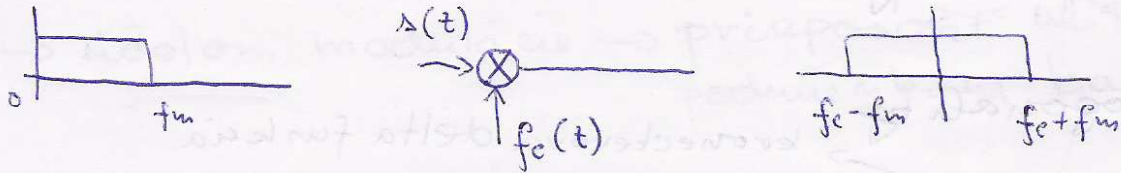
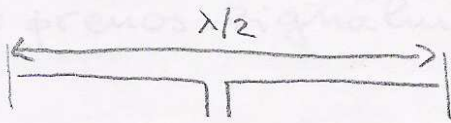


oviko 9
21.11.08

Modulácie (digitálne)



počet stavov modulácie $M = 2^k$

k - počet bitov na 1 moduláciu symbol

$$k = \log_2 M$$

ale: $M = 2$ binárne mod
 $M > 2$ M-árne
 Viacstavové } modulácie

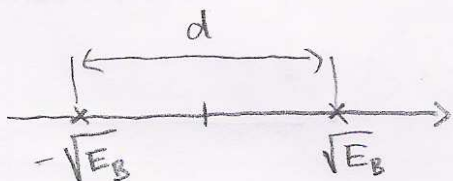
detekcia:

- koherentná (synchr. fázy)
- nekoherentná

Binárne modulácie (M=2)

1.) koherentná fázová modulácia BPSK

nejzrobustnejšia



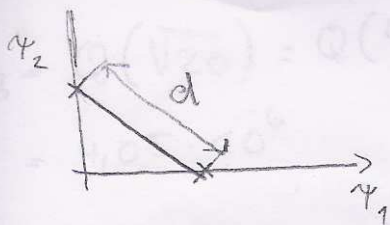
$$P_B = Q\left(\sqrt{\frac{2E_B}{N_0}}\right)$$

2.) koherentná BFSK

$$s_1(t) \dots \dots f_1$$

$$s_2(t) \dots \dots f_2$$

$$\Delta f = \frac{1}{2T_B}$$



$$P_B = Q\left(\sqrt{\frac{E_B}{N_0}}\right)$$

or 3dB horúiu chybovosť ako BFSK

6.) nekoherentná (diferenciálna)

DBSK

$$P_B = \frac{1}{2} e^{-\frac{E_B}{N_0}}$$

4.) nekoherentná BFSK

$$P_B = \frac{1}{2} e^{-\frac{E_B}{2N_0}}$$

2 dB rozdiel oproti koš. BFSK

Viacstavové ($M > 2$)

5.) koherentná MPSK

$$P_S(M) \approx 2Q\left(\sqrt{\frac{2E_s}{N_0}} \sin \frac{\pi}{M}\right)$$

6.) Nekoherentná (dif) DMPSK

$$P_S(M) \approx 2Q\left(\sqrt{\frac{2E_s}{N_0}} \sin \frac{\pi}{\sqrt{2}M}\right)$$

7.) koherentná MFSK

$$P_S^{(M)} \leq (M-1)Q\left(\sqrt{\frac{E_s}{N_0}}\right)$$

8.) Nekoherentná

$$P_S(M) = \frac{1}{M} \exp\left[-\frac{E_s}{N_0}\right] \sum_{j=2}^M (-1)^j \binom{M}{j} \exp\left(\frac{E_s}{jN_0}\right)$$

ortogonálna modulácia
(MFSK)

$$P_B = \frac{\frac{M}{2}}{M-1} P_s$$

neortogonálna modulácia
(MPSK)

$$P_B = \frac{P_s}{\log_2 M}$$

Pr. systém s koherenčnou BPSK mod urobí 100 chyb/b/d

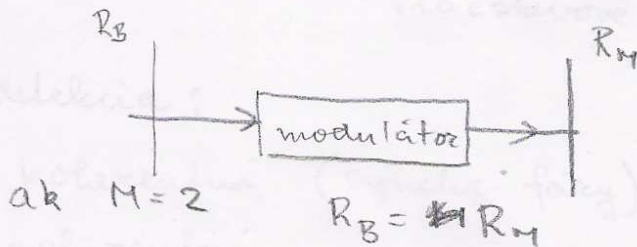
$$R_B = 1 \text{ kb/s}$$

PSD AWGN $N_0 = 10^{-10} \frac{\text{W}}{\text{Hz}}$

a.) Vypočítajte P_B

b.) bude na zabezpečenie $P_B \approx$ a.) stačí- sbr. výkon sig.

$$S = 10^{-6} \text{ W}$$



ak $M=2$ $R_B = R_M$

$M > 2$ $R_B = k \cdot R_M$

R_B [b/s]
 R_M [band] = [s/s]

$$\frac{100}{24 \cdot 3600} = 1,1574 \cdot 10^{-3}$$

a.) $P_B = \frac{1,1574 \cdot 10^{-3}}{1000} = 1,1574 \cdot 10^{-6}$

b.) $S = 10^{-6} \text{ W}$

~~$P_B = \dots$~~

$$\frac{E_B}{N_0} = \frac{S}{N_0} \cdot T_B = \frac{S}{N \cdot R_B} = \frac{10^{-6}}{10^{-10} \cdot 1000} = 10$$

$$P_B = Q(\sqrt{20}) = Q(4,472) = 4,05 \cdot 10^{-6} \quad P_B = Q$$

výkon nebude stačit na dosialnutie tejto chybovosti

2) Máme systém s AWGN

kt. systém má nižšiu chybovosť

a.) ortogonálny koh. BPSK $\frac{E_B}{N_0} = 12 \text{ dB}$

b.) nekoh. BPSK $\frac{E_B}{N_0} = 14 \text{ dB}$

$$P_B = Q\left(\sqrt{\frac{E_B}{N_0}}\right) = Q(\sqrt{12}) = Q(3,464) = 36,25 \cdot 10^{-6}$$

$$P_B = \frac{1}{2} e^{-\frac{E_B}{2N_0}} = 1,75 \cdot 10^{-6}$$

$$10 \log \frac{E_B}{N_0} = 12$$

a.) $P_B = Q\left(\sqrt{\frac{E_B}{N_0}}\right) = Q(\sqrt{15,849}) = Q(3,981) = 36,25 \cdot 10^{-6}$

b.) $P_B = \frac{1}{2} e^{-\frac{E_B}{2N_0}} = \frac{1}{2} e^{-\frac{25,12}{2}} = 1,756 \cdot 10^{-6}$

Pr) Máme systém s AWGN, ktorá modulácia má nižšiu chybovosť

a.) koh. QPSK $\frac{E_B}{N_0} = 8 \text{ dB}$

$$10 \log \frac{E_B}{N_0} = 8$$

$$\frac{E_B}{N_0} = 10^{0,8} = 6,309$$

b.) nekoh. QPSK $\frac{E_B}{N_0} = 13 \text{ dB}$

a.) $P_s = (M-1) \cdot Q\left(\sqrt{\frac{E_B}{N_0}}\right) = P_s(8) = 7 \cdot Q(\sqrt{6,509}) = 7 \cdot Q(2,549)$

$$\frac{E_s}{N_0} = k \cdot \frac{E_B}{N_0} = 3 \cdot 6,31 = 18,93$$

$$\frac{E_s}{N_0} = k \cdot \frac{E_B}{N_0}$$

$$P_s(8) \leq 7 \cdot Q(\sqrt{18,93}) \quad P_s(8) \leq 4,9 \cdot 10^{-5}$$

$$P_B = \frac{4}{7} \cdot 4,9 \cdot 10^{-5} = 2,85 \cdot 10^{-5} \quad \text{W} = (SFM, H) \cdot \varnothing = (\sqrt{2}) \cdot \varnothing = \varnothing$$

b.) $P_s(\xi) = 2 \varphi \left(\sqrt{\frac{2E_s}{N_0}} \cdot \sin \frac{\pi}{8} \right)$ $\frac{E_B}{N_0} = 19,9$

$$P_s(\xi) = 2,9 \cdot 10^{-6} \quad \frac{E_s}{N_0} = 59,86$$

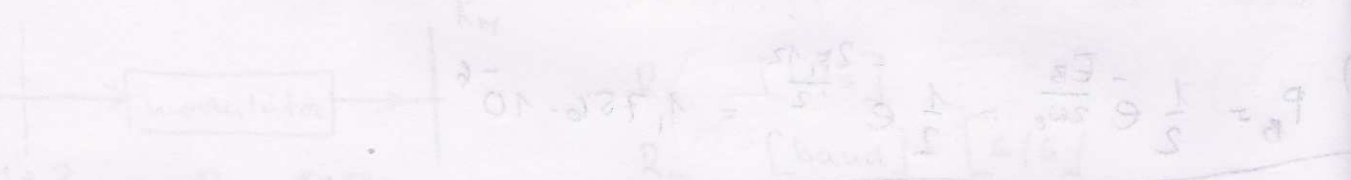
$$P_B = \frac{P_s}{\log_2 M} = \underline{\underline{9,96 \cdot 10^{-6}}} \quad \sqrt{\frac{E_s}{N_0}} = 7,736$$

System 2 Modulation BPSK mod. u. BPSK

$$P_B = \frac{P_s}{\log_2 M} = \frac{2,9 \cdot 10^{-6}}{\log_2 4} = 7,25 \cdot 10^{-7}$$

a) $P_s = \frac{P_B \cdot \log_2 M}{\log_2 M} = \frac{7,25 \cdot 10^{-7} \cdot 2}{1} = 1,45 \cdot 10^{-6}$

b) $P_s = \frac{P_B \cdot \log_2 M}{\log_2 M} = \frac{7,25 \cdot 10^{-7} \cdot 2}{1} = 1,45 \cdot 10^{-6}$



System 2 Modulation BPSK mod. u. BPSK

$$P_B = \frac{P_s}{\log_2 M} = \frac{1,45 \cdot 10^{-6}}{\log_2 2} = 1,45 \cdot 10^{-6}$$

a) $P_s = \frac{P_B \cdot \log_2 M}{\log_2 M} = \frac{1,45 \cdot 10^{-6} \cdot 2}{1} = 2,9 \cdot 10^{-6}$

b) $P_s = \frac{P_B \cdot \log_2 M}{\log_2 M} = \frac{1,45 \cdot 10^{-6} \cdot 2}{1} = 2,9 \cdot 10^{-6}$