National Institute of Technology Sikkim,

Department of Electronics and Communication Engineering

Digital Communication (EC15101)

Practice Questions

Set B: Signals, ISI, Noise and Communication

1. A binary baseband digital communication system employs the signal

$$p(t) = \begin{cases} \dfrac{1}{\sqrt{T_s}}, & 0 \le t < T_s \\ 0, & \text{otherwise} \end{cases}$$

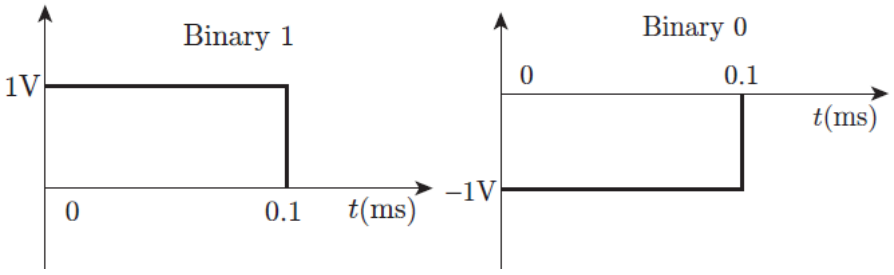
for transmission of bits. What should be the matched filter output? Plot the output.

2. The bit rate of digital communication system is 128 kbps. The modulation used is 32 QAM. What is the minimum bandwidth required for ISI-free transmission?

3. An analog pulse $s(t)$ is transmitted over an additive white Gaussian noise (AWGN) channel. The received signal is $r(t) = s(t) + n(t)$, where $n(t)$ is additive white Gaussian noise with power spectral density $N_0/2$. The received signal is passed through a filter with impulse response $h(t)$. Let E_s and E_h denote the energies of the pulse $s(t)$ and the filter $h(t)$ respectively. When the signal to noise ratio (SNR) is maximized at the output of the filter ($SNR_{\max}$) find the relation between E_s and E_h, and express $SNR_{\max}$ in terms of E_s and N_0.

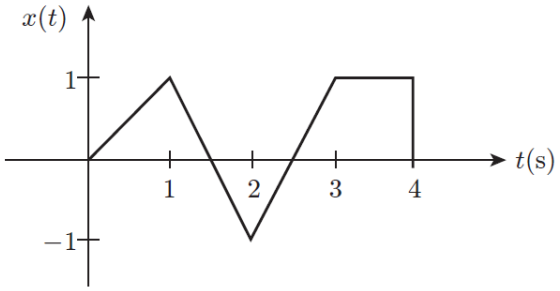
4. A voice-grade AWGN (additive white Gaussian noise) telephone channel has a bandwidth of 4.0 kHz and two sided noise power spectral density $\frac{N_0}{2} = 2.5 \times 10^{-5}$ Watt per Hz. If information at the rate of 52 kbps is to be transmitted over this channel with arbitrarily small bit error rate, then compute the minimum bit-energy E_b (in mJ/bit) necessary.

5. A source produces binary data at the rate of 10 kbps. The binary symbols are represented as shown in the figure below. The source output is transmitted using two modulation schemes, namely, binary PSK (BPSK) and quadrature PSK (QPSK). Assuming that the bandwidth of the above rectangular pulses is 10 kHz, compute the bandwidth requirements of BPSK and QPSK.

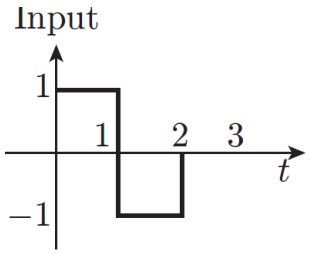


6. Consider a binary digital communication system with equally likely 0's and 1's. When binary 0 is transmitted, the detector input can lie between the levels −0.25 V and +0.25 V with equal probability. When binary 1 is transmitted, the voltage at the detector can have any value between 0 and 1 V with equal probability. If the detector has a threshold of 0.2 V (i.e., if the received signal is greater than 0.2 V, the bit is taken as 1), compute the average bit error probability.

7. Consider the signal $x(t)$ shown in the figure. Plot $h(t)$, the impulse response of the filter matched to $x(t)$, and compute the slope of $h(t)$ in $3 \le t < 4$. Plot the output of the matched filter.



8. A signal as shown in the following figure is applied to a matched filter. Plot the output of the filter.

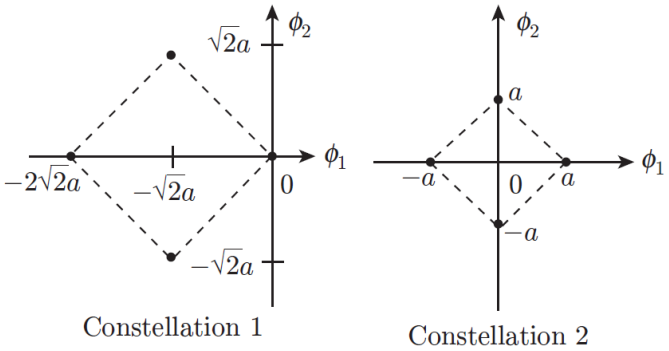


9. A 1 kHz sinusoidal signal is ideally sampled at 1500 samples/s and the sampled signal is passed through an ideal low-pass filter with cut-off frequency 800 Hz. What are the spectral components present at the output?

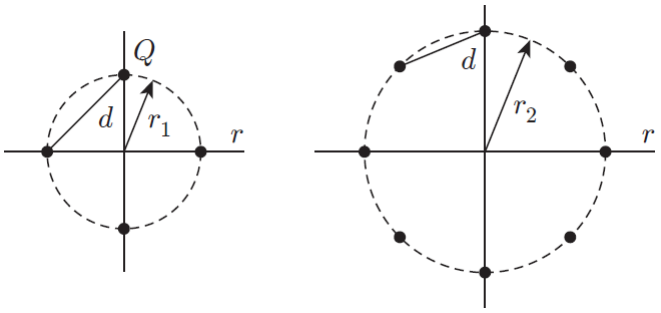
10. The raised cosine pulse p(t) is used for zero ISI in digital communications. The expression for $p(t)$ with unity roll-off factor is given below. Compute $p\left(\frac{1}{4W}\right)$.

$$p(t) = \frac{\sin 4\pi Wt}{4\pi Wt}\frac{1}{(1-16W^2t^2)}$$

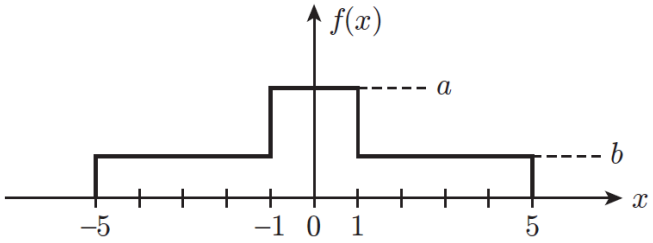
11. Two 4-ary signal constellations are shown. It is given that ϕ_1 , and ϕ_2 constitute an orthonormal basis for the two constellations. Assume that the four symbols in both the constellations are equiprobable. Let $N_0/2$ denote the power spectral density of white Gaussian noise. What is the ratio of the average energy of constellation 1 to the average energy of constellation 2?



12. Four-phase and an eight-phase signal constellation are shown in the following figure. For the constraint that the minimum distance between pairs of signal points be d for both constellations, express the the radii r_1 and r_2 of the circles in terms of d. If high SNR and that all signals are equally probable, what is the additional average transmitted signal energy required by the 8-PSK signal to achieve the same error probability as the 4-PSK signal?



13. An input to a 6-level quantizer has the probability density function f(x) as shown in the given figure. Decision boundaries of the quantizer are chosen so as to maximize the entropy of the quantizer output. It is given that three consecutive decision boundaries are `−1', `0' and `1'.



Find a and b. Assuming that the reconstruction levels of the quantizer are the mid-points of the decision boundaries compute $SQNR$.

14. The amplitude of a random signal is uniformly distributed between −5 V and 5 V. If the signal-to-quantization-noise ratio required in uniformly quantizing the signal is 43.5 dB, then estimate the step size of the quantization. If the positive values of the signal are uniformly quantized with a step size of 0.05 V, and the negative values are uniformly quantized with a step size of 0.1 V, compute resultant $SQNR$.

15. In a baseband communications link, frequencies up to 3500 Hz are used for signalling. Compute the maximum possible signalling rate in symbols/s for a raised cosine pulse with 75% excess bandwidth and for no ISI.

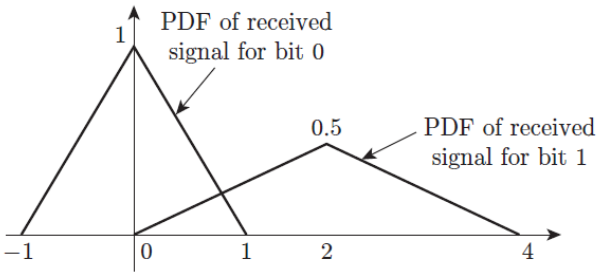
16. A BPSK scheme operating over an AWGN channel with noise power spectral density of $N_0/2$ uses equiprobable signals

$$s_1(t) = \sqrt{\frac{2E_b}{T_s}} \sin \omega_c t$$

$$s_2(t) = -\sqrt{\frac{2E_b}{T_s}} \sin \omega_c t$$

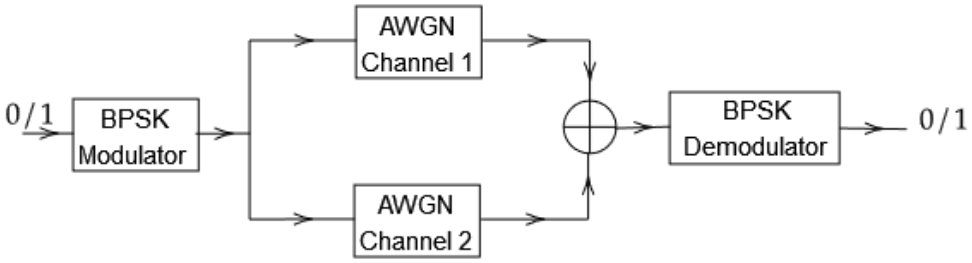
over the symbol internal $(0, T_s)$. If the local oscillator in a coherent receiver is ahead in phase by 45° with respect to the received signal, find the probability of the error in the resulting system, if $E_b/N_0 = 18$ dB. (Follow the Q-table for it).

17. Bits 1 and 0 are transmitted with equal probability. At the receiver, the PDF of the respective received signals for both bits are as shown in the following figure.



Compute the BER if the detection threshold is 1. Compute the optimum threshold (for achieving the minimum BER).

18. Let $Q(y)$ be the BER of a BPSK system over an AWGN channel with two-sided noise power spectral density $N_0/2$. The parameter g is a function of bit energy and noise power spectral density. A system with two independent and identical AWGN channels with noise power spectral density $N_0/2$ is shown in the figure. The BPSK demodulator receives the sum of outputs of both the channels. What is the value of b if BER is $Q(b\sqrt{y})$.



19. Coherent orthogonal binary FSK modulation is used to transmit two equiprobable symbol waveforms

$$s_1(t) = \alpha \cos 2\pi f_1 t$$
$$s_2(t) = \alpha \cos 2\pi f_2 t$$

where $\alpha = 4$mV. Assume an AWGN channel with two-sided noise power spectral density $\frac{N_0}{2} = 0.5 \times 10^{-12}$ W/Hz. Using an optimal receiver and the relation

$$Q(v) = \frac{1}{\sqrt{2\pi}} \int_v^{\infty} e^{-u^2/2} du$$

Compute the BER for a data rate of 500 kbps. (using the Q-table).

20. An M-level PSK modulation scheme is used to transmit independent binary digits over a band-pass channel with bandwidth 100 kHz. The bit rate is 200 kbps and the system characteristic is a raised cosine spectrum with 100% excess bandwidth. What should be the minimum value of M?

21. An ideal band pass channel 500Hz - 2000Hz is deployed for communication. A modem is designed to transmit bits at the rate of 4800 bits/s using 16 - QAM. What is the roll off factor for the cosine spectrum that utilizes the entire frequency band?

22. Three analog signals having bandwidths 1200, 600 and 600 Hz are sampled at their respective Nyquist rates, encoded with 12-bit words and time-division multiplexed. What should be the bit rate for the Multiplexed signal?

23. In a code-division multiple access (CDMA) system with $N = 8$ chips, what is the maximum number of users who can be assigned mutually orthogonal signature sequences?