Çankaya University – ECE Department – ECE 376

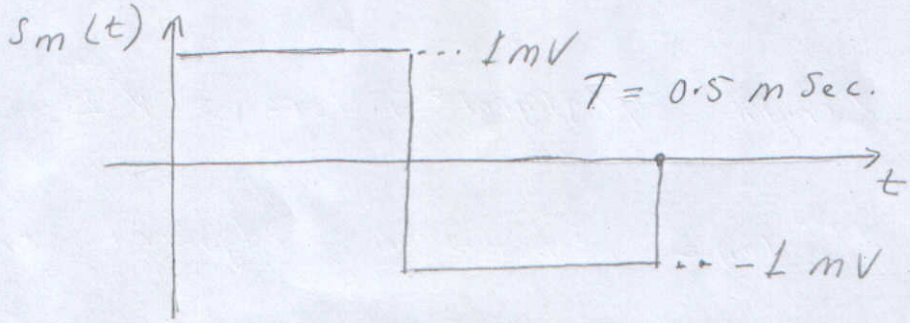
Student Name :
Student Number :

Duration : 2 hours
Open book exam

Questions

1. (40 Points) According to Proakis 2002, pp. 416, Eq. (7.6.58), probability of symbol error for M-ary PSK, P_M can be approximated to

$$P_M \simeq 2Q\left[\sqrt{\frac{2E_s}{N_0}}\sin\left(\frac{\pi}{M}\right)\right]$$



Find P_M for the received signal shown above, where $M = 8$ and $N_0 = 10^{-11}$ W/Hz. State your assumptions. Comment how probability of bit error, P_b would be different from P_M. For this modulation, sketch the signal space diagramme, showing the length and position of signal vectors and the distance between the adjacent signal vectors. Determine SNR for symbols and bits.

Solution: $E_s = \int_0^T s_m^2(t)\,dt = 1\times10^{-6}\,t\Big|_0^{0.5\times10^{-3}}$

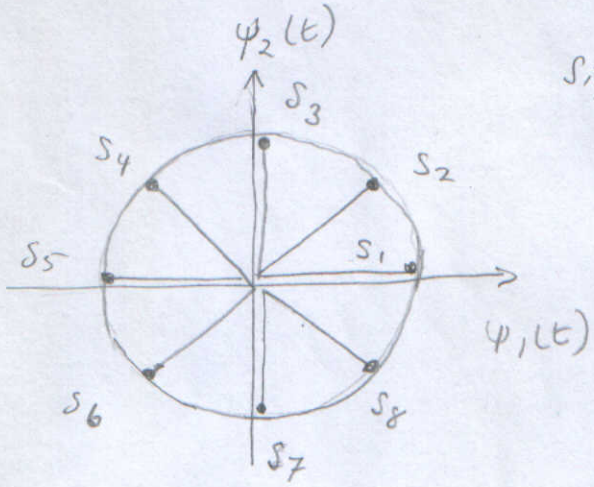
$= 5\times10^{-10}$ J

$\sqrt{\frac{2E_s}{N_0}}\sin\left(\frac{\pi}{m}\right) = \sqrt{\frac{10\times10^{-10}}{10^{-11}}}\times\sin\left(\frac{\pi}{8}\right) = 3.827$

$P_m = 2\times Q(z) = 1.3\times10^{-4}$

Since $2^k = M$, $2^k = 8$, $k = 3$

$P_e = \frac{P_m}{3} = 4.3\times10^{-5}$



Signal Space (Constellation) Diagramme for 8 PSK

Length of signal vectors $= \sqrt{E_s} = 2.236 \times 10^{-5}$ J

Distance between adjacent ones

$$d_{18}^2 = s_1^2 + s_8^2 - 2 s_1 s_8 \cos 45^\circ$$

$$d_{18} = 1.711 \times 10^{-5}$$

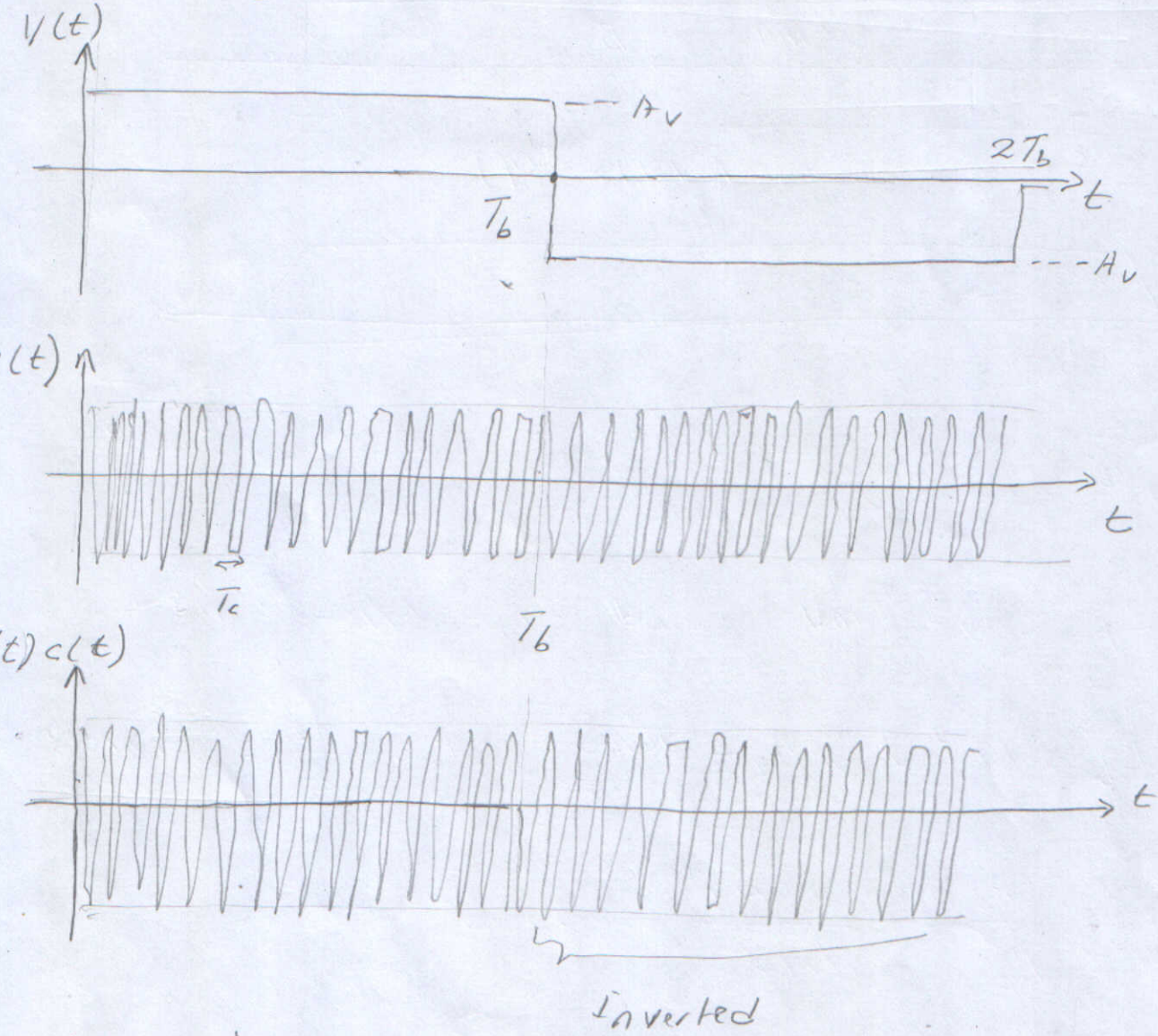
$$SNR \text{ (of symbols)} = \frac{E_s}{N_0} = \frac{50 \times 10^{-11}}{10^{-11}} = 50$$

$$SNR \text{ (of bits)} = \frac{E_s/3}{N_0} = \frac{E_b}{N_0} = 16$$

2. (30 Points) In a DS communication system, a message signal of 1 kbit/sec is multiplied and spread by a signal of 1 Mbit/sec. Find T_b, T_c, L (processing gain). Plot the approximate time waveforms and frequency spectrums. If this signal is received as a bipolar waveform of 1 mV amplitude and a signal of 0.01V p-p sinusoidal interference is present, find the SNR after the dispreading operation.

Solution: $T_b = 1\,m\,Sec.$, $T_c = 1\,\mu\,Sec.$

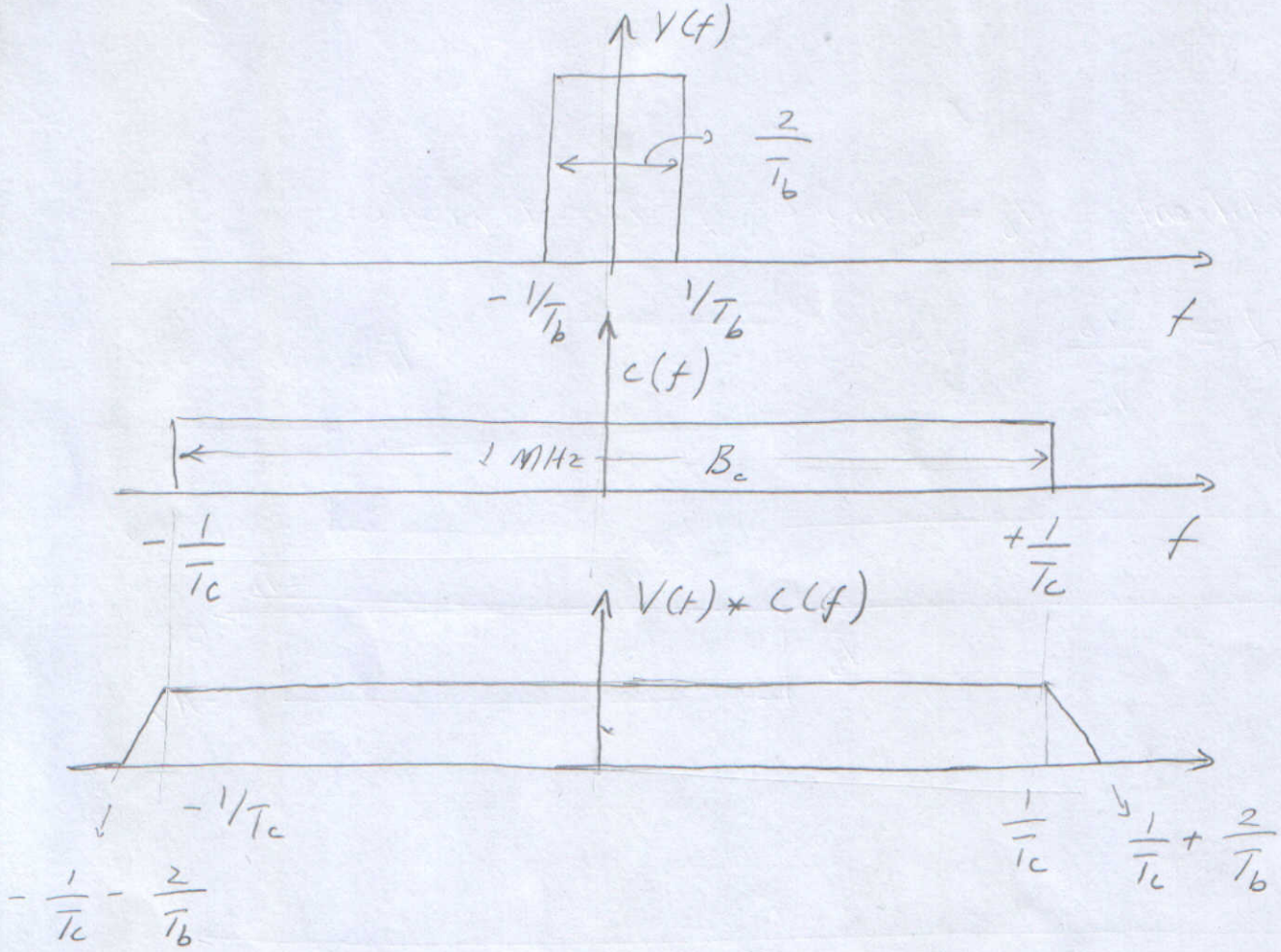
$$L = \frac{T_b}{T_c} = 1000$$



(Typical)
Time waveforms of DS-spectrum systems

Q2 Continued

Assuming $A_V \simeq A_C$ meaning $P_V \simeq P_C$



If $A_V = 1\,mV$ and $T_b = 1/R = 1\,m\,sec.$

$E_b = 10^{-9}\,J$, $A_I = 10\,mV$, $P_I = \frac{A_I^2}{2} = 0.5 \times 10^{-4}$

$$I_0 = \frac{P_I}{B_C} = \frac{0.5 \times 10^{-4}}{1 \times 10^6} = 0.5 \times 10^{-10}$$

$$\frac{E_b}{I_0} = \frac{10 \times 10^{-10}}{0.5 \times 10^{-10}} = 20$$ (SNR after despreading operation)

3. (30 Points) Answer the following questions as **True** or **False**. For the **False** ones give the correct answer or the reason

a) For FM, the performance against noise is better than PM : True. To have performance improvement, we must have bandwidth expansion, which is present in FM but not in PM.

b) PN sequences are orthogonal sequences : True. PN sequences of different users should ideally be orthogonal to each other

c) There are 4 matched filters in 8-ary QAM demodulator (receiver) : False
Since PSK is two dimensional, two matched filters are sufficient for a PSK receiver.

d) Probability of error measures the number of symbols received within a symbol period : False
Prob. of error takes the ratio of errored symbols to total number of symbols transmitted

e) PPM is multidimensional : True
PPM is a perfect exampk of multidemensional signal.