Problem 1

Binarny FSK system prenasa binarne data prensovou rychlostou R = 2 Mbps, R=1/Tb. Predpokladajme AWGN kanal s nulovou strednou hodnotou a vykonnovou spektralnou hustotou No/2 = 1. 10^{-20} W/Hz. Amplituda prijimaneho signalu je 1 microvolt. Vypocitajte priemernu bitovu chybovost Pe.

$$P_{be-FSK} = Q\left(\sqrt{\frac{E_b}{N_0}}\right)$$

Riešenie:

$$E_b = \frac{1}{2} A^2 T_b$$

$$T_b = \frac{1}{R}$$

$$\longrightarrow \quad E_b = \frac{A^2}{2\,R} \quad \longrightarrow \quad \frac{E_b}{N_o} = \frac{A^2}{2\,R\,N_o}$$

$$\sqrt{\frac{E_b}{N_o}} = \sqrt{\frac{A^2}{2\,R\,N_o}} = \sqrt{\frac{(10^{-6})^2}{2\;2\;10^6\;2\;10^{-20}}} = \sqrt{0{,}125\;10^2} = \sqrt{12{,}5} = 3{,}5355$$

$$P_{be-\_FSK} = Q\left(\sqrt{\frac{E_b}{N_o}}\right) = Q(3{,}5355) = 0.00019262$$

Problem 2

Binarny PSK system prenasa binarne data prenosovou rychlostou R = 1 Mbps, R=1/Tb. Predokladajme AWGN kanal s nulovou strednou hodnotou a vykonnovou spektralnou hustotou No/2 = 1. 10^{-12} W/Hz. Chceme dosiahnut pravdepodobnost chybneho bitu Pe=10^{-4}.

Vypocitajte priemernu hodnotu vykonu nosnej na vstupe prijimaca, ak je detektor koherentneho typu

$$P_{be-PSK} = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$$

Riešenie:

Ak P je priemerna hodnota vykonu nosnej na vstupe prijmaca, potom $E_b = P\,T_b$

$$T_b = \frac{1}{R} \Rightarrow \frac{E_b}{N_o} = \frac{P}{N_o\,R}$$

$$P_{be-PSK} = Q\left(\sqrt{\frac{2\,E_b}{N_o}}\right) = 10^{-4}$$

$$\sqrt{\frac{2\,E_b}{N_o}} = 3{,}7 \Rightarrow \frac{2\,E_b}{N_o} = 13{,}69$$

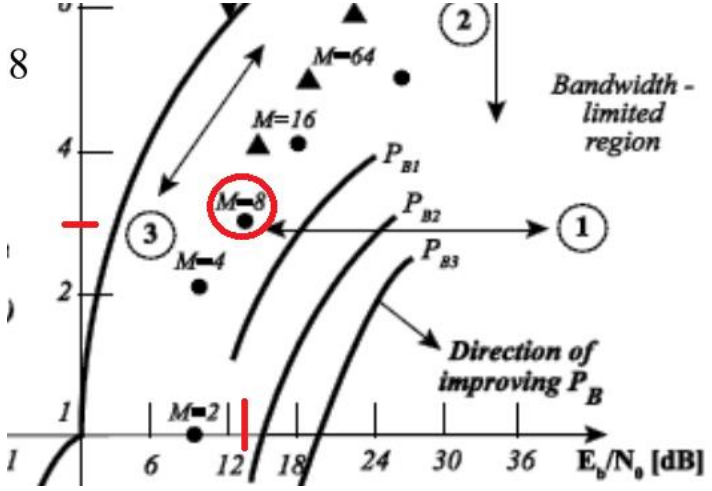
$$\frac{E_b}{N_o} = 6{,}845 = \frac{P}{N_o\,R} \Rightarrow P = 6{,}845\,N_o\,R = 6{,}845\,2\,10^{-12}\,10^{6} = 13{,}69\,10^{-6}\ \text{W}$$

Problem3: Majme komunikacny system s nasledovnymi parametrami:
Sirka pasma B = 4000 Hz
Prenosova rychlost R = 9600 bit/s
Bitova chybovost $P_b = 10^{-5}$
Hodnota $P_r / N_0 = 53$ dB na vstupe prijimaca
Urcte vhodny typ modulacie!

Riešenie:
R = 9600 bit/s
B = 4000 Hz
$\Rightarrow \frac{R}{B} = 2{,}4 \frac{bit}{s}/H \Rightarrow$ Typ bude MPSK alebo MQAM, nie MFSK

$\frac{P_r}{N_o} = \frac{E_b}{N_o} R$ ak všetko máme v dB, teda $\frac{E_b}{N_o} = \frac{P_r}{N_o} - 10 \log R = 53 - 10 \log 9600 = 13{,}2\ dB$

Z obrázkov Ulohy345 alebo z knihy Theory of Telecommunications Networks Tabulka 7.1 str. 159 máme že týp modulacie je 8-PSK



M	k	R [bit/s]	R_s [symbol/s]	MPSK Minimum Bandwidth [Hz]	MPSK $\frac{R}{B}$	MPSK $\frac{E_b}{N_0}$ [dB] $P_B = 10^{-5}$
2	1	9600	9600	9600	1	9,6
4	2	9600	4800	4800	2	9,6
8	3	9600	3200	3200	3	13,0
16	4	9600	2400	2400	4	17,5
32	5	9600	1920	1920	5	22,4

Problem4: Majme komunikacny system s nasledovnymi parametrami:

Sirka pasma B = 45 000 Hz

Prenosova rychlost R = 9600 bit/s

Bitova chybovost $P_b = 10^{-5}$

Hodnota $P_r / N_0 = 48$ dB na vstupe prijimaca

Urcte vhodny typ modulacie!

Riešenie:

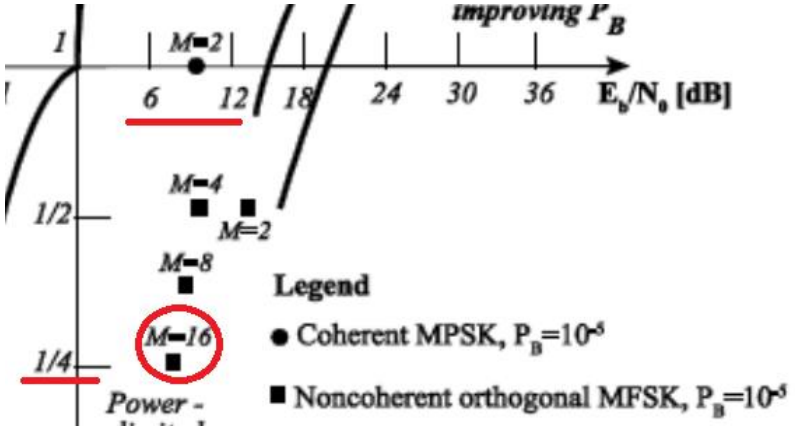
R = 9600 bit/s
B = 45000 Hz

$$\frac{R}{B} = 0{,}213 \frac{bit}{s}/H$$

Typ bude MFSK

$\frac{P_r}{N_o} = \frac{E_b}{N_o} R$ ak všetko máme v dB, teda $\frac{E_b}{N_o} = \frac{P_r}{N_o} - 10 \log R = 48 - 10 \log 9600 = 8{,}2\ dB$

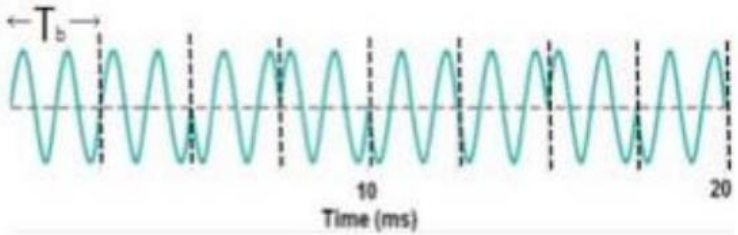
Z obrázkov Ulohy345 alebo z knihy Theory of Telecommunications Networks Tabulka 7.1 str. 159 máme že týp modulacie je 16-FSK



M	k	R [bit/s]	R_s [symbol/s]	Noncoherent Orthog MFSK Min Bandwidth [Hz]	MFSK $\frac{R}{B}$	MFSK $\frac{E_b}{N_0}$ [dB] $P_B = 10^{-5}$
2	1	9600	9600	19,200	1/2	13,4
4	2	9600	4800	19,200	1/2	10,6
8	3	9600	3200	25,600	1/3	9,1
16	4	9600	2400	38,400	1/4	8,1
32	5	9600	1920	61,440	5/32	7,4

Problem5:

Priebeh na obrazku reprezentuje BPSK prenos. Vertikalne prerusovane ciary oddeluju jednotlive bity.



Binarna '1' je reprezentovana nasledovnym signalom:

a. Urcte postupnost bitov (nul a jedniciek) na obrazku.
b. Urcte prenosovu (bitovu) rychlost.
c. Urcte sirku pasma pre tento typ prenosu.

Riešenie:

a) Postupnosť bitov(nul a jedničiek) = 1 1 0 1 0 0 1 0

b) $R_b = \frac{1}{T_b} = \frac{1}{10/4} = \frac{1}{2{,}5\ ms} = \frac{1}{2{,}5\ 10^{-3}} = 0{,}4\ 10^3\ bit/sec$

c) $B = 2\ R_b = 0{,}8\ kHz$

Problem6:

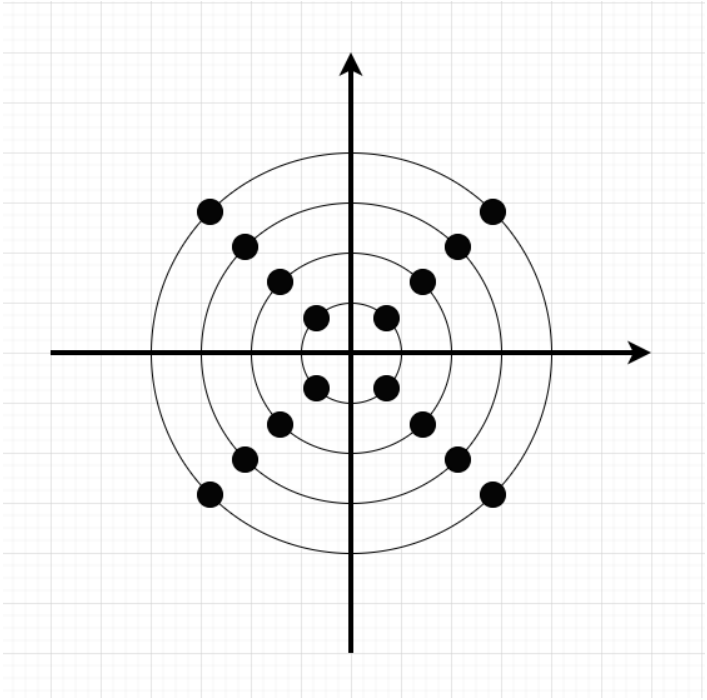
Predpokladajme modulaciu typu 16-QAM.

a) Uvazujme 4 rozdielne fazy a 4 rozdielne amplitudy v tomto 16-QAM modulacnom systeme.
Nakreslite constellation diagram (diagramy) pre tento modulacny system (nemusite oznacovat jednotlive bity pre kazdy symbol, len nakreslit polohy symbolov).

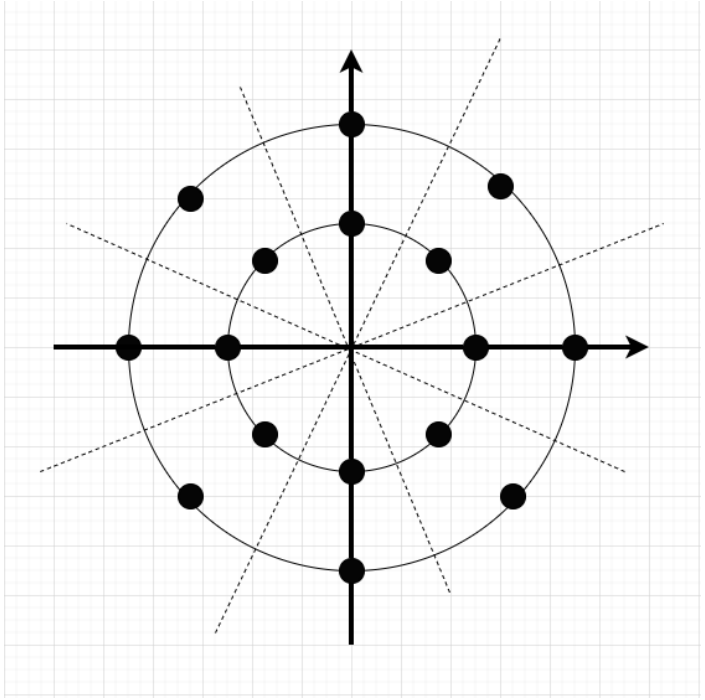
b) Uvazujme 8 rozdielnych faz a 2 rozdielne amplitudy v tomto 16-QAM modulacnom systeme.
Nakreslite constellation diagram (diagramy) pre tento modulacny system (nemusite oznacovat jednotlive bity pre kazdy symbol, len nakreslit polohy symbolov).

Riešenie:

a) 4 fazy, 4 amplitudy



b) 8 faz, 2 amplitudy



Problem7:

Komunikacny system prenasa bity rychlostou 100 kbps.
Pre jednotlive typy modulacie uvedene nizsie, urcte frekvencnu sirku pasma prenosu (bandwidth).

a. FSK, with frequency deviation 200 kHz.
b. OOK.
c. QPSK.
d. 16-PSK.
e. 16-QAM.
f. 512-QAM.

Bandwidth (BW) for FSK : BW = 2 ($\Delta f + R_b$)
For other types of modulation: BW = 2 R_b / k ; $k=\log_2 M$

Riešenie:

a) $BW = 2(\Delta f + R_b)$

$BW = 2(200\ 10^3 + 100\ 10^3) = 600\ kHz$

b) $BW = \frac{2\ R_b}{k} = |k = 1| = \frac{2\ 100\ 10^3}{1} = 200\ kHz$

c) $BW = \frac{2\ R_b}{k} = |k = 2| = \frac{2\ 100\ 10^3}{2} = 100\ kHz$

d) $BW = \frac{2\ R_b}{k} = |k = 4| = \frac{2\ 100\ 10^3}{4} = 50\ kHz$

e) $BW = \frac{2\ R_b}{k} = |k = 4| = \frac{2\ 100\ 10^3}{4} = 50\ kHz$

f) $BW = \frac{2\ R_b}{k} = |k = 9| = \frac{2\ 100\ 10^3}{9} = 22{,}22\ kHz$

Problem8:

Predpokladajme ze telekomunikacny urad vam udelil cast frekvencneho spectra od 1.2 MHz do 1.3 MHz pre vas komunikacny system.
V tomto pripade, bandwidth = 1.3 MHz – 1.2 MHz = 100 kHz
Aku maximalnu bitovu rychlost mozme dosiahnut pri pouziti nasledovnych modulacnych schem:

a. FSK, with *fmark* = 1.27 MHz and *fspace* = 1.23 MHz.
b. ASK.
c. BPSK.
d. 8-PSK.
e. 32-QAM.
f. 256-QAM.

Riešenie:

a) $BW = \left(f_{mark} - f_{space} + R_b\right) \rightarrow\ R_b = \frac{BW-(f_{mark}-f_{space})}{2}$

$$R_b = \frac{BW - (f_{mark}-f_{space})}{2} = \frac{100\ 10^3 - (1{,}27 - 1{,}23)10^6}{2} = \frac{100\ 10^3 - 40\ 10^3}{2} = 30\ kbps$$

b) $R_{max} = \frac{BW\ \log_2 M}{2} = \frac{BW\ k}{2} = \frac{100\ 10^3}{2} = 50\ kbps$

c) $R_{max} = \frac{BW\ \log_2 M}{2} = \frac{BW\ k}{2} = \frac{100\ 10^3}{2} = 50\ kbps$

d) $R_{max} = \frac{BW\ \log_2 M}{2} = \frac{BW\ k}{2} = \frac{100\ 10^3\ 3}{2} = 150\ kbps$

e) $R_{max} = \frac{BW\ \log_2 M}{2} = \frac{BW\ k}{2} = \frac{100\ 10^3\ 5}{2} = 250\ kbps$

f) $R_{max} = \frac{BW\ \log_2 M}{2} = \frac{BW\ k}{2} = \frac{100\ 10^3\ 8}{2} = 400\ kbps$