

2.

$$s_i(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + i \frac{2\pi}{M}\right)$$

$$\text{QPSK}, T_s = 0,001 \text{ s}, A = 2 \text{ V}$$

a. QPSK sama dengan 4-PSK dengan beda fasa  $90^\circ$

$$M = 4$$

$$b. s_0(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + 0 \cdot \frac{2\pi}{4}\right) = \sqrt{\frac{2E_s}{T_s}} \cos(2\pi f_c t)$$

$$s_1(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + 1 \cdot \frac{2\pi}{4}\right) = \sqrt{\frac{2E_s}{T_s}} \cos(2\pi f_c t + 90^\circ)$$

$$s_2(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + 2 \cdot \frac{2\pi}{4}\right) = \sqrt{\frac{2E_s}{T_s}} \cos(2\pi f_c t + 180^\circ)$$

$$s_3(t) = \sqrt{\frac{2E_s}{T_s}} \cos\left(2\pi f_c t + 3 \cdot \frac{2\pi}{4}\right) = \sqrt{\frac{2E_s}{T_s}} \cos(2\pi f_c t + 270^\circ)$$

$$c. T_s = T_b \log M$$

$$T_b = \frac{T_s}{\log M} = \frac{0,001 \text{ s}}{\log 4} = \frac{0,001}{2} = 0,0005 \text{ s} = 0,5 \text{ ms}$$

$$R_b = \frac{1}{T_b} = \frac{1}{0,5 \text{ ms}} = 2000 \text{ Hz} = 2 \text{ kHz}$$

$$R_s = \frac{1}{T_s} = \frac{1}{0,001 \text{ s}} = 1000 \text{ Hz} = 1 \text{ kHz}$$

d.

$$A = \sqrt{\frac{2E_s}{T_s}}$$

$$A^2 = \frac{2E_s}{T_s}$$

$$E_s = \frac{A^2 T_s}{2} = \frac{2^2 \cdot 0,001}{2} = 0,002 \text{ J}$$

$$E_b = \frac{E_s}{2 \log M} = \frac{0,002}{2 \log 4} = 0,001 \text{ J}$$

$$N_0 = 2 \times 10^{-4} \text{ W/Hz}$$

$$P_e = 2 Q \left( \sqrt{\frac{2E_b}{N_0}} \right) \left[ 1 - \frac{1}{2} Q \left( \sqrt{\frac{2E_b}{N_0}} \right) \right]$$

$$= 2 Q \left( \sqrt{\frac{2 \cdot 0,001}{2 \times 10^{-4}}} \right) \left[ 1 - \frac{1}{2} Q \left( \sqrt{\frac{2 \cdot 0,001}{2 \times 10^{-4}}} \right) \right]$$

$$= 2 Q(\sqrt{10}) \left[ 1 - \frac{1}{2} Q(\sqrt{10}) \right]$$

$$= 2 \cdot 0,00078 \left( 1 - \frac{1}{2} \cdot 0,00078 \right)$$

$$= 1,56 \times 10^{-3}$$

$$= 0,156 \%$$