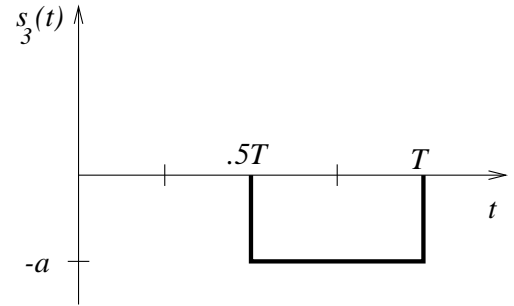
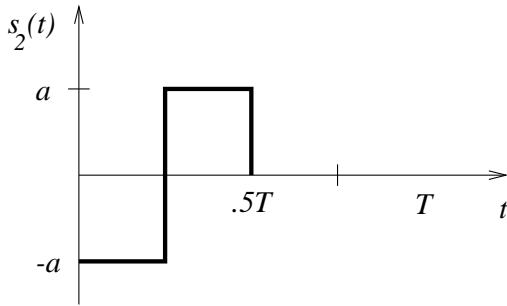
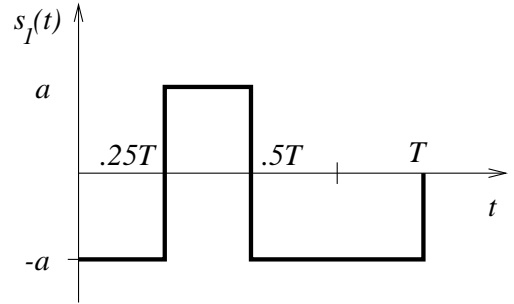
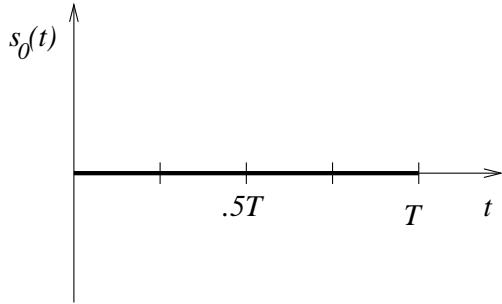


- 1) Please attempt each problem on a new page.
- 2) Show all your work clearly.

1. Binary Data of rate $R_b = 500$ bits/sec. is to be transmitted across an AWGN channel with noise power spectral density $S_{N_w}(f) = 10^{-5}$ watts/Hz. The available frequency band is (2500, 3500) Hz. Find the smallest power P with which bit error probability of $P_b(E) = 10^{-5}$ can be achieved using
 - (a) i. Any PSK system (Binary, 4-ary, 8-ary, etc.).
 - ii. Any FSK system (Binary, 4-ary, 8-ary, etc.).
 - iii. Any ASK system (Binary, 4-ary, 8-ary, etc.).
 - iv. Any QASK system (Binary, 4-ary, 16-ary, etc.).
 - v. Any system whatsoever.
- (b) Repeat the above assuming that the data rate is $R_b = 3500$ bits/sec.
2. The following signal set is used to transmit binary equiprobable data of rate $R_b = 1000$ bits/sec. across an AWGN channel with power spectral density of $\frac{N_0}{2}$ Watts/Hz.
 - (a) Find an orthonormal basis for the signal set and plot the vector representation of the signals.
 - (b) Find the value of T and the bandwidth of the signal produced by the modulator.
 - (c) Draw a block diagram for the optimal receiver. Make sure you identify every component in your diagram.
 - (d) Evaluate the probability of error for the optimal receiver.



3. Consider the following ternary communication system which transmits one of three equally likely signals $s_0(t) = 0$, $s_1(t) = A \sin(2\pi f_c t)$ or $s_2(t) = -A \sin(2\pi f_c t)$ for $0 \leq t \leq T$. Assume that the channel is AWGN channel with power spectral density $S_{N_w}(f) = \frac{N_0}{2}$ watts/Hz.
- Diagram the optimal receiver that minimizes the error probability. Make sure you specify the function of each component in your diagram.
 - Find the conditional probability of correct reception when $s_0(t)$, $s_1(t)$ or $s_2(t)$ is transmitted.
 - Find the probability of error for the optimal receiver.
 - Compare the performance of this system (in terms of $\frac{R_b}{W}$ and $\frac{E_b}{N_0}$) to that of a BPSK system.
4. A system must be designed to transmit binary equiprobable data at rate R_b across an AWGN channel with $S_{N_w}(f) = \frac{N_0}{2}$ Watts/Hz. The available power is P ; the available half power bandwidth is W . It is required that $P_b(E) \leq 10^{-5}$.
- Suppose BPSK is used. For the following conditions find the largest rate R_b at which this is possible.
 - $\frac{P}{N_0} = 5000$, $W = 1000$.
 - $\frac{P}{N_0} = 1.5 \times 10^5$, $W = 10,000$
 - Repeat for QPSK.
 - Repeat for BFSK.

5. The following signal set is used to transmit a binary iid equiprobable source with rate $R_b = 1000$ bits/sec. across an AWGN channel with power spectral density $S_{N_w}(f) = \frac{N_0}{2}$ Watts/Hz.

$$s_i(t) = \frac{1}{\sqrt{T}} [a_i \cos(2\pi f_0 t) + b_i \sin(2\pi f_0 t)] \quad 0 \leq t \leq T$$

where a_i and b_i take all the possible values in the following set.

$$\left\{ \pm \frac{7A}{2}, \pm \frac{5A}{2}, \pm \frac{3A}{2}, \pm \frac{A}{2} \right\}$$

- (a) Find a vector representation for this signal set. What type of modulation system is this?
- (b) Find the average energy of the signal set.
- (c) Draw the block diagram of a complete system (modulator/demodulator) to transmit the binary source across the AWGN channel.
- (d) Find the value of T .
- (e) Calculate the probability of error for this modulation system and give an approximate formula for the bit error probability. You may use the results that have been previously derived in class. Find the R_b/W and E_b/N_0 needed to get $P_b(E) = 10^{-5}$.