

EE 3008 Test 2 Answer

Q1) (a) Average power for each symbol =

$$\frac{1}{\tau} \int_0^{\tau} (Ab)^2 \cos^2(2\pi f_0 t) dt = \frac{0.5(Ab)^2}{\tau} \int_0^{\tau} (1 + \cos(2 \times 2\pi f_0 t)) dt = 0.5A^2b^2.$$

For $A = 0.2$ and $b = 0, 2, 4$, and 6 , the average transmission power is

$$P_s = 0.5 \times 0.2^2 \times (0^2 + 2^2 + 4^2 + 6^2)/4 = 0.28W.$$

(b) Symbol rate $R_s = 1/\tau$.

Number of bits per symbol $k = \log_2(4) = 2$.

Information rate $= R_s \times k = 1/10^{-2} \times 2 = 200$ bits/second.

(c) Each symbol energy =

$$\int_0^{\tau} (Ab)^2 \cos^2(2\pi f_0 t) dt = 0.5(Ab)^2 \int_0^{\tau} (1 + \cos(2 \times 2\pi f_0 t)) dt = 0.5A^2b^2\tau.$$

For $A = 0.2$ and $b = 0, 2, 4$, and 6 , the average energy per symbol is

$$E_s = 0.5 \times 0.2^2 \times 10^{-2} \times (0^2 + 2^2 + 4^2 + 6^2)/4 = 2.8 \times 10^{-3} J.$$

Q2) (a) $E_b = \int_0^T p^2(t) \cos^2(t) dt = (A)^2 \frac{T}{4} + (2A)^2 \frac{T}{4} = \frac{5}{4} A^2 T$

(b) $BER = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q\left(\sqrt{\frac{5A^2T}{2}}\right)$

Q3) Since the rule is same $\rightarrow 1$, different $\rightarrow 0$, the transmit signal is given by

message: 0 1 0 1 1 0 1 0

transmit signal: +1 -1 -1 +1 +1 +1 -1 -1 +1

Q4) The bandwidth of the input signal is $W=10$ kHz, thus the Nyquist rate is $R_s=2W=20$ k sample/second. Symbol rate $1/\tau=B=60$ k symbol/second for all two schemes.

(a) For BPSK, bit rate $R=1/\tau=60$ kbps, $k=R/R_s=3$ and so $n = 2^k = 8$.

(b) For QPSK, bit rate $R=2/\tau=120$ kbps, $k=R/R_s=6$ and so $n = 2^k = 64$.

Q5) Let $D = 40\text{dB}$ (dynamic range)

(a) Ratio of max to min quantization power levels can be found as follows.

$$D = 20\log_{10}(A_{\max}/A_{\min}) = 40\text{dB}.$$

$$A_{\max}/A_{\min} = 10^{40/20} = 10^2 = 100.$$

(b) We take $n = 2^k = 2^7 = 128$, thus the required number of quantization bits is $k=7$ bits.

Q6) To use μ -law formula, the system should be first normalized into the amplitude range $[-1\text{V}, +1\text{V}]$. In this normalized μ -law system, the minimum quantization value $|Q_{\min,\mu}^{\text{norm}}| = |Q_{\min,\mu}|/1 = 1/63$. Substitute $|Q_{\min,\mu}^{\text{norm}}|$ into the μ -law formula, then we have the minimum quantization value of the normalized uniform quantization

$$|Q_{\min,\text{unif}}^{\text{norm}}| = \frac{\log_2(1 + \mu|Q_{\min,\mu}^{\text{norm}}|)}{\log_2(1 + \mu)} = \frac{\log_2(1 + 1)}{\log_2(1 + 63)} = \frac{1}{6},$$

$$n = \frac{1}{|Q_{\min,\text{unif}}|} = 6 \Rightarrow k = 3 \text{ bits}$$

Q7) Note that $20\cos(1600\pi t) + 20\cos(2400\pi t) = 40\cos(400\pi t)\cos(2000\pi t)$. Therefore

$$\begin{aligned} s(t) &= 20\cos(1600\pi t) + 60\cos(2000\pi t) + 20\cos(2400\pi t) \\ &= 60\cos(2000\pi t) + 40\cos(400\pi t)\cos(2000\pi t) \\ &= 40(1.5 + \cos(400\pi t))\cos(2000\pi t) \end{aligned}$$

Comparing with $s_{\text{AM-DSB-C}}(t) = A(c + s_m(t))\cos(2\pi f_c t)$, we find that

(a) The frequency of the information signal is 200 Hz, i.e., $f_m = 200\text{Hz}$.

(b) The carrier frequency $f_c = 1000$ Hz.

(c) Since $c=1.5$, then $m = 1/c s_{\max} = 1/1.5 \times 1$, i.e., the modulation index is 0.667.

(d) The power efficiency is

$$\eta = \frac{m^2 / 4}{1/2 + m^2 / 4} = \frac{2}{11} \approx 18.2\%$$

Q8)

(a) The modulation index is $0.2/20=0.01$.

(b) The FM signal can be obtained by an Armstrong modulator, the structure is given below.

