Answers & Hints to the exam in the course Digital Communications (ETT051), October 22, 2010, 14-19.

Problem 1.

a) The energy efficiency is better for 64-QAM since $d^2_{min} = 6/21$, compared with $24/255$ for 16-PAM. The bandwidth efficiency for 64-QAM is $6\rho_{BPSK}$, and for band pass 16-PAM it is $4\rho_{BPSK}$ (worse than 64-QAM). However, the bandwidth efficiency for base band 16-PAM is $8\rho_{BPSK}$(better than 64-QAM).

When comparing 64-QAM with base band 16-PAM the statement is FALSE.

When comparing 64-QAM with band pass 16-PAM the statement is TRUE.

b) TRUE, since $W_{lobe} = 4/T = 8R_b/3$.

c) TRUE, since $P_s \approx 2Q(\sqrt{d^2_{\min}\mathcal{E}_b/N_0}) = 2Q(5.273) \approx 1.14 \cdot 10^{-7}$.

d) TRUE, since $D^2_{min} = 2\mathcal{E}_b 0.8 = 2(PT_s/4)0.8 = PT_s 0.4$

e) FALSE, since $d^2_{min} = 4$ for 16-PPM, and it is smaller for 16-QAM.

Problem 2.

With α and $R_b = 384$ kbps it is given that $P_b = Q(\sqrt{d^2\mathcal{E}_b/N_0}) = Q(\sqrt{\frac{d^2\alpha^2 P_{sent}}{R_b N_0}}) = 10^{-8} = Q(5.612)$.

a) $P_b = Q(\sqrt{\frac{d^2\alpha^2 P_{sent}}{100 R_b N_0}}) = Q(0.5612) \approx 0.28$.

b) $\frac{d^2\alpha^2 P_{sent}}{R_b N_0} = 5.612^2$

The ratio α^2/R_b must be held constant.

i) $\alpha^2/R_b = (\alpha/10)^2/R_{b,new}$ leading to that $R_{b,new} = 3.84$ kbps.

ii) $\alpha^2/R_b = (10\alpha)^2/R_{b,new}$ leading to that $R_{b,new} = 38.4$ Mbps.

c) It is given that $P_b = Q(\sqrt{d^2\mathcal{E}_b/N_0}) = Q(\sqrt{d^2 19.953}) = 10^{-8} = Q(5.612)$. This gives $d^2 = 1.578$ which is 1.98 dB better than binary orthoganal signaling.

Problem 3.

a) The output signal alternative will be:

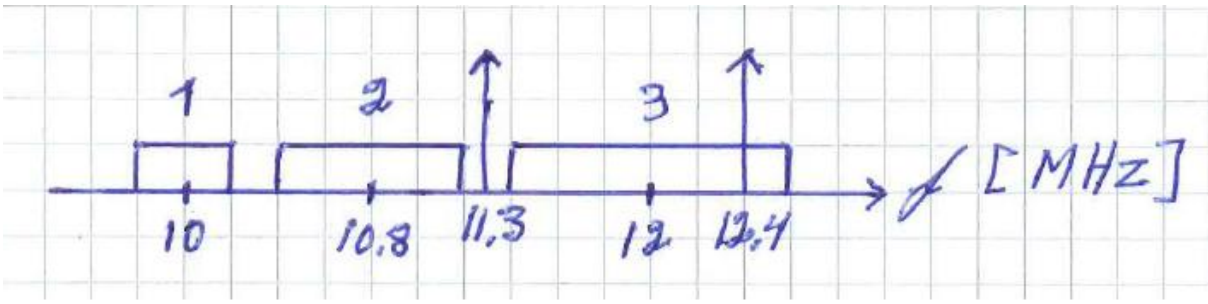
0 in the time interval $t < 0$.
$1.5A$ in the time interval $0 < t < 0.1T_s$.
$0.6A$ in the time interval $0.1T_s < t < 0.3T_s$.
$1.2A$ in the time interval $0.3T_s < t < 0.5T_s$.
$-0.3A$ in the time interval $0.5T_s < t < 0.6T_s$.
$0.6A$ in the time interval $0.6T_s < t < 0.7T_s$.
$0.3A$ in the time interval $0.7T_s < t < 0.8T_s$.
$-0.3A$ in the time interval $0.8T_s < t < 1.2T_s$.
0 in the time interval $1.2T_s < t$.

b) See the compendium (e.g. Chapter 6).

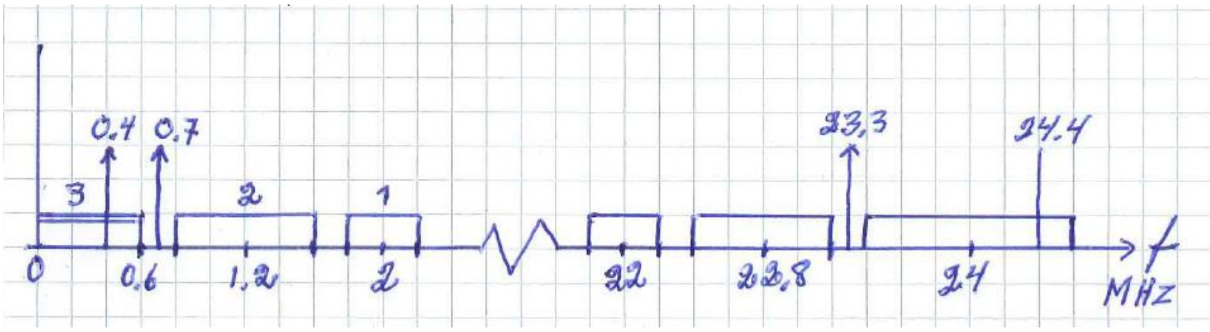
Problem 4.

a)

i) r(t): (symmetry around f=0)



ii) y(t): (symmetry around f=0)



iii) Correct user signal (user 3) at base band in $y(t)$. A disturbance at 400 kHz. Low pass filter bandwidth should be 600 kHz.

b)

i) Close to the true P_s at medium and high snr. Also then a simple expression.

ii) It determines the energy efficiency (and P_s) at medium and high snr.

iii) The bandwidth efficiency is low.

Problem 5.

a) $d^2_{min}\mathcal{E}_b/N_0 \geq 6.3613^2 = 40.466$ leads to that

$R_b \leq \frac{3log_2(M)10^9}{(M-1)40.466}$ which gives maximum allowed bit rates for different values of M.

The requirement on the width of the main lobe is $W_{lobe} = 4/T = 16R_b/(3k) = 5 \cdot 10^6$ which can be formulated as $R_b = 15k10^6/16$, and from this expression we get the bit rate for different k (or M).

We want as high bit rate as possible, so we calculate R_b for increasing k. However, we must not violate the maximum bit rates obtained above!

It is found that $M = 64$ should be used and the bit rate then is $R_b = 5.625$ Mbps.

b) From the maximum allowed bit rates in a) we find that we should use $M = 4$ and the bit rate $R_b = 49.4$ Mbps.

W_{lobe} will in this case be $W_{lobe} = (16/6)R_b = 131.7$ Mhz.