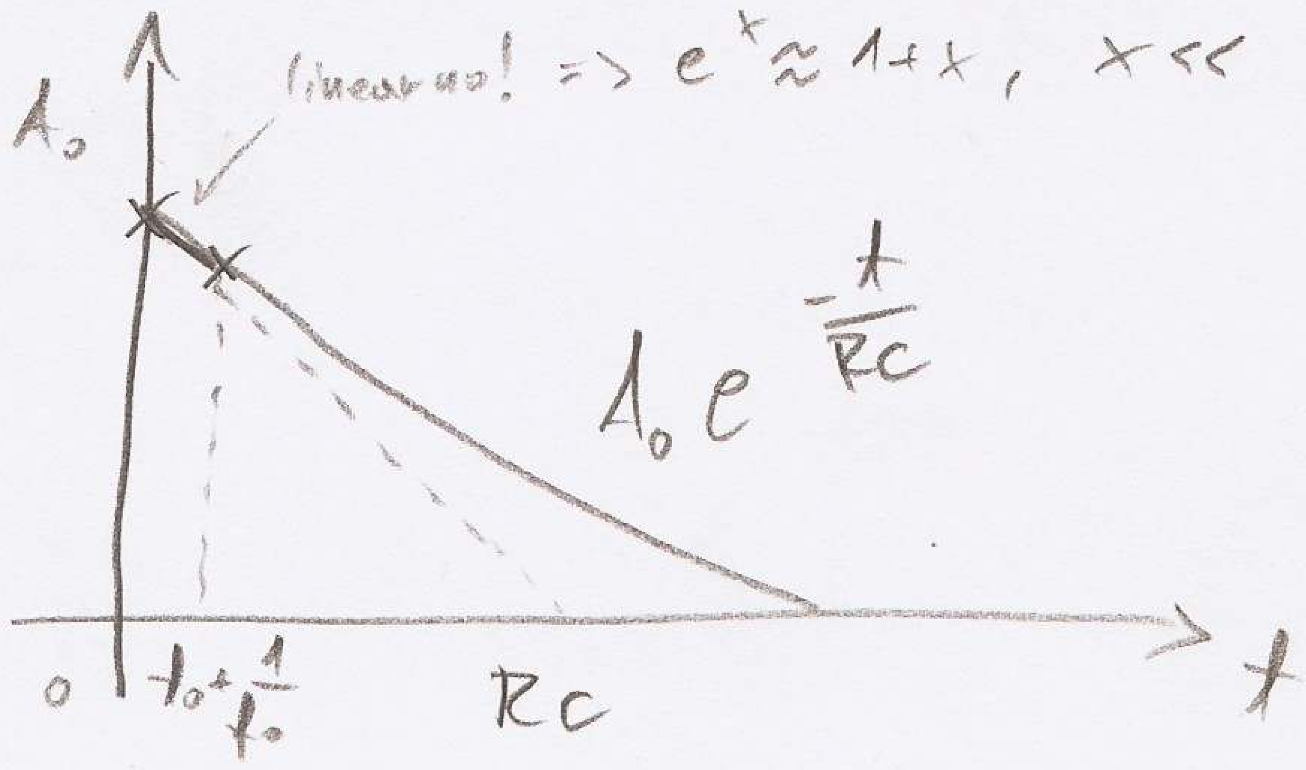


Iz trenutaka kada anvelopa raste možemo odrediti donju ogradu za RC. To je $RC \gg \frac{1}{\omega_0}$.

Iz trenutaka kada anvelopa pada možemo odrediti gornju ogradu za RC.

$$u_{AM}(t) = (U_0 + K_a \underbrace{u_m(t)}_{= U_m \cos(\omega_m t)}) \cos(\omega_0 t) = U_0 (1 + m \cdot \cos(\omega_m t)) \cos(\omega_0 t)$$

Pretpostavimo da se kondenzator izbija od maksimalne vrijednosti $A_0 = U_0(1 + m \cdot \cos(\omega_m t_0))$. Napon na RC članu je



$$u_{ADM}(t) = A_0 e^{-\frac{t-t_0}{RC}}$$

8. Za $RC >> \frac{1}{\omega_0}$ vrijedi aproksimacija

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

Napon na kondenzatoru ne smije preći maksimum u sljedećoj poluperiodi.

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

$$\underbrace{U_0\left(1 + m \cdot \cos(\omega_m t_0)\right)}_{A_0} \cdot \left(1 - \frac{1}{RCf_0}\right) \leq U_0\left[1 + \underbrace{m\cos\left(\omega_m t_0 + \frac{\omega_m}{f_0}\right)}\right]$$

Za $\omega_m << \omega_0$ vrijedi $= m\cos(\omega_m t_0)\overbrace{\cos\left(\frac{\omega_m}{f_0}\right)}^{\approx 1} -$

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

$$\cancel{1} + \cancel{m \cdot \cos(\omega_m t_0)} - \frac{1}{RCf_0}\left(1 + m \cdot \cos(\omega_m t_0)\right) \leq \cancel{1} + \cancel{m\cos(\omega_m t_0)} - \frac{m\omega_m}{f_0}\sin(\omega_m t_0) \quad / \cdot (-1)$$

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

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

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

$$\frac{1}{RC} \geq m\sqrt{\omega_m^2 + \left(\frac{1}{RC}\right)^2} \quad /^2$$

...

$$\boxed{RC \leq \frac{1}{\omega_m}\frac{\sqrt{1 - m^2}}{m}} \qquad RC >> \frac{1}{\omega_0}$$

Pr.: $f_m = 3\,kHz$, $f_0 = 1\,MHz$, $m = 0.9$

$RC >> 1.6 \cdot 10^{-7}\,s$, $RC \leq 2.6 \cdot 10^{-5}\,s$

3. $U_0 = 1{,}5\ V$

$f_0 = 1\ MHz$

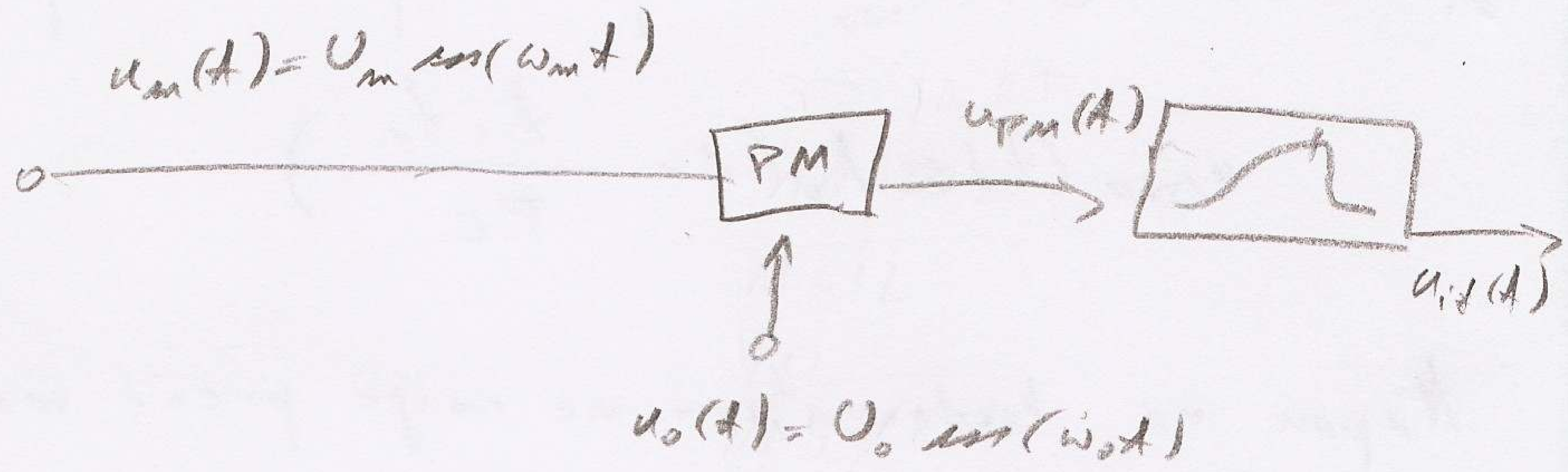
$f_m = 5\ kHz$

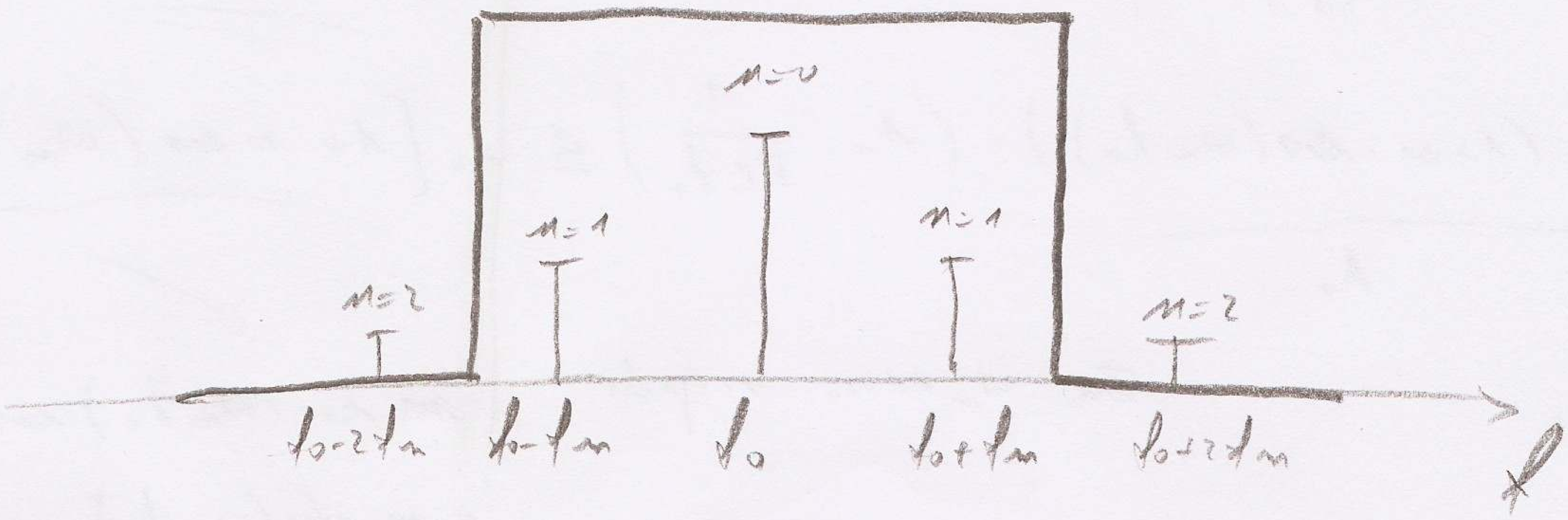
$\Delta\varphi = 0{,}5\ rad \Rightarrow m = 0{,}5$

$f_c = 1\ MHz = f_0$

$B = 15\ kHz$

$m_{AM} = ?$





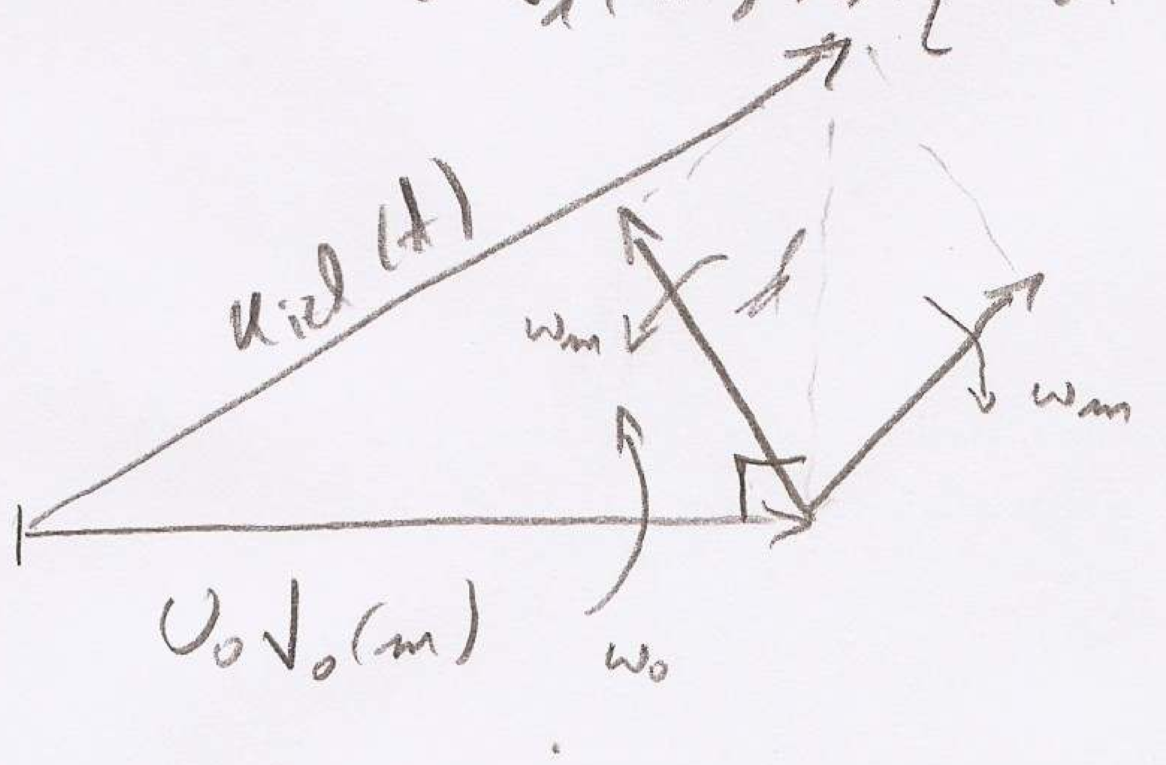
$$u_{PM}(t) = U_0 \cos\left[\omega_0 t + K_p\, u_m(t)\right] = U_0 \cos(\omega_0 t + m \cdot \cos(\omega_m t))$$

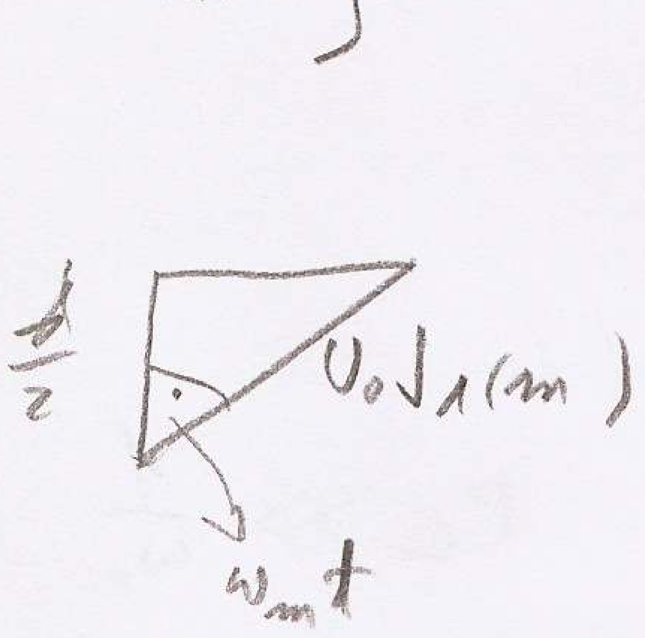
$$m = K_p\, |u_m(t)|_{MAX}$$

Na predavanjima je izvedeno

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

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





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

9.

$$u_{anvelopa}(t) = \text{anvelopa od } u_{iz}(t)$$

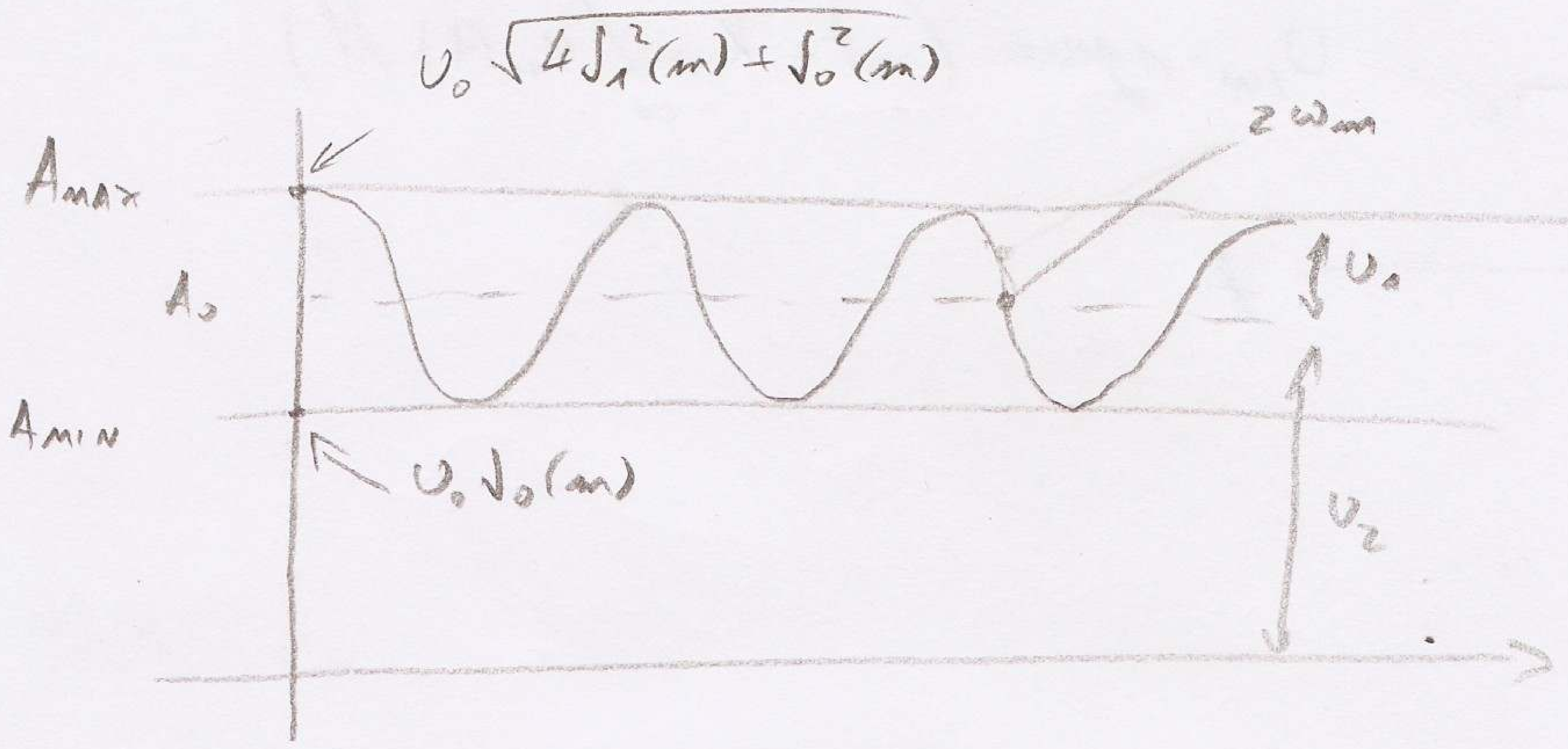
$$= \sqrt{\mathcal{A}^2 + U_0^2 J_0^2(m)}$$

$$= U_0 \sqrt{4 J_1^2(m) \underbrace{\cos^2(\omega_m t)}_{=\frac{1}{2}+\frac{1}{2}\cos(2\omega_m t)} + J_0^2(m)}$$

$$= U_0 \sqrt{2 J_1^2(m) \cos(2\omega_m t) + 2 J_1^2(m) + J_0^2(m)}$$

-1 $+1$

↳ PARAZITNA AM!



$$m_{AM} = \frac{U_1}{U_2} = \frac{A_{max} - A_0}{A_0}$$

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

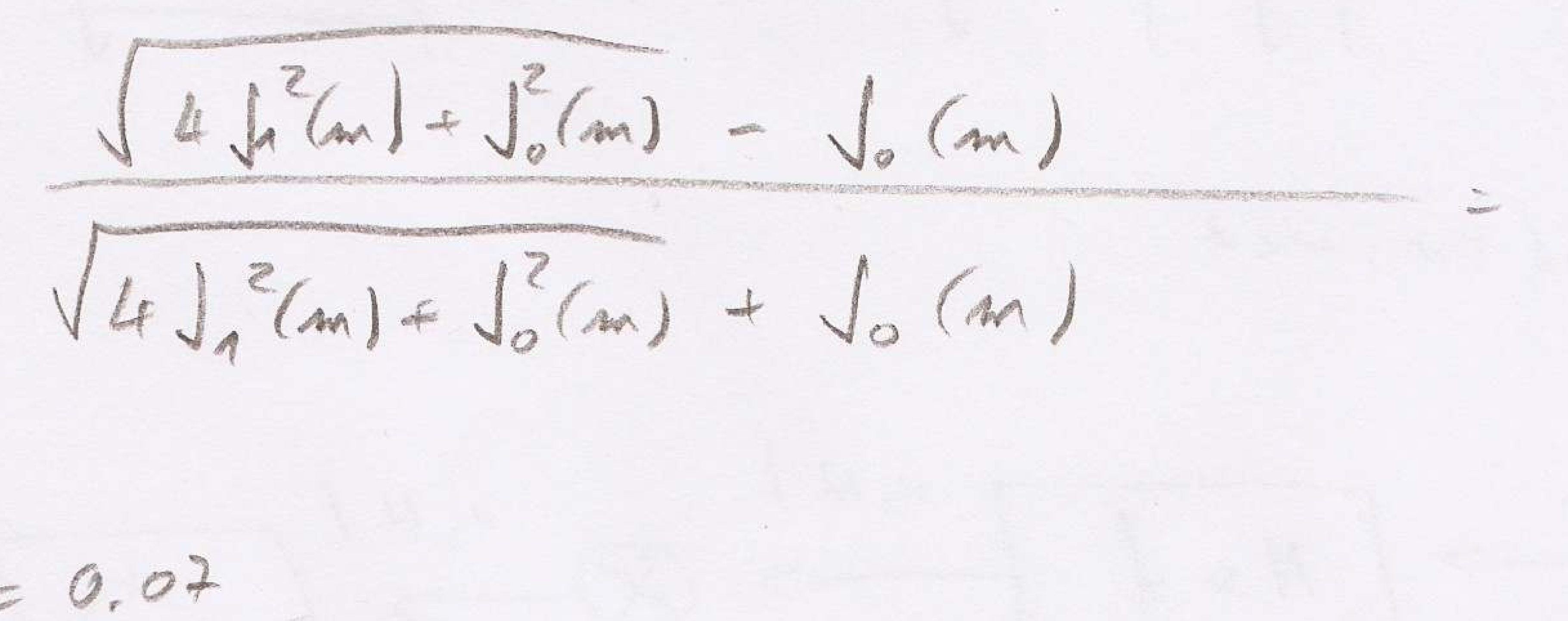
$$m_{AM} = \frac{\sqrt{4 J_1^2(m) + J_0^2(m)} - J_0(m)}{\sqrt{4 J_1^2(m) + J_0^2(m)} + J_0(m)} =$$

$J_0(0.5) = 0.92$

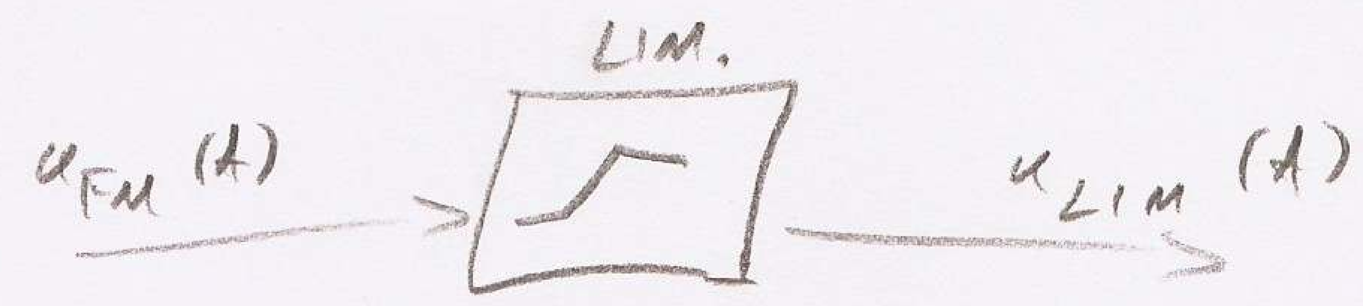
$J_1(0.5) = 0.26$

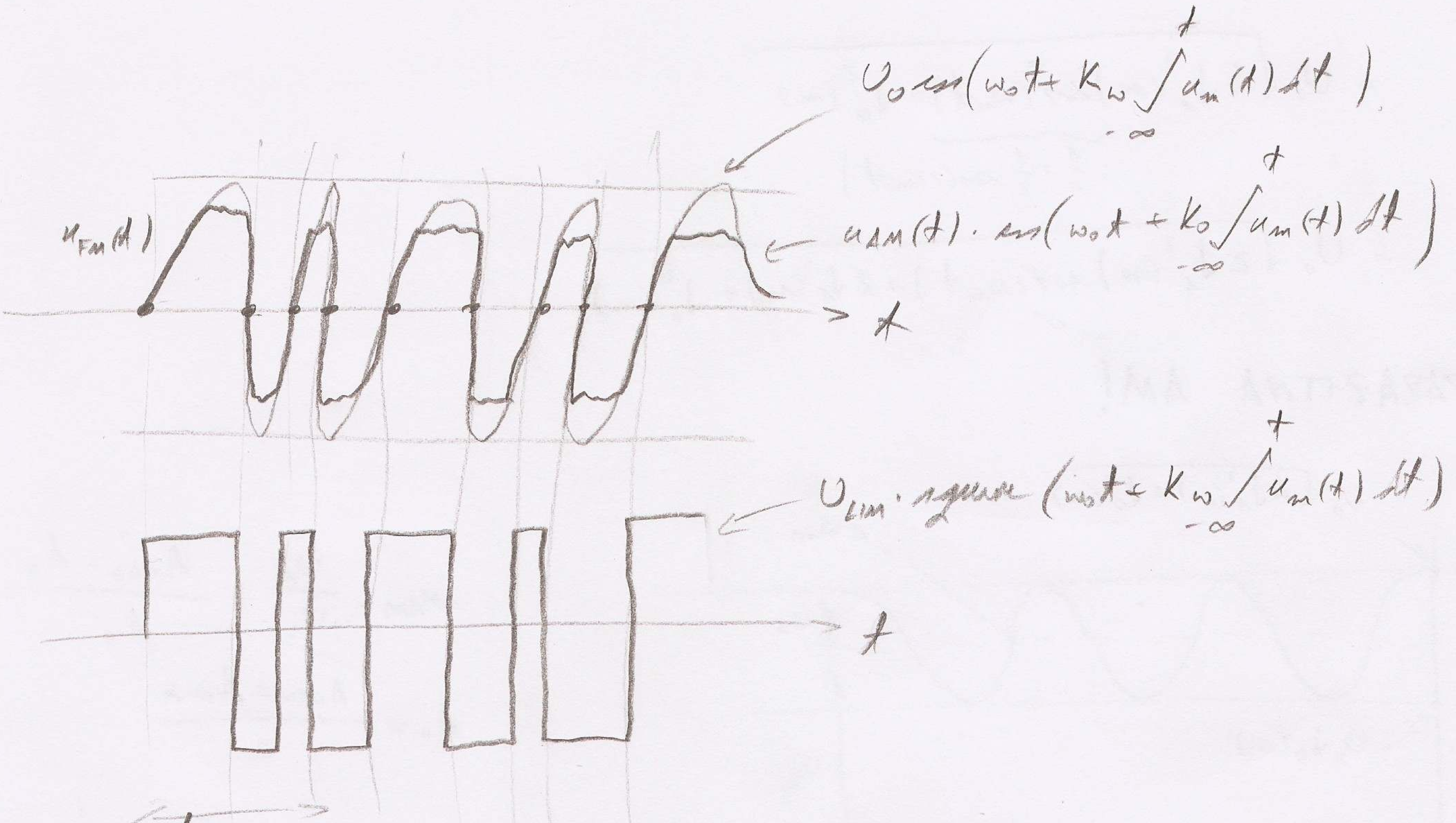
$$m_{AM} = 0.07$$

Ograničavanje beskonačnog spektra FM signala uzrokuje pojavu PARAZITNE AM koja se u postupku demodulacije uklanja limiterima (realni demodulator) i dijelilom (kompleksni modulator).



U postupku demodulacije

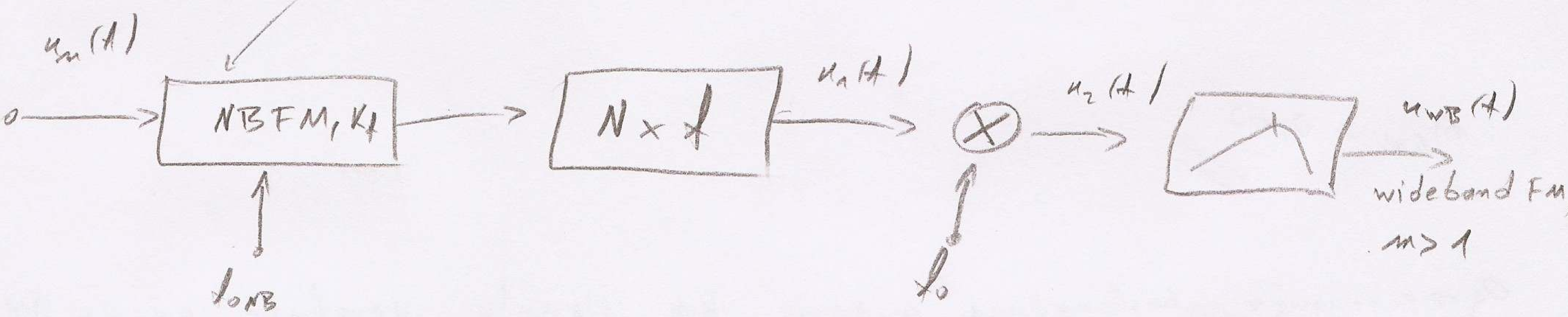




$T = \frac{1}{f_0 + K_f u_m(t)}$, $K_\omega = 2\pi K_f$

$u_{LIM}(t)$ je FM signal kod kojeg je signal nosioca pravokutnog valnog oblika.

10.



$u_m(t)$: $f_M = 15\ kHz$

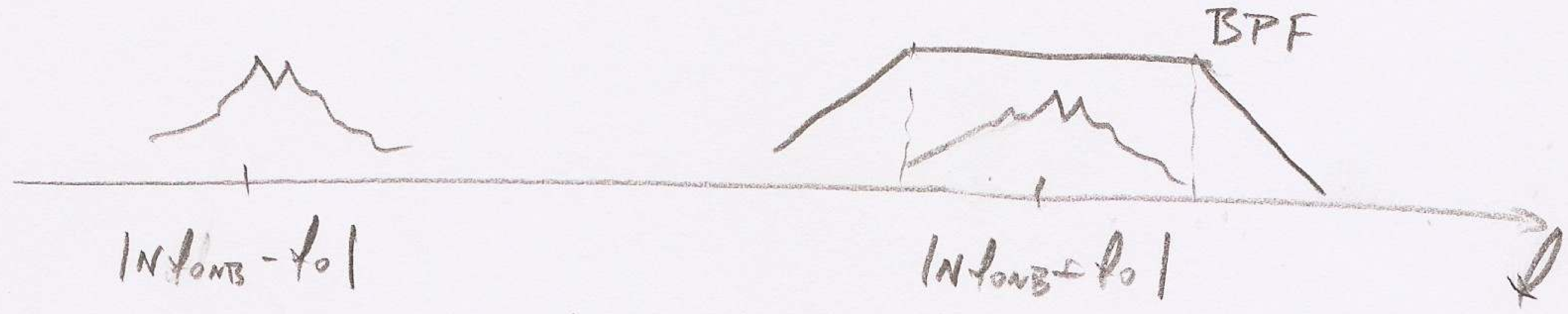
$u_{NB}(t)$: $f_{NB} = f_{0NB} + K_f \cdot u_m(t)$, $\Delta f_{NB} = K_f \cdot |u_m(t)|_{max} = 3k \cdot 0.5 = 1.5\ kHz$

$u_1(t)$: $f_1 = N f_{NB} = N f_{0NB} + N K_f u_m(t)$

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

=> dobivamo 2 FM signala

10.



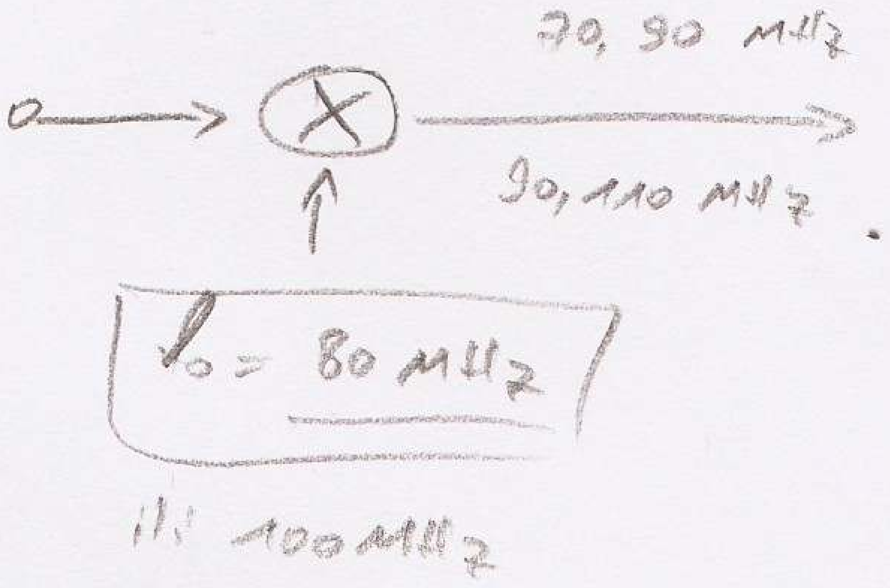
$$\Delta f_{WB} = N K_f \underbrace{|u_m(t)|_{max}} = N \Delta f_{NB}$$

$$\Rightarrow \quad N = \frac{\Delta f_{WB}}{\Delta f_{NB}} = \frac{75k}{1.5k} = 50$$

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

$50 \cdot 200k$

$= 10\ MHz$



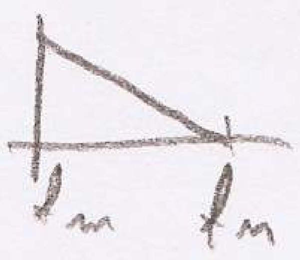
$$u_{WB}(t): \; f_{WB} = N f_{0NB} + f_0 + N K_f u_m(t)$$

BPF:

$f_m \cdot m$

$$B = 2 f_m (m+1) = 2(\Delta f + f_m)$$

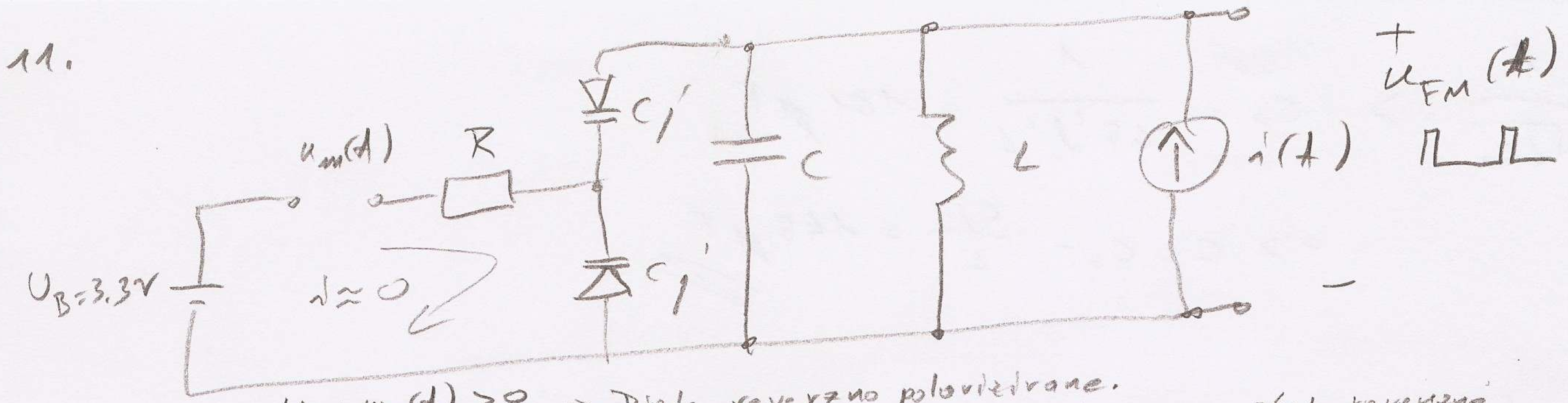
$m \quad +2$



$$B = 2 \cdot (75k + 15k) = 180\ kHz$$

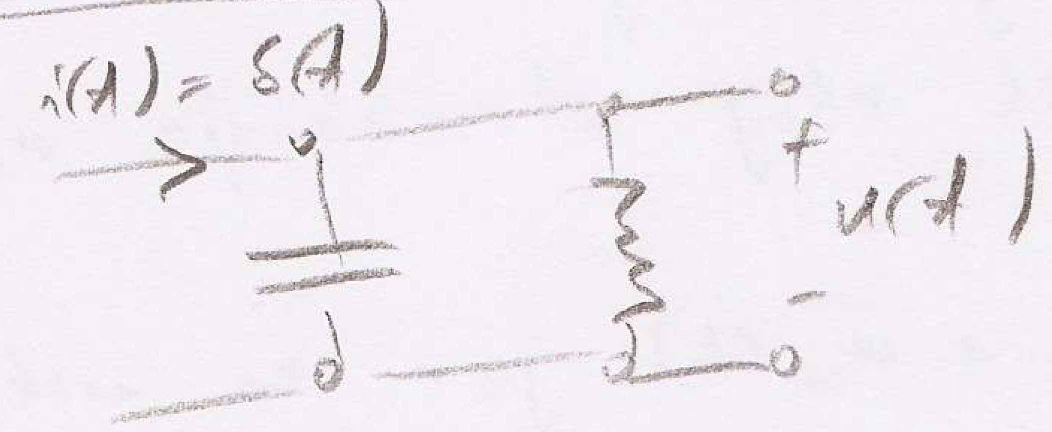
$$f_c = 90\ MHz$$

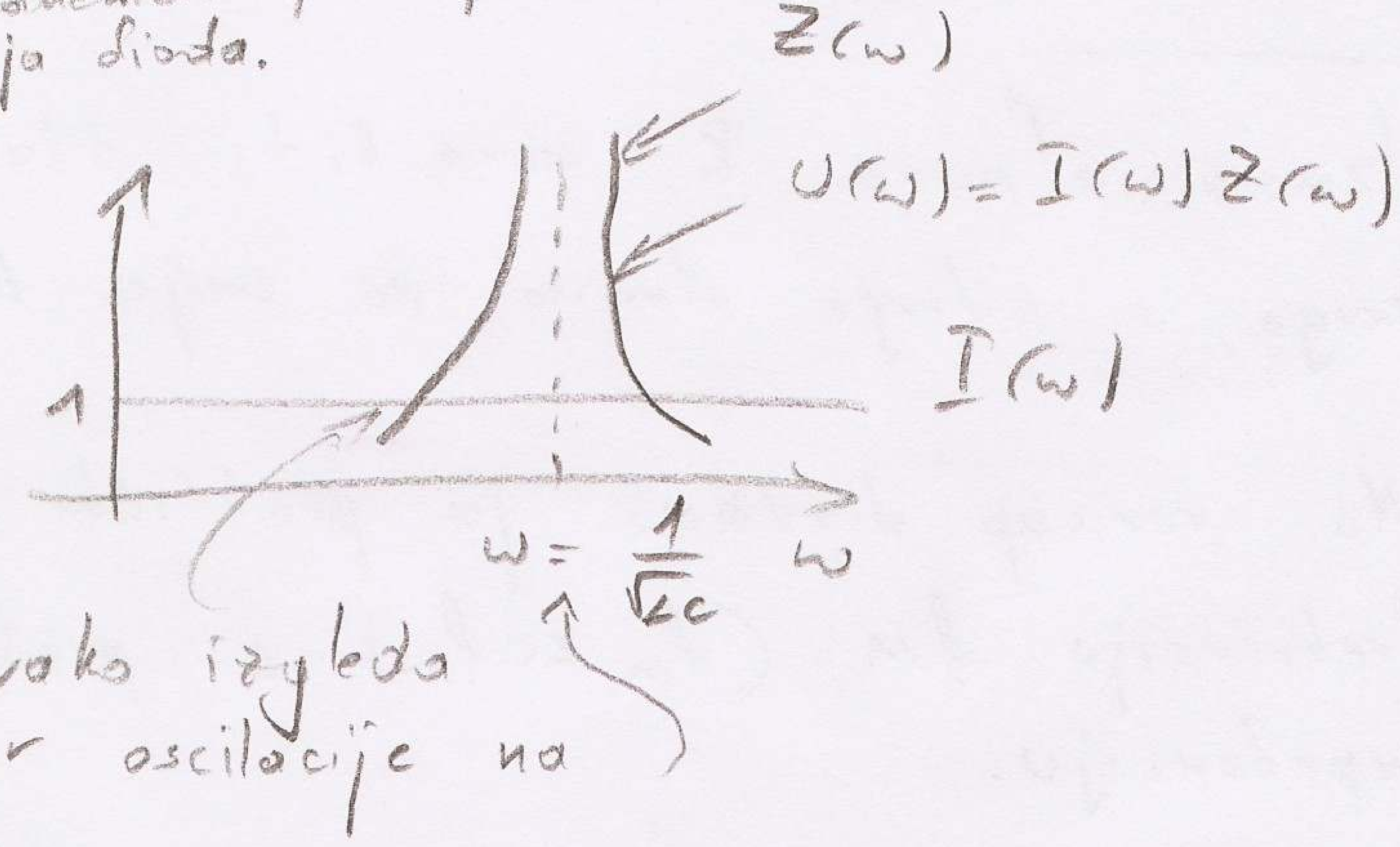
11.



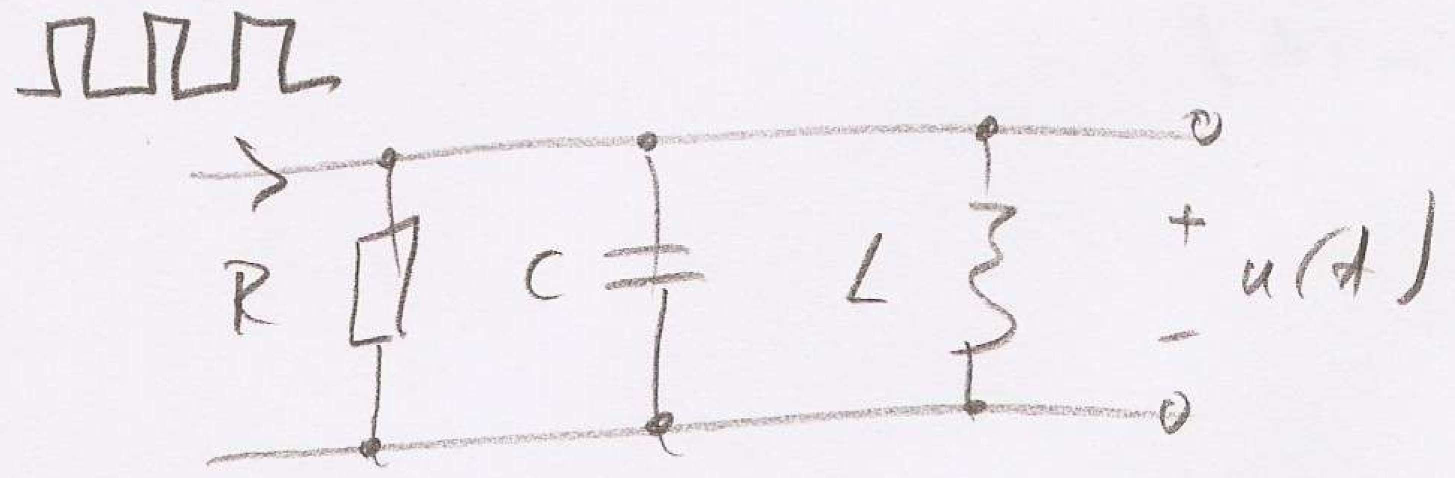
$U_B + u_m(t) > 0$ → Diode reverzno polarizirane.
Na otporniku zanemariv pad napona zbog reverzne struje zasićenja dioda.

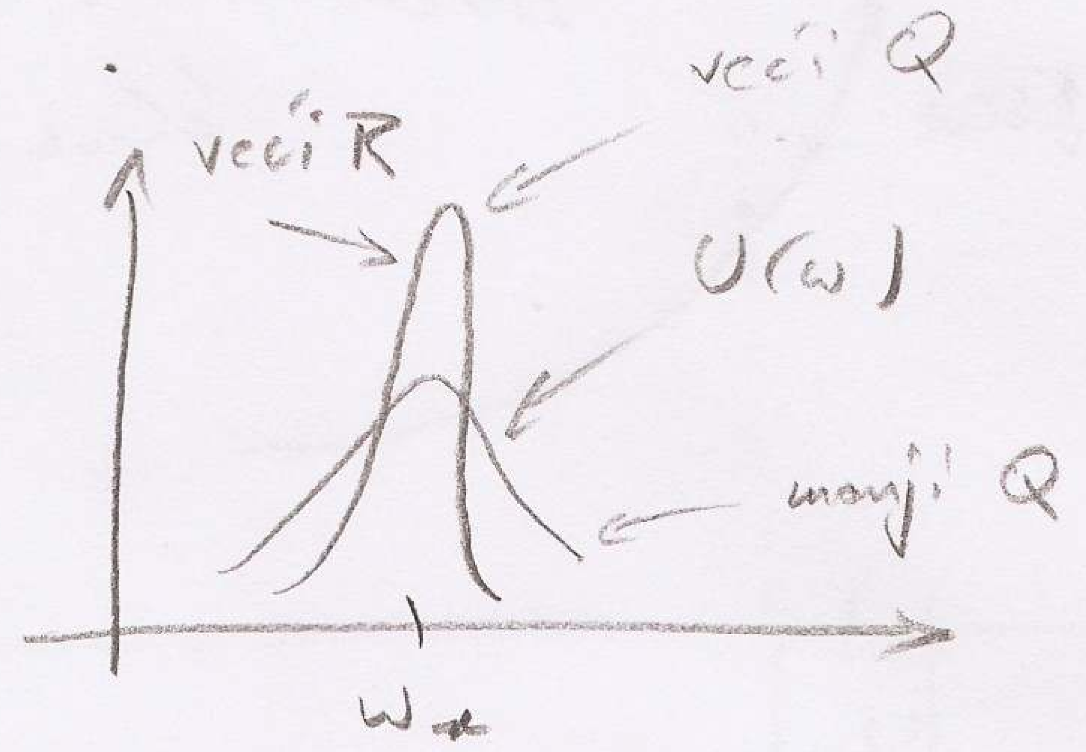
Idealni LC oscilator

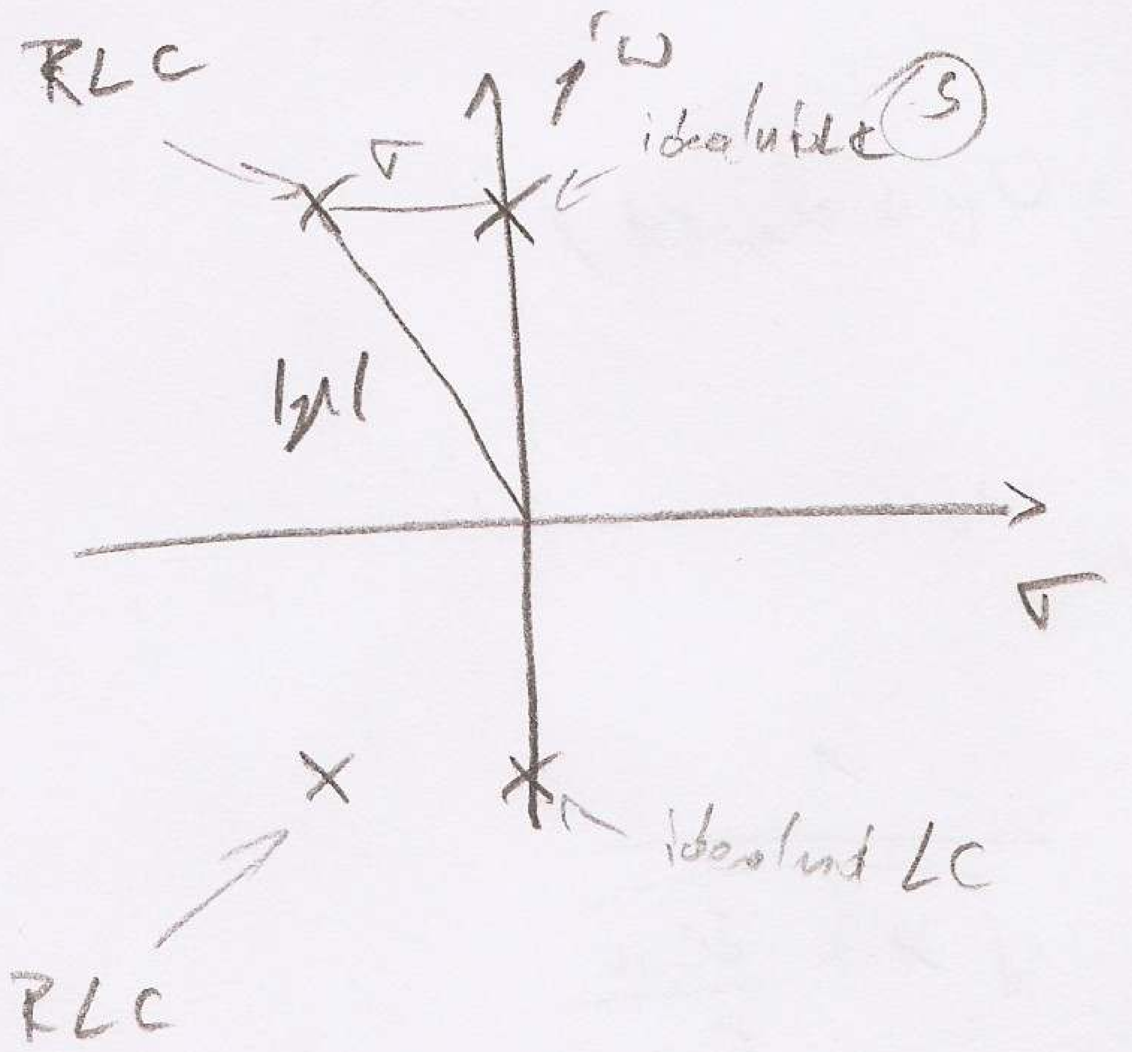




U praksi imamo otporničke gubitke.







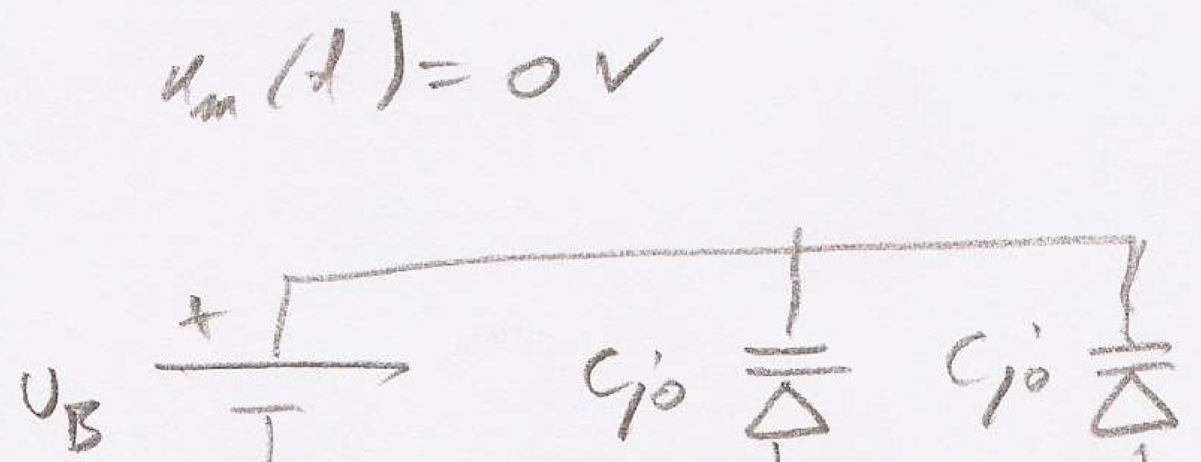
$$Q = \frac{|\omega|}{2\sigma} = R\sqrt{\frac{C}{L}}$$

Za LC oscilatore Q red veličine 100

Za kvarcne oscilatore Q red veličine 1000

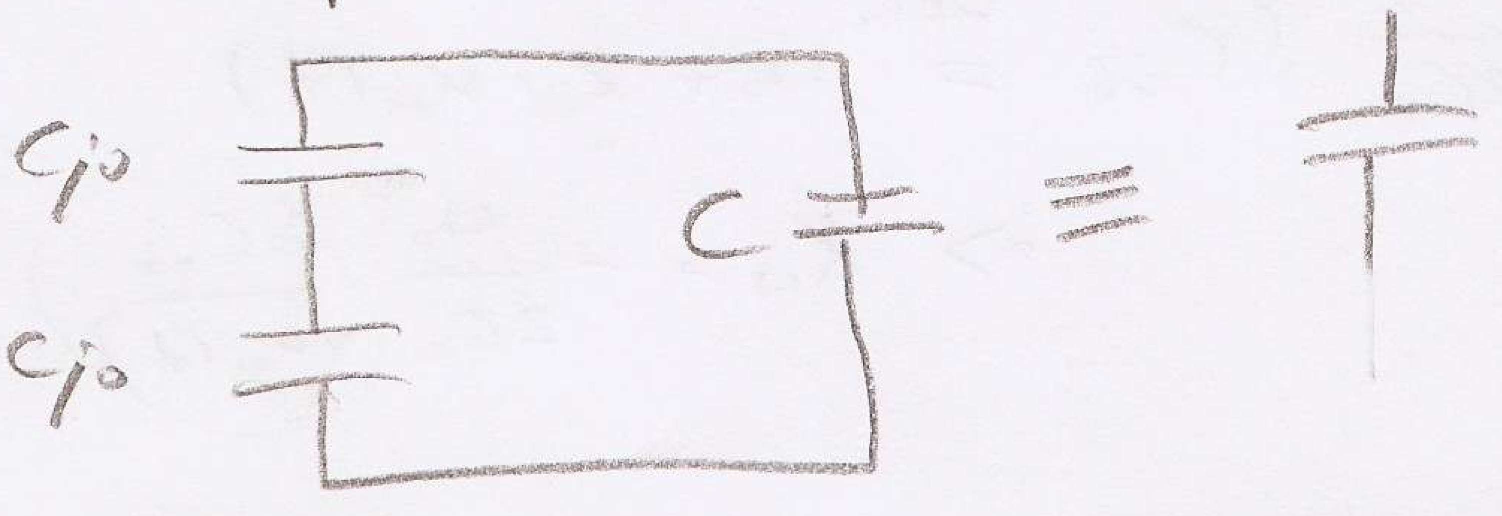
DC analiza

$u_m(t) = 0\,V$



$$C_{j0} = \frac{120}{\sqrt{U_B}} = \frac{120}{\sqrt{3.3}} = 66\ pF$$

Strujni izvor vidi kapacitet



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

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

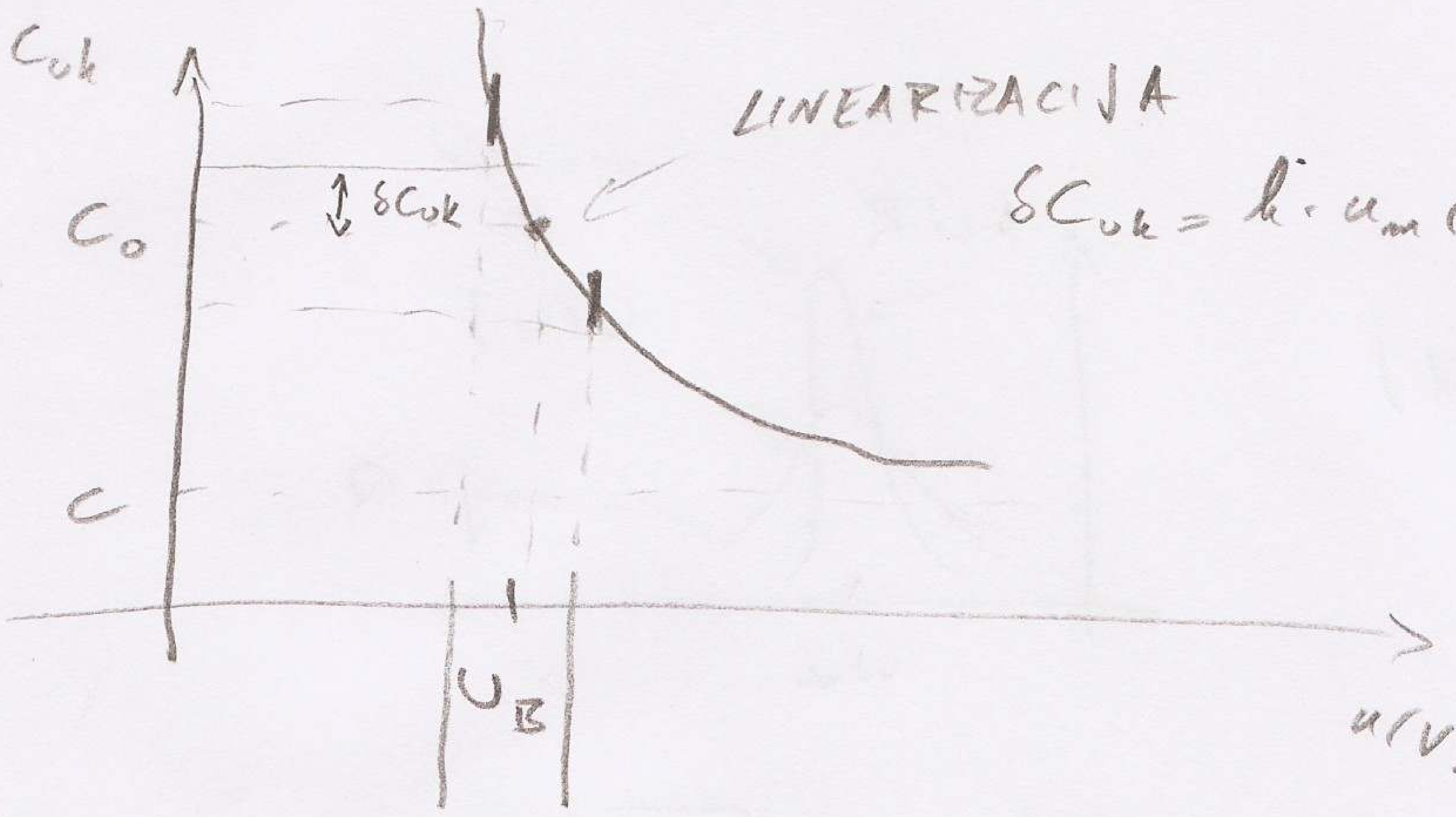
$$\Rightarrow C = C_0 - \frac{C_{j0}}{2} = 148\ pF$$

AC analiza

1) Iznos otpora R mora biti što veći zbog visokog Q faktora LC kruga, a s druge strane ne smije biti prevelik zbog atenuacije $u_m(t)$.

2) Na varicap diodama je praktički napon $U_B + u_m(t)$ jer za nisku frekvenciju f_M ($f_m \ll f_0$) L predstavlja vrlo nisku, a C vrlo visoku impedanciju.

$$C_{uk}(t) = C + \frac{C_j(t)}{2} = C + \frac{C_{j0} + \delta C_j(t)}{2} = C_0 + \underbrace{\frac{\delta C_j(t)}{2}}_{\delta C_{uk}(t)}$$



$$\delta C_{uk} = k \cdot u_m(t)$$

Trenutna frekvencija

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

Uz $\delta C_{uk} \ll C_0$ vrijedi

$$\omega_i = \omega_0 \left(1 - \frac{\delta C_{uk}}{2C_0}\right) \qquad \left(\frac{1}{\sqrt{1+x}} \approx 1 - \frac{x}{2},\ x \ll \right)$$

$$\omega_i = \omega_0 - \frac{\omega_0}{2C_0}\delta C_{uk} \overset{DEF.}{=} \omega_0 + K_\omega \cdot u_m(t)$$

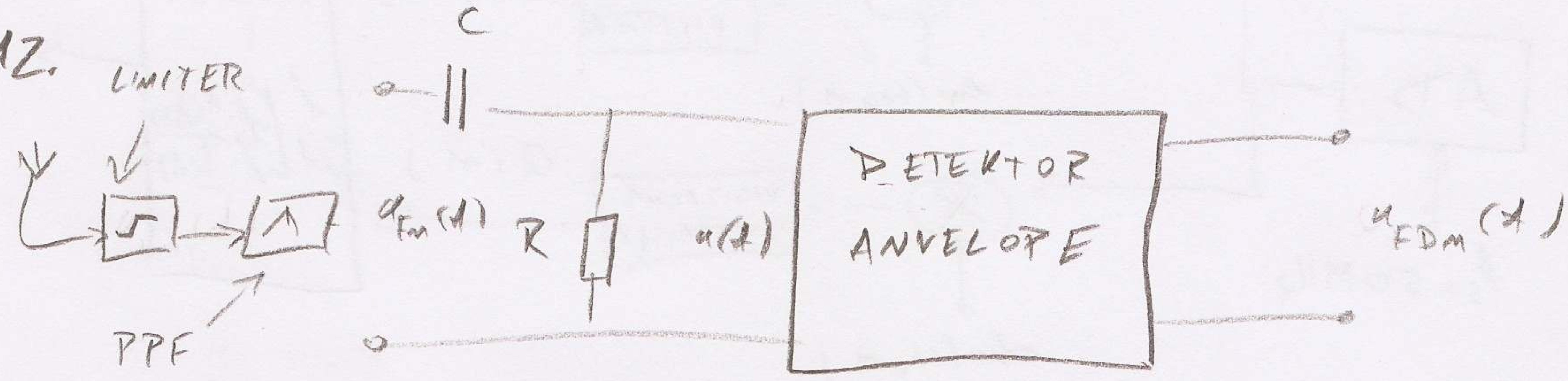
$$\Rightarrow K_\omega = -\frac{\omega_0}{2C_0} \underbrace{\frac{\delta C_{uk}}{u_m(t)}}_{k}$$

$$k = \frac{d\overset{C+\frac{C_j}{2}}{C_{uk}}}{du}\Bigg|_{u=U_B} = \frac{1}{2}\,\frac{dC_j}{du}\Bigg|_{u=U_B} = -\frac{30}{\sqrt{U_B^3}}$$

$$\Rightarrow \quad K_f = -\frac{f_0}{2C_0}\,\frac{-30}{\sqrt{U_B^3}} = \frac{2\cdot 10^6\cdot 30}{2\cdot 181\cdot\sqrt{3{,}3}} = 27{,}6\ \frac{kHz}{V}$$

$$B = 2\Delta f + 2f_m = 2k_f\underbrace{|u_m(t)|_{max}}_{50\,mV} + \underbrace{2f_m}_{10\,kHz} = \underbrace{22.8\ kHz}_{NBFM}$$

12.



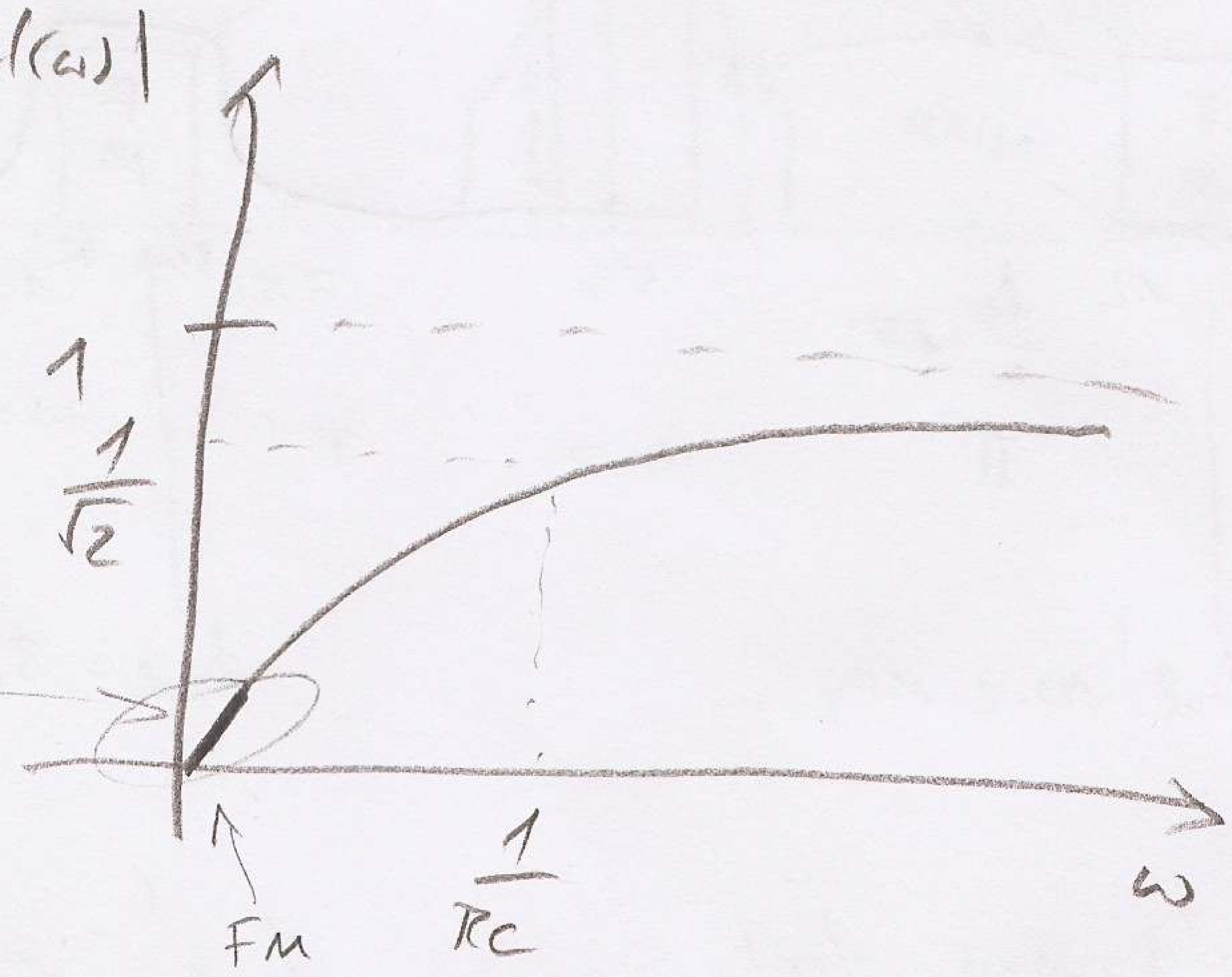
$$R \ll \frac{1}{\omega C} \quad \text{za} \quad \omega_0 - \frac{B_{FM}}{2} \le \omega \le \omega_0 + \frac{B_{FM}}{2}$$

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

$$H(\omega) = \frac{R}{\underset{\text{zanemarivo}}{R} + \frac{1}{j\omega C}} \simeq j\omega RC$$

$$\boxed{H(s) = sRC}$$

DERIVATOR
u području
gušenja



$$u(t) = RC\,\frac{du_{FM}(t)}{dt}$$

$$u_{FM}(t) = U_0\cos\left[\omega_0 t + k_\omega\int_{-\infty}^{t} u_m(t)\,dt\right]$$

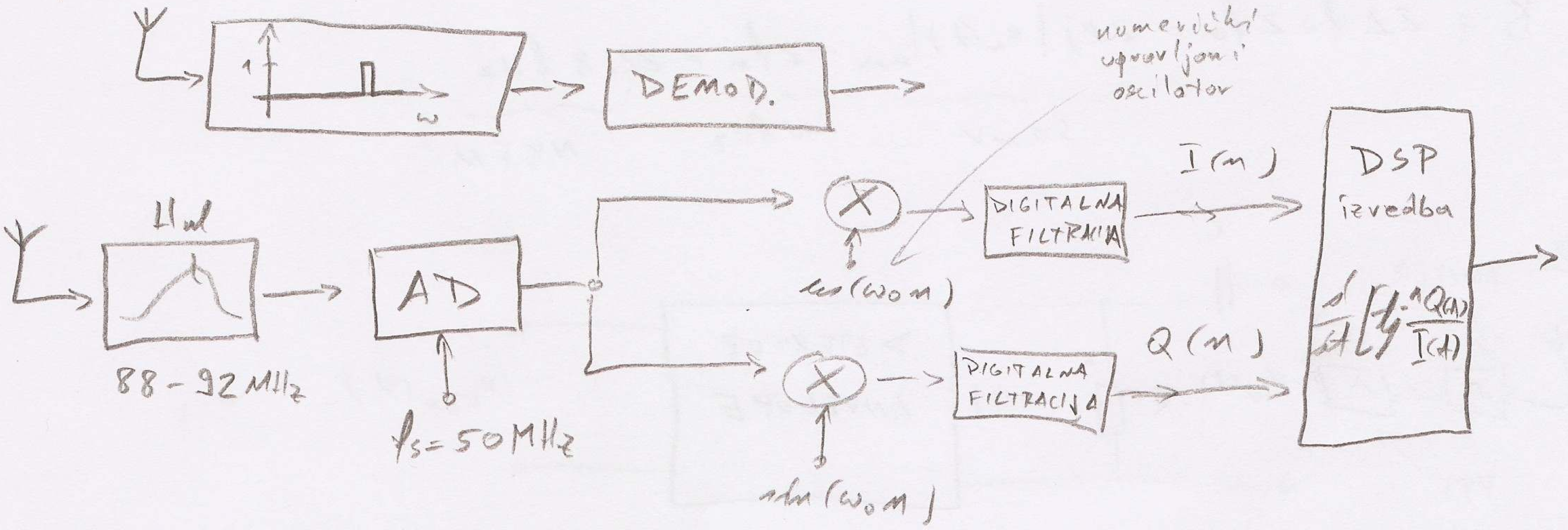
$$\Rightarrow \quad u(t) = -RCU_0\,\underbrace{\sin\left[\omega_0 t + k_\omega\int_{-\infty}^{t} u_m(t)\,dt\right]}_{FM}\cdot\underbrace{\left[\omega_0 + k_\omega u_m(t)\right]}_{AM}$$

Ovo se zove DISKRIMINATOR jer FM pretvara u AM.

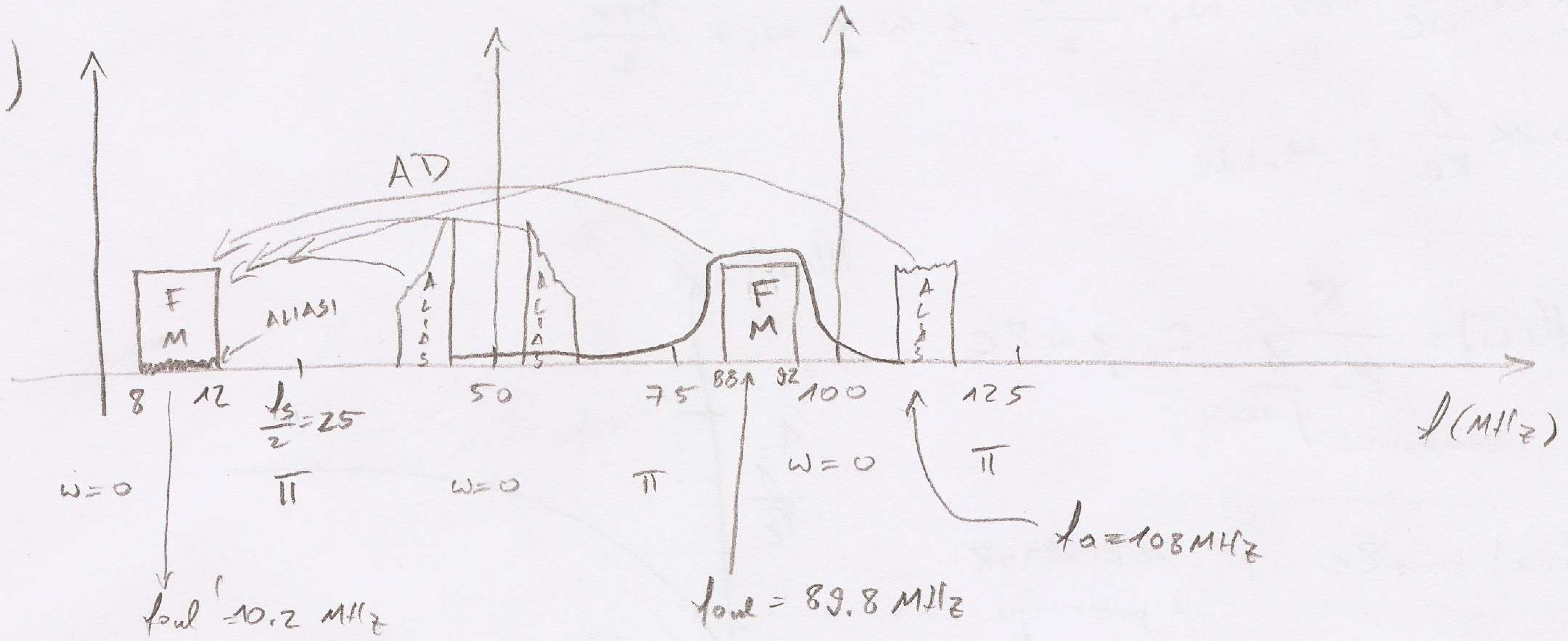
Uz idealan detektor anvelope dobivamo

$$u_{FDM}(t) = RCU_0\,\omega_0 + RCU_0\,K_\omega \cdot u_m(t)$$

13. a)



b)



f_{osl} odgovara frekvenciji $f_{osl}' = 100 - 89.8 = 10.2$ MHz

Budući se radi o direktnoj pretvorbi, digitalni oscilator mora odgovarati toj frekvenciji tj. $\omega_0 = \frac{10.2}{25}\pi = 0.408\pi$ rad

c) $H(f)$ je antialiasing filtar (AAF) za AD.

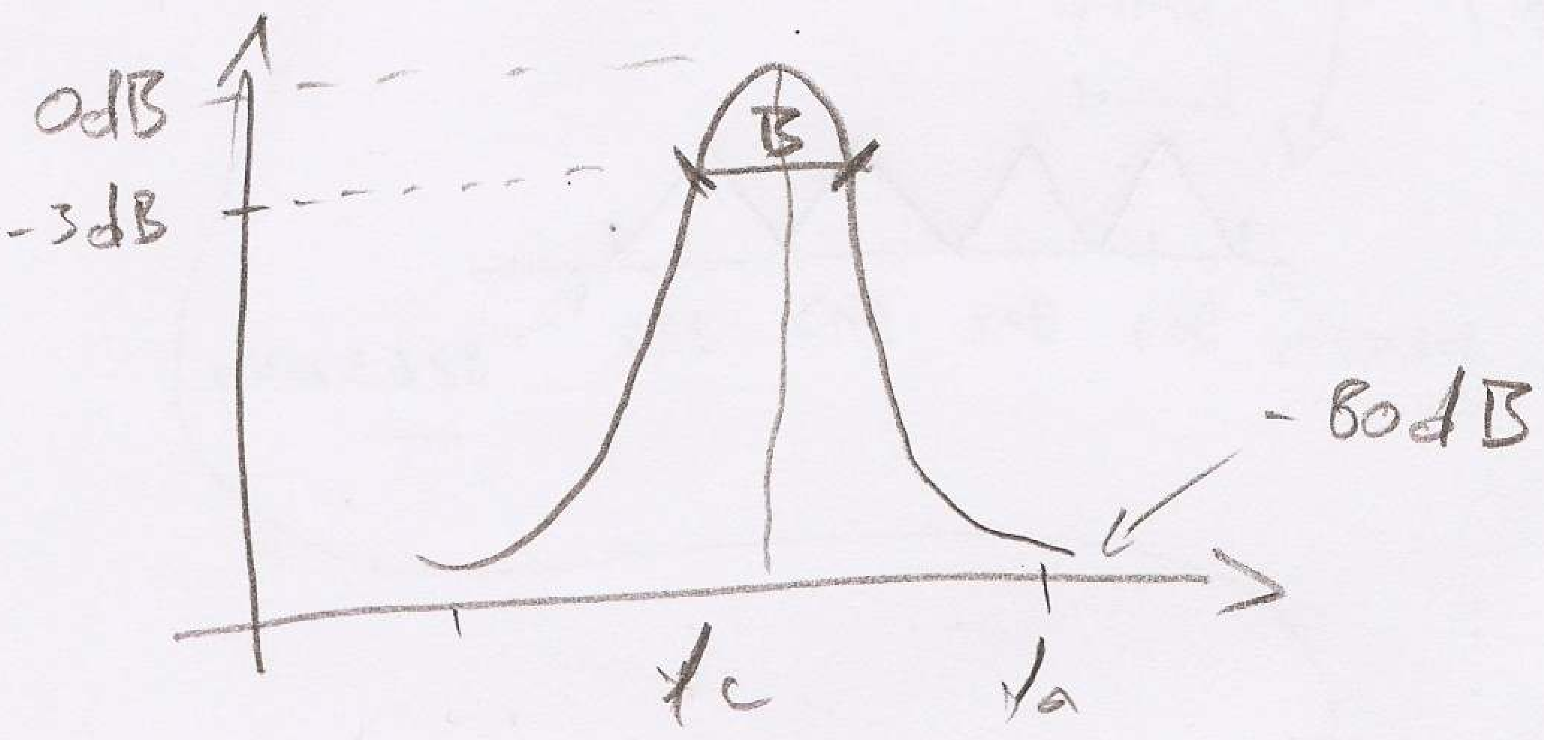
Najbliža alias komponenta kanalima je $f_a = 108$ MHz.

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

$$B = 4 \text{ MHz}$$

BP Butterworthov filtar reda N ima karakteristiku

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



$$20 \lg |H(f_a)| \le -80 \text{dB}$$

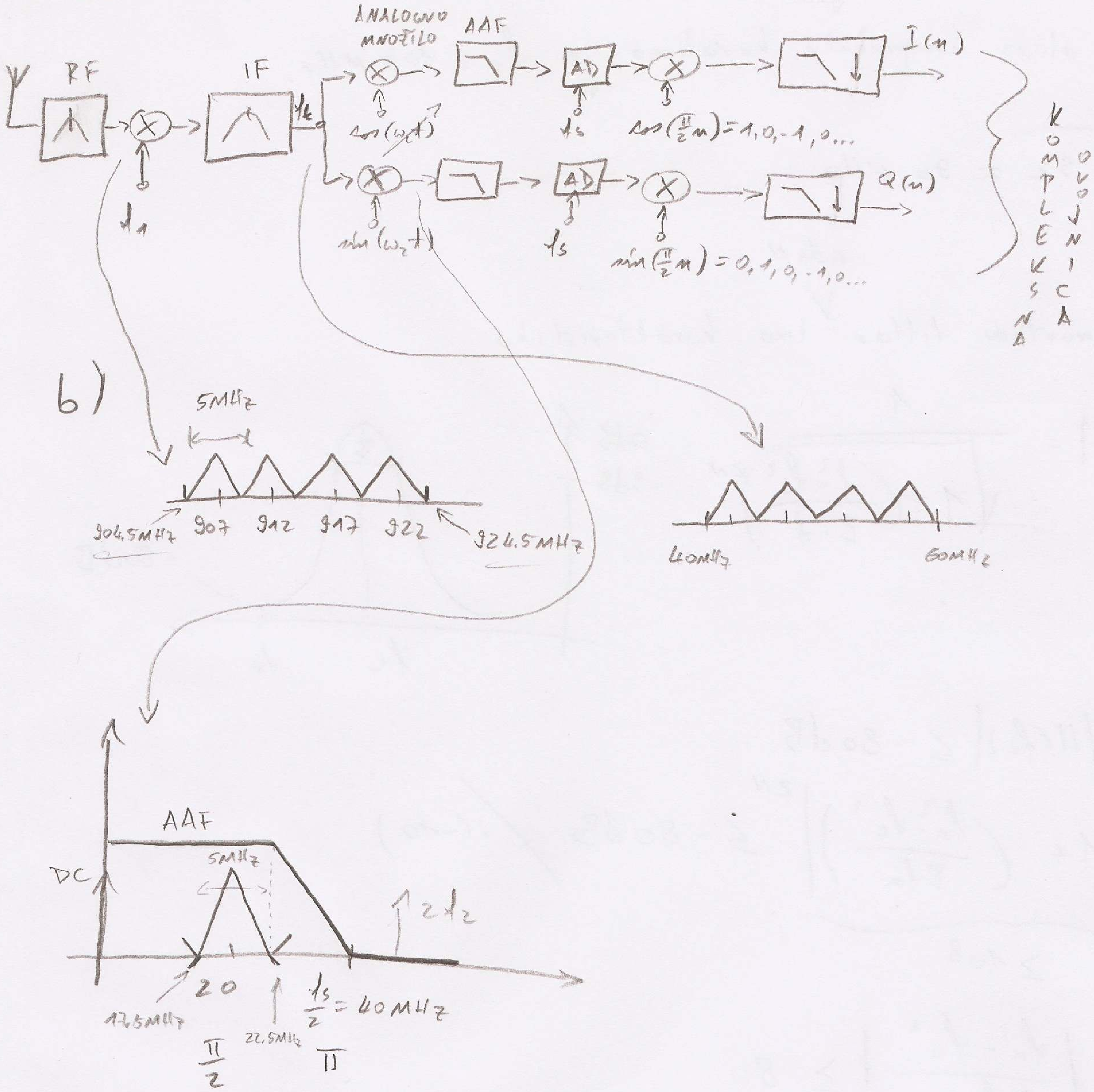
$$\underbrace{-10 \lg \left|1+\left(\frac{f_a^2-f_c^2}{Bf_a}\right)\right|^{2N}}_{\ge 10^8} \le -80 \text{dB} \quad / :(-10)$$

$$2N \lg \left|\frac{f_a^2-f_c^2}{Bf_a}\right| \ge 8$$

$$N \ge \frac{4}{\lg\left|\frac{108^2-90^2}{4\cdot 108}\right|} = 4.3 \Rightarrow N=5$$

U praksi se koristi eliptički filtar.

14. a)



$f_1 = 904.5\,\text{MHz} - 40\,\text{MHz} = 864.5\,\text{MHz}$

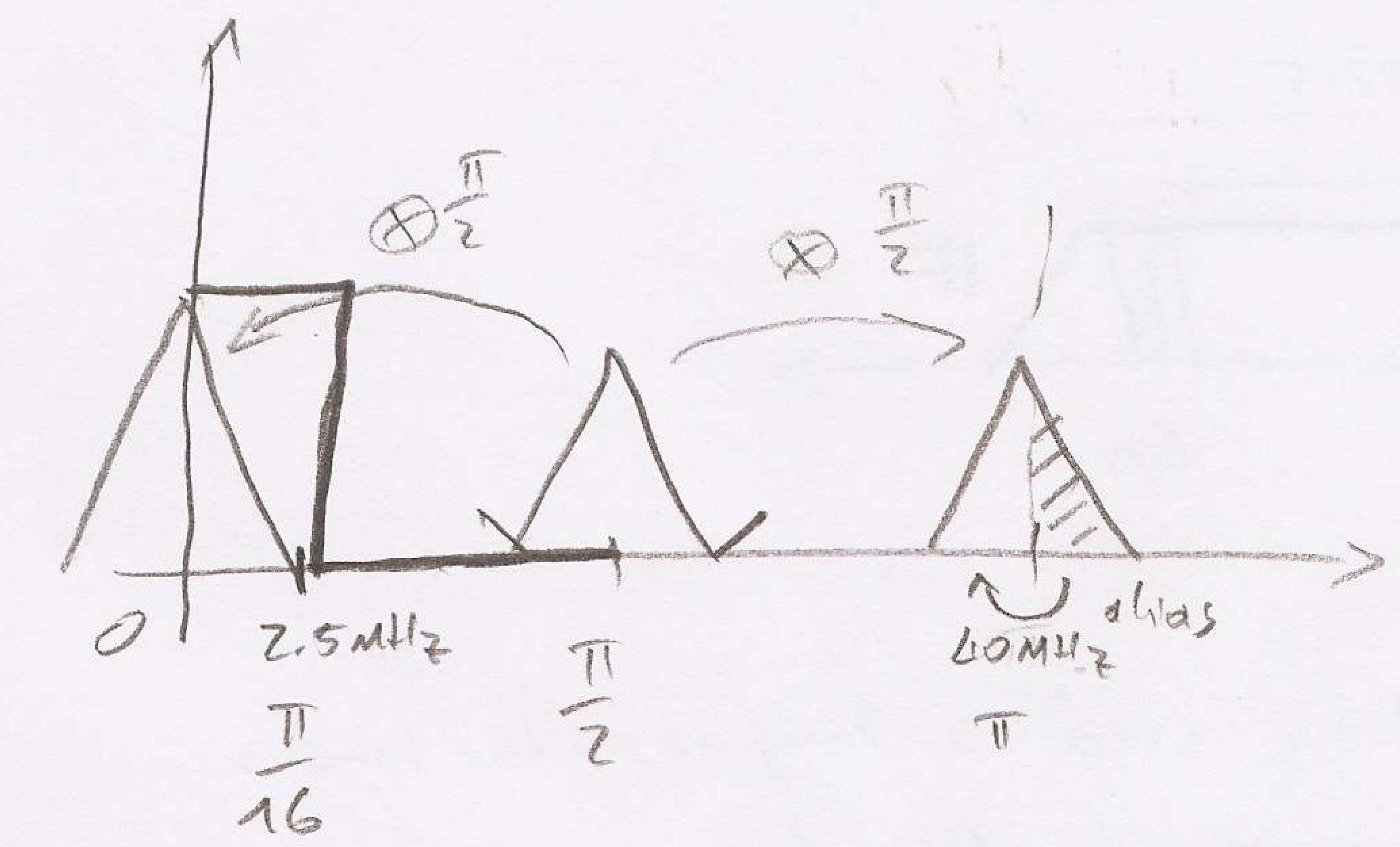
$f_k = \{42.5,\ 47.5,\ 52.5,\ 57.5\}$ MHz

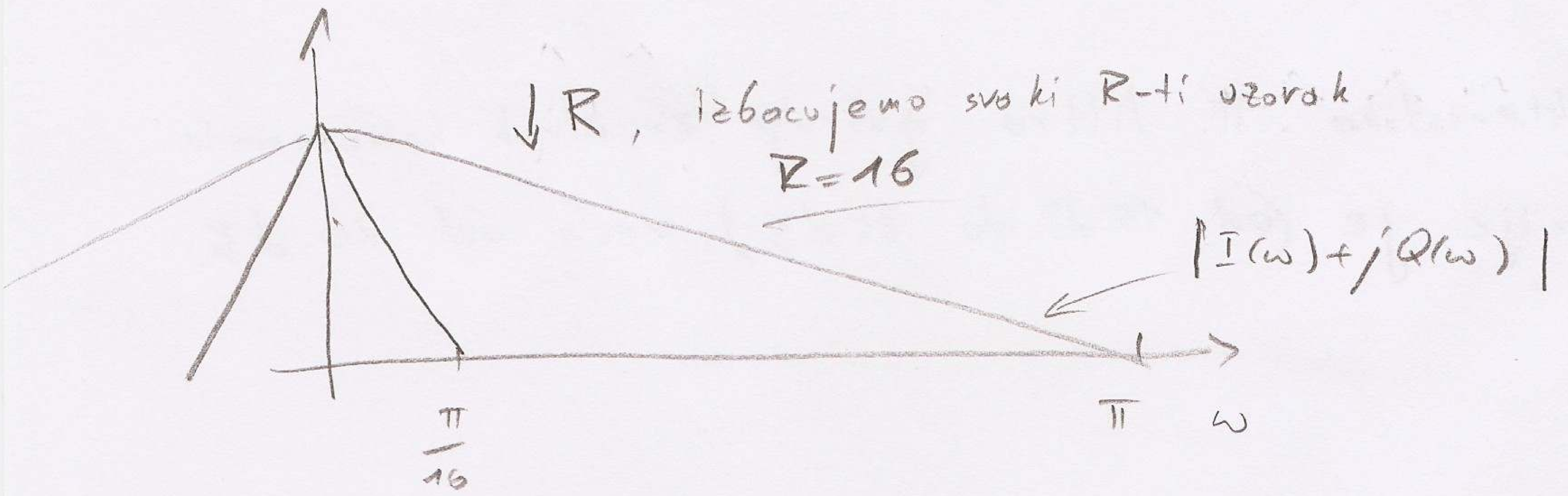
$f_2 = f_k - 20 =$

$= \{22.5,\ 27.5,\ 32.5,\ 37.5\}$ MHz

Zbog analognog mješala dolazi do preslušavanja f_2 na signalni ulaz. Pritom se javljaju komponente $2f_2$ i 0 koje u našem slučaju ne upadaju u kanal.
Zato se radi mješanje sa f_2 i $\frac{\pi}{2}$.

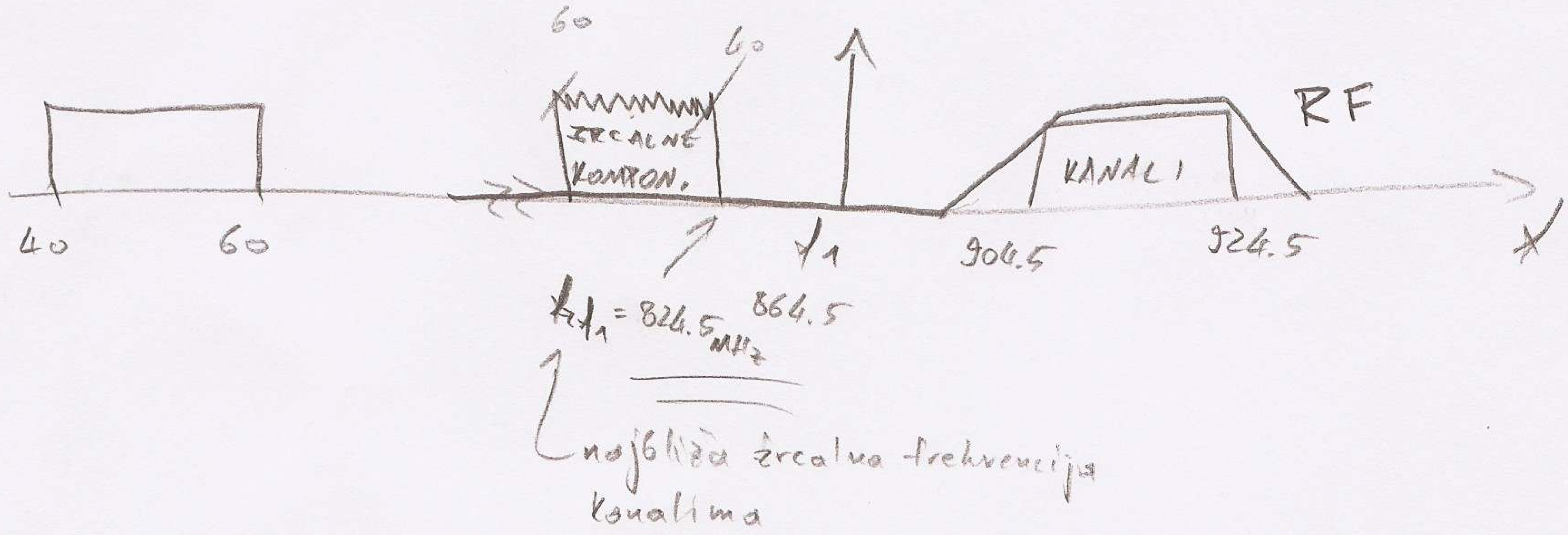
14. Dobivanje kompleksne ovojnice $I+jQ$ u digitalnoj domeni.



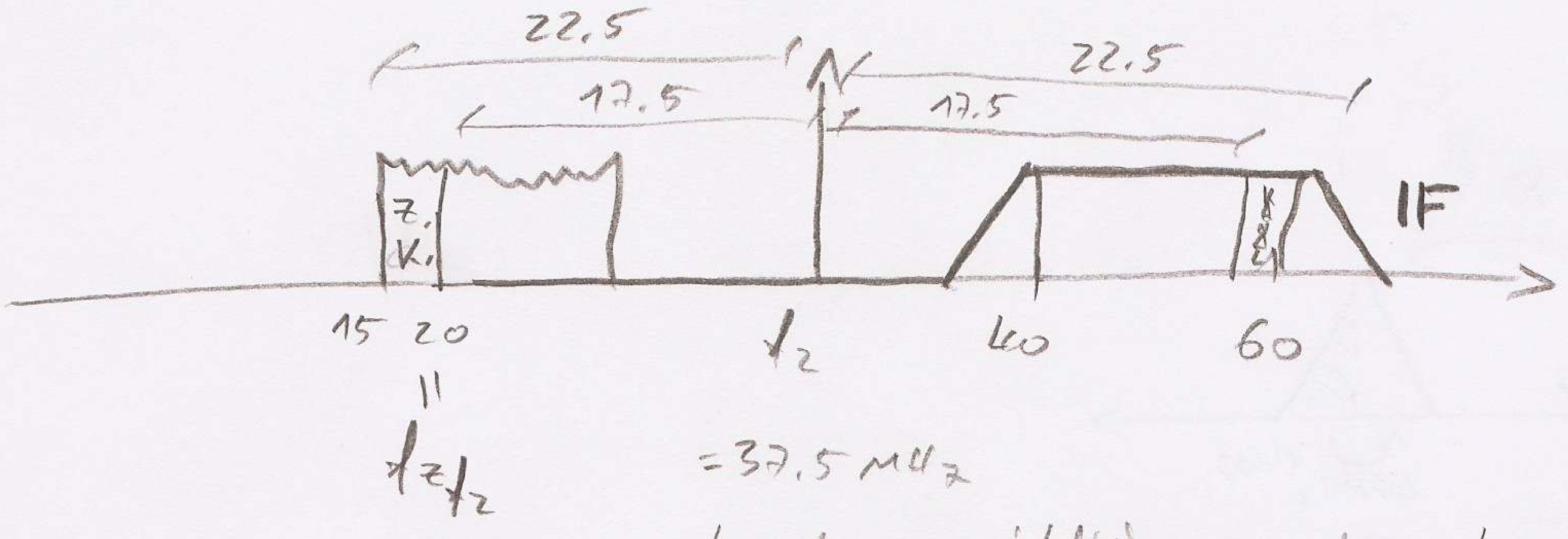


$$f_{s_L} = \frac{f_s}{R} = \frac{80}{16} = 5\,MHz$$

c) Zrcalne frekvencije se pojavljuju kod svake transpozicije frekvencije (osim na frekvenciju nula).
U našem slučaju su to kod miješanja s f_1 i f_2.



Očitavanjem iz amplitudne karakteristike RF filtra vidimo da je gušenje veće od 50 dB.



$= 37.5$ MHz

↳ daje najbližu zrcalnu komponentu kanala (najgore, najstrmiji filtar!)

Očitovanjem iz karakteristike IF filtra gušenje zrcalnih komponenti kod druge transpozicije je (od 15 dB do 85 dB) veće od 70 dB.