Nachrichtentechnik
Probeklausur Sommer 2004
Lösung

Aufgabe 1:

a)

$f_{ZF} = f_S - f_{LO} = 0{,}4\ MHz$

$f_i = f_{LO} - f_{ZF}$

$= f_{LO} - (f_S - f_{LO})$

$= 1{,}6 - (2 - 1{,}6) = 1{,}2\ MHz$

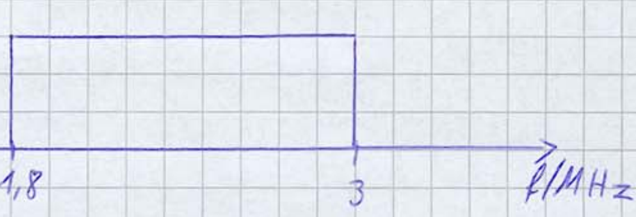
Gleichlagenabwärtsmischung

b)

$f_{LO} = f_P - f_{ZF}$

$f_{P,min} = f_{S,min} - f_{ZF}$

$= 1{,}8 - 0{,}4 = 1{,}4\ MHz$



$f_{P,max} = f_{S,max} - f_{ZF} = 1{,}4 - 0{,}4 = 1\ MHz$

$f_{i,min} = f_{P,min} - f_{ZF} = 1{,}4 - 0{,}4 = 1\ MHz$

$f_{i,max} = f_{P,max} - f_{ZF} = 2{,}6 - 0{,}4 = 2{,}2\ MHz$

Gestörter Empfangsbereich:

2,6 - 3 MHz

c)

$$\left(f_m - \frac{B_{HF}}{2} \; ; \; f_m + \frac{B_{HF}}{2}\right)$$

$$f_{s,min} = f_m - \frac{B_{HF}}{2} \quad ; \quad f_{s,max} = f_m + \frac{B_{HF}}{2}$$

$$f_{sp,max} \leq f_{s,min} \qquad (f_{sp,max} = f_{i,max})$$

$$f_{p,max} - f_{ZF} \leq f_m - \frac{B_{HF}}{2}$$

$$f_{s,max} - f_{ZF} - f_{ZF} \leq f_m - \frac{B_{HF}}{2}$$

$$\cancel{f_m} + \frac{B_{HF}}{2} - 2 f_{ZF} \leq \cancel{f_m} - \frac{B_{HF}}{2}$$

$$\cancel{2} \frac{B_{HF}}{2} \leq 2 f_{ZF} \qquad B_{HF} = 2 f_{ZF} = 0{,}8\ MHz$$

Aufgabe 2:

a)

$$a_F = 20 \cdot \lg\left(\frac{4\pi d}{\lambda}\right)$$

$$10^{\frac{a_F}{20}} = \frac{4\pi d}{\lambda} \Rightarrow \lambda = \frac{4\pi d}{10^{\frac{a_F}{20}}}$$

$$= \frac{4\pi\, 36 \cdot 10^6\,m}{10^{\frac{200}{20}}}$$

$$= 0{,}045\ m$$

b)

$$L_{s2} = L_{s1} + G_s - a_F + G_E$$

$$G_s = L_{s2} - L_{s1} + a_F - G_E$$

$$= -80\,dBm - (20\,dBW) + 200\,dB - 30\,dB$$

$$= -80\,dBm - (50\,dBm) + 200\,dB - 30\,dB$$

$$= -130\,dB + 170\,dB = \underline{\underline{40\,dB}}$$

$$SNR_2 = L_{s2} - L_{n2}$$

$$L_{n2} = L_{s2} - SNR_2 = -80\,dBm - 17\,dB$$

$$= -97\,dBm$$

$$= -127\,dBW$$

$$L_{n2} = 10 \lg \frac{P_{n2}}{1mW} \Rightarrow P_{n2} = 10^{\frac{L_{n2}}{10}}$$

$$\Rightarrow P_{n2} = 10^{-9{,}7} \cdot 10^{-3}\,W = 10^{-12{,}7}\,W$$

$$= 1{,}995 \cdot 10^{-13}\,W$$

$$P_{n2} = k\,T_2\,B_n \Rightarrow T_2 = \frac{P_{n2}}{k B_n} = \frac{1{,}995 \cdot 10^{-13}\,W}{1{,}38 \cdot 10^{-23}\,\frac{Ws}{K} \cdot 2{,}5 \cdot 10^9\,s}$$

$$\Rightarrow T_2 = \underline{\underline{5783{,}4\ K}}$$

c) ← lineare Dämpfung der Leitung

$T_L = T_{phys} \, (a-1)$

$a = l \cdot a' = 20m \cdot 0{,}5\,dB/m = 10\,dB$

$a = 10 \Rightarrow T_L = 300\,K\,(10-1) = 2700\,K$

$$T_{sys2} = T_2 + T_{Amp1} + \frac{T_L}{g_1} + \frac{T_{Amp2}}{g_1 \cdot \frac{1}{a}}$$

$$= T_2 + T_{Amp2} + \frac{T_L}{g_1} + \frac{T_{Amp2} \cdot a}{g_1}$$

$$T_{sys2} = 5783{,}4\,K + 900k + \frac{2700\,K}{100} + \frac{2700 \cdot 10}{100}$$

$T_{Amp1} = T_0\,(F-1)$ $\quad F_1 = 6\,dB \Rightarrow F_1 = 4$

$F_2 = 10\,dB \Rightarrow F_2 = 10$

$T_{Amp1} = 300K\,(4-1) = 900K$ $\quad g_{1p} = 20\,dB \Rightarrow g_1 = 100$

$T_{Amp2} = 300K\,(10-1) = 2700\,K$

$T_{sys2} = 5783{,}4 + 900K + 27K + 270K = \underline{\underline{6980{,}4\,K}}$

$SNR_5 = SNR_2$

$$SNR_2 = 10\,lg\,\frac{P_{s2}}{P^*_{n2}}$$

$P^*_{n2} = k \cdot T_{sys2} \cdot B_n$

$$SNR_2 = \underbrace{10\,lg\,P_{s2}}_{L_{s2}} - 10\,lg\,(k\,T_{sys2}\,B_n)$$

$$= L_{s2} - 10\,lg\,(k\,T_{sys2}\,B_n)$$

$$= -80\,dBm - 10\,lg\,\frac{1{,}38 \cdot 10^{-23}\,\frac{Ws}{K} \cdot 6980{,}4K \cdot 25 \cdot 10^6 s^{-1}}{10^{-3}W}$$

$$= -80\,dBm - (-126{,}2\,dBW)$$

$$SNR_2 = -110\,dBW + 126{,}2\,dBW = 16{,}2\,dB$$

d)

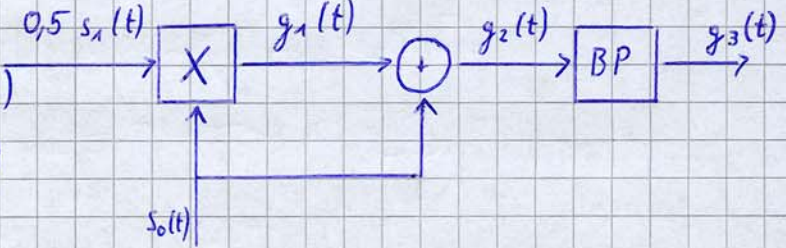
$V_1: \quad g_1 = 20\,dB \qquad F_1 = 6\,dB$

$V_2: \quad g_2 = 30\,dB \qquad F_2 = 10\,dB$

$V_3: \quad g_3 = 30\,dB \qquad F_3 = 6\,dB$

$\underline{\underline{V_3 \text{ — } V_1}}$

Aufgabe 3:



$s_0(t) = A_0 \cos(2\pi f_0 t)$

$s_1(t) = \cos(2\pi f_1 t)$

$f_0 = 200\ MHz$

$f_1 = 5\ MHz$

$A_0 = 800\,V$

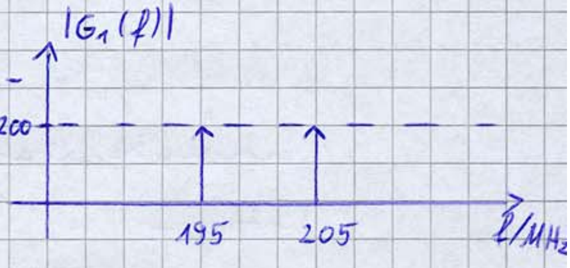
a)

$$g_1(t) = 0{,}5 \cdot s_1(t) \cdot s_0(t) = 0{,}5 \cdot \cos[2\pi \cdot f_1 t]\, A_0 \cos[2\pi f_0 t]$$

$$= 0{,}5 \cdot A_0 \cdot \frac{1}{2} \left\{ \cos[2\pi (f_0 - f_1) t] + \cos[2\pi (f_0 + f_1) t] \right\}$$

$$g_1(t) = 200\,V \left\{ \cos[2\pi \cdot 195\, t] + \cos[2\pi \cdot 205\, t] \right\}$$

Zweiseitenband Amplitudenmodulation ohne Träger

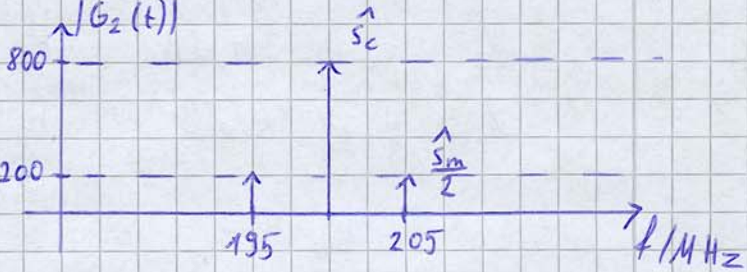


$$P_{g_1(t)} = \frac{(200)^2}{2R} + \frac{(200)^2}{2R}$$

$$= \frac{200^2}{R} = \frac{40000}{40} = 1000\,W = 1\,kW$$

b)

$$g_2(t) = g_1(t) + s_c(t) = 200\left[\cos(2\pi\, 195\cdot t) + \cos(2\pi\cdot 205\cdot t)\right] + 800\cos(2\pi\cdot 200 t)$$



$$g_2(t) = 400\cdot\frac{1}{2}\left\{\cos\left[2\pi(200-5)t\right]\cdot 800 + \cos\left[2\pi(200+5)t\right]\right\} + 800\cdot\cos\left[2\pi\, 200 t\right]$$

$$= 400\cos\left[2\pi\, 200 t\right]\left[\cos\left[2\pi\cdot 5 t\right] + 800\cdot\cos\left[2\pi 200 t\right]\right.$$

$$= \underbrace{800}_{\hat{s}_c}\left(\cos 2\pi \underbrace{200}_{f_c} t\right)\left[1 + \underbrace{\frac{1}{2}}_{m}\cos\left[2\pi \underbrace{5}_{f_m} t\right]\right]$$

$$m = \frac{1}{2}$$

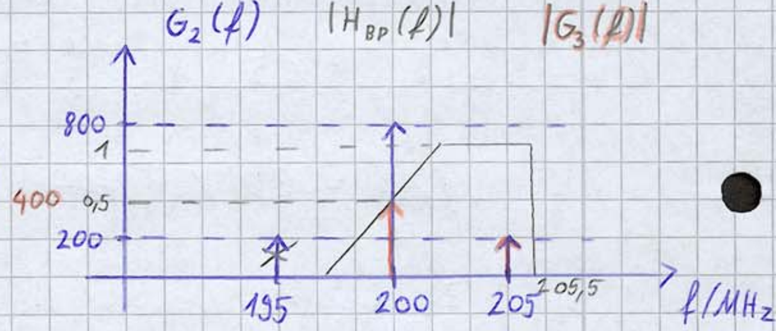
oder $m = \frac{\hat{s}_m}{\hat{s}_c} = \frac{400}{800} = \frac{1}{2}$

$$P_{g_2(t)} = P_{g_1(t)} + \frac{(800)^2}{2R} = 1\,kW + \frac{640000}{2\cdot 40} = 1\,kW + 8\,kW$$

$$P_{g_2(t)} = 9\,kW$$

c)

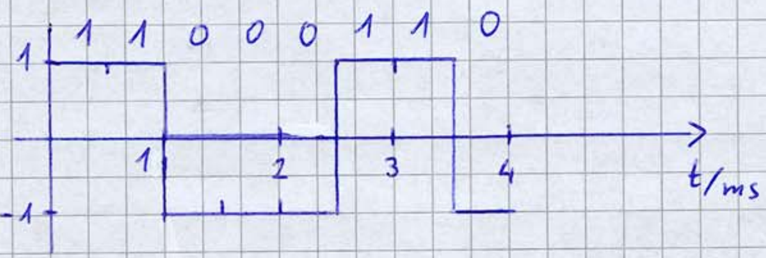
$$g_3(t) = 400\cdot\cos\left[2\pi\, 200 t\right] + 200\cos\left[2\pi\, 205 t\right]$$



Einseitenbandmodulation mit unterdrückten Träger

$$P_{g_3(t)} = \frac{(400)^2}{2R} + \frac{(200)^2}{2R} = \frac{160000}{80} + \frac{40000}{80}$$

$$P_{g_3(t)} = 2000 + 500 = \underline{\underline{2{,}5\,kW}}$$



d)

$R_b = n\ f_p$

$R_b = 2 \cdot 1\,kHz = 2\,kbit/s$

$B_ü \geq \frac{R_b}{2}$ $\qquad B_{ü,min} = 1\,kHz$

Aufgabe 5:

a)

$h_2(t) = s(iT - t)$

Der Matched-Filter ist so angepasst, damit der Signal zu Rauschabstand maximiert wird.

b)

$R_b = \frac{m}{1+r} \cdot B_{RF}$

2 ASK: $m = ld(M) = ld(2) = 1$

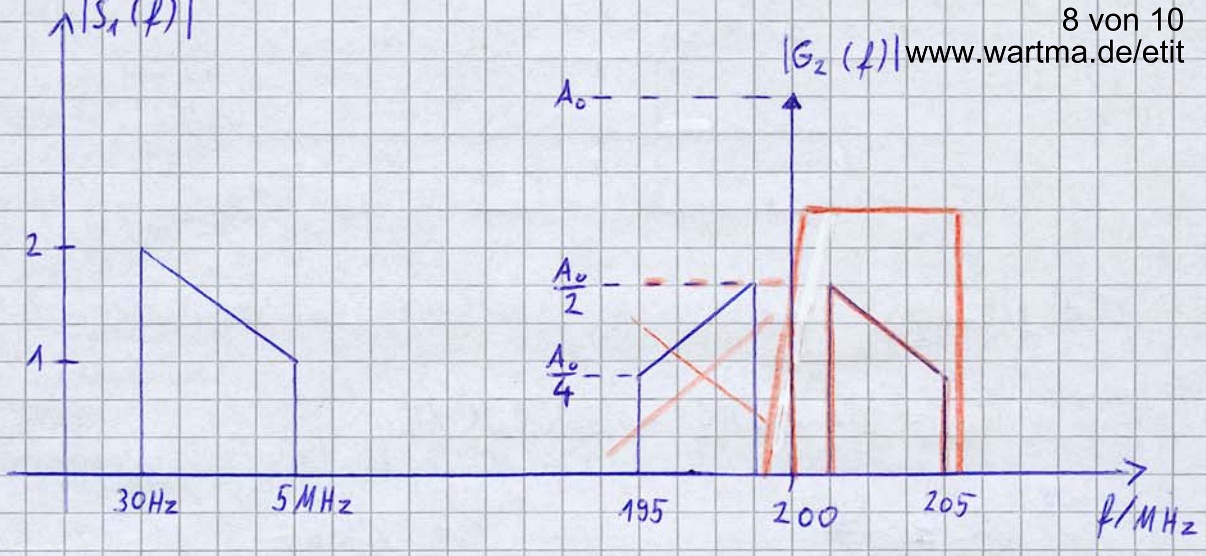
$M = 2$

- $r = 0{,}25 \Rightarrow R_b = \frac{1}{1{,}25} \cdot 4 = 3{,}2\ Mbit/s$
- $r = 0{,}5 \Rightarrow R_b = \frac{1}{1{,}5} \cdot 4 = 2{,}\overline{66}\ Mbit/s$

4 ASK: $m = 2$

- $r = 0{,}25 \Rightarrow R_b = 6{,}4\ Mbit/s$
- $r = 0{,}5 \Rightarrow R_b = 5{,}\overline{33}\ Mbit/s$

Vorteil 4 ASK	Nachteil 4 ASK
• höhere Übertragungsrate	• störanfälliger
• geringerer Bandbreitenbedarf	• kleinere Abstände zwischen den Zuständen bei gleicher Leitung



Aufgabe 4:

a)

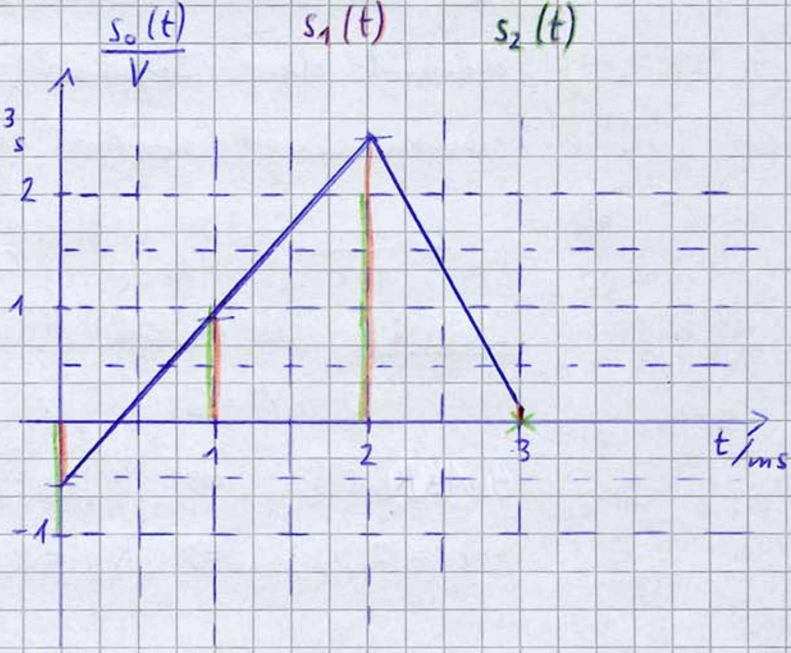
$f_p \geq 2 f_g$ Nyquist - Theorem

$f_g \leq \frac{f_p}{2} = \frac{1\,kHz}{2} = 500\,Hz$

b)

$T_p = \frac{1}{f_p} = \frac{1}{10^3} = 10^{-3}\,s$

$T_p = 1\,ms$



c)

Coderwortlänge = 2 bit

Grey - Code ⇒ Abstand 1 zw. Stufen

Quantisierungsstufen	Codewort
2	01
1	00
0	10
-1	11

-1 1 2 0

⇒ 11 00 01 10

$$P_4 = \frac{1}{4}\left[0 + \frac{(A_4)^2}{2R} + \frac{(2A_4)^2}{2R} + \frac{(3A_4)^2}{2R}\right]$$

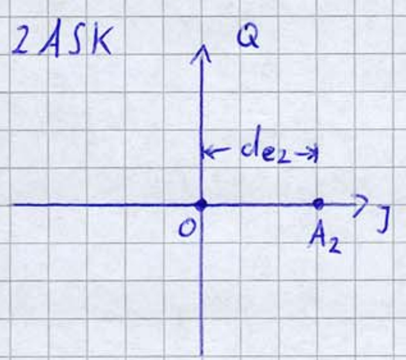
$$= \frac{1}{8R}\left(0 + A_4^{\,2} + 4A_4^{\,2} + 9A_4^{\,2}\right)$$

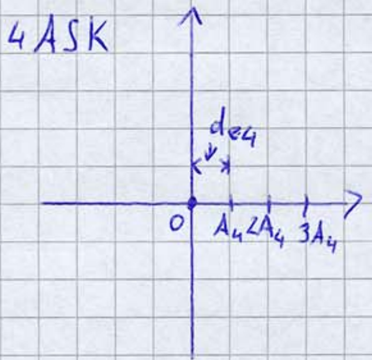
$$= \frac{14A_4^{\,2}}{8R}$$

$$P_2 = \frac{1}{2}\left[0 + \frac{A_2^{\,2}}{2R}\right] \quad \frac{A_2^{\,2}}{4R}$$

$$\frac{A_2^{\,2}}{4R} = \frac{14A_4^{\,2}}{8R} \Rightarrow A_2^{\,2} = 7A_4^{\,2}$$

$$\frac{A_4}{A_2} = \frac{1}{\sqrt{7}}$$



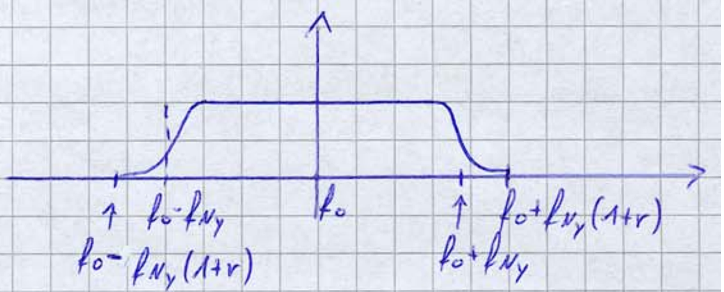


d)

$$B_{n\,Trc} = f_{Ny} \quad \forall r \in [0,1]$$

$$B_{n\,Trc} = \frac{B_{RF}}{2(1+r)}$$

$$B_{RF} = f_0 + f_{Ny}(1+r) - [f_0 - f_{Ny}(1+r)] = 2 f_{Ny}(1+r)$$



$$r = 0{,}25 \Rightarrow B_{n\,Trc} = \frac{4}{2\cdot 1{,}25} = \frac{4}{2{,}5} = 1{,}6\ MHz$$

$$r = 0{,}5 \Rightarrow B_{n\,Trc} = \frac{4}{2\cdot 1{,}5} = \frac{4}{3} = 1{,}\overline{33}\ MHz$$

e)

$R_b = 80 \cdot 64\,kbit/s = 5{,}12\,Mbit/s$

4 ASK $\Rightarrow$ $m = 2$

$R_b = \frac{m}{1+r} B_{RF}$

$r = \frac{m}{R_b} B_{RF} - 1 = \frac{2}{5{,}12} \cdot 4 - 1 = 0{,}5625$