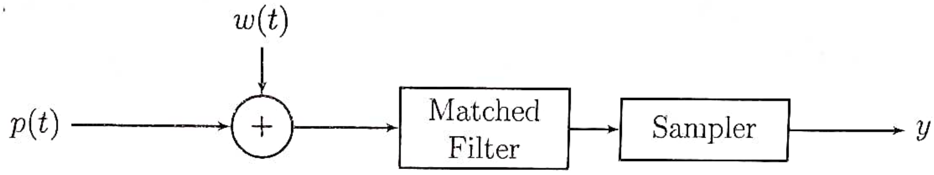
Indian Institute of Space Science and Technology
AV324 - Communication Systems II
Department of Avionics

Quiz 1 for **B.Tech Semester VI** on **22/02/2024**

Note to the student

1. There are **3 questions** in this question paper on **1 page**, for a total of **15 marks.**
2. Answer **all** questions.

Question 1 (5 marks): Consider the following system:



Here $p(t)$ is a time-limited signal in the time interval $[0, T_b]$ (i.e. $p(t)$ is zero outside the interval $[0, T_b]$) and $w(t)$ is a zero mean white Gaussian noise process with power spectral density $\frac{N_0}{2}$. The sampler block samples the output of the matched filter at T_b. Derive the response of the matched filter which is used to maximise the SNR at the sampling instant T_b. What is this maximum SNR at the sampling instant T_b?

Question 2 (6 marks): Briefly explain the three major challenges faced in a baseband point to point digital communication link (each challenge should be explained in at most two sentences). For each challenge briefly explain a method which can be used to mitigate that challenge.

Question 3 (4 marks): Suppose $p_1(t)$ denote a rectangular pulse of unit duration, i.e, $p_1(t) = 1, t \in [0, 1]$ and 0 otherwise. Consider two 4-ary signal sets as follows:

1. signal set A: $s_i(t) = p_1(t - i)$, for $i = 0, 1, 2, 3$, and
2. signal set B: $s_0(t) = p_1(t)+p_1(t-3)$, $s_1(t) = p_1(t-1)+p_1(t-2)$, $s_2(t) = p_1(t)+p_1(t-2)$, and $s_3(t) = p_1(t-1) + p_1(t-3)$.

Note that each set of signals are defined in the time interval $[0, 4]$.

1. Find out the signal space representation for signal set A using any means
2. Find out the signal space representation for signal set B using Gram Schmidt procedure.

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Quiz 2 for B.Tech Semester VI on 05/04/2024

Note to the student: There are **3 questions** in this question paper on **2 pages**, for a total of **15 marks**. Answer **all** questions. Clearly state all assumptions.

Question 1 (5 marks): Show that the MAP decision rule is also the minimum symbol error probability decision rule in the context of symbol detection with additive white Gaussian noise. Your proof should clearly define and explain all needed notation and terms.

Question 2 (5 marks):

1. Consider the following signal flow diagram showing how a frame consisting of $M+1$ bits is transmitted using binary phase shift keying (BPSK) over a passband channel. Write down what $p(t)$ is, and what are the functions of the blocks A, B, C, and D.

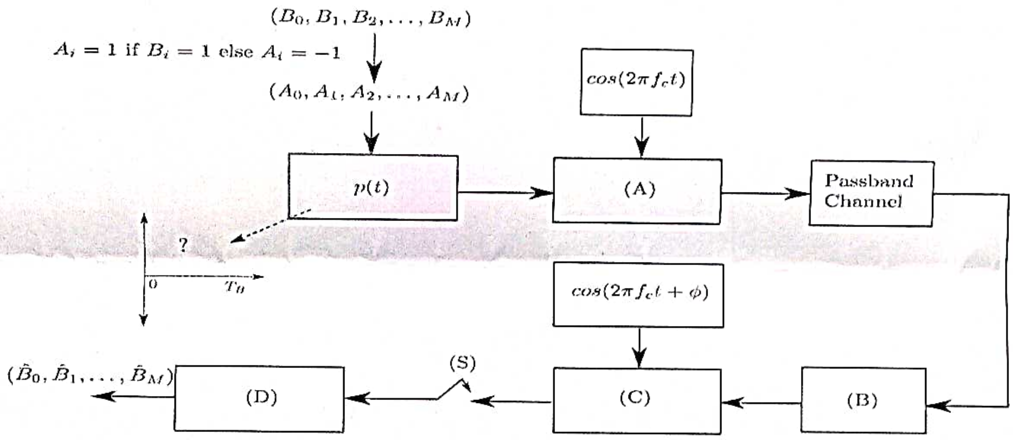

Figure 1: Signal flow diagram for question 2

2. Suppose the system has noise. Assume that at the point of sampling (shown as (S)), the m^{th} sample contains additive noise N_m which is Gaussian with mean 0 and variance σ^2.

3. Also assume that the receiver local oscillator produces a carrier which is ϕ radians out of phase with the received carrier signal.

4. Derive the bit error rate ($Pr\{B_m \neq \hat{B}_m\}$) of the system taking points (2) and (3) into account.

Question 3 (5 marks $= 0.5 \times 4 + 1 + 2$**):** Consider a baseband communication system which uses a rectangular pulse shape of amplitude 1 and duration $T_b = 10s$ for signalling bits. Assume that the transmitter transmits a sequence 011010 of bits. In the following, for all the plots, please clearly label the x and y axes, also indicate the amplitudes for complete credit.

1. Draw the baseband line code at the transmitter assuming that transmission starts at a global time 0.

2. Assume that the baseband signal is transmitted through an ideal baseband channel without noise and without distortion. However, the channel introduces a delay of 3/4 seconds. Assuming that the receiver clock also starts at the global time 0, draw the received baseband line code at the receiver.

3. Assuming that the receiver does matched filtering, draw the signal after the matched filter.

4. Assuming that the receiver clock also starts at the global time 0, the receiver clock knows that T_b is $1s$, but not the delay, make a separate plot showing the matched filtered output signal and the times at which samples are taken at the receiver. Note that no clock synchronization has been carried out. Also indicate the amplitudes of the samples that are obtained in the same plot.

5. Assume that early late gating is used at the receiver on the matched filter. Write down the early late update equation, with Δ being the time offset used for obtaining the early and late samples. Also denote the step size used in your algorithm by μ.

6. For $\Delta = 1$ and $\mu = 1$, derive the first three sample times obtained by the early late algorithm for the input sequence.

End of question paper.

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Final Exam for B.Tech Semester VI on 09/05/2024

Note to the student: There are **7 questions** in this question paper on **2 pages**, for a total of **50 marks**. Answer **all** questions. Please write all steps concisely and be direct in your answers. Clearly state all assumptions. Write your answer to a question on contiguous pages of your answer sheet

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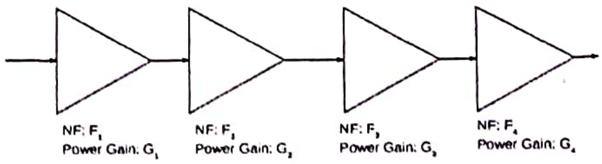
Question 1 (5 marks):

1. Derive the equation for the combined noise figure for a receiver which is composed of different stages as shown in the figure. The noise figures (NF) and power gains of each stage are denoted as F_i and G_i respectively (these are not in dB).
2. Using the equation that you derived above explain why it is important to have a low noise figure for the first receiver stage.



Question 2 (10 marks): Consider a point to point radio link (such as a satellite link) with link parameters: (a) EIRP: 50 dB, (b) Frequency of operation: 14 GHz, (c) distance between transmitter and receiver: 50000 km. There are no other losses. The receiver of the radio link is as shown in Figure 1. The gains (absolute power gains, not in dB) and equivalent noise temperatures of each block are shown either above or below the respective block. Assuming that the link uses BPSK modulation, what is the maximum rate of transmission for a bit error rate of 10^{-6}? (You can assume that the $Q(x)$ function is approximated by $\frac{1}{2}e^{-x^2/2}$.). (assume the margin used for E_b/N_0 is 0).

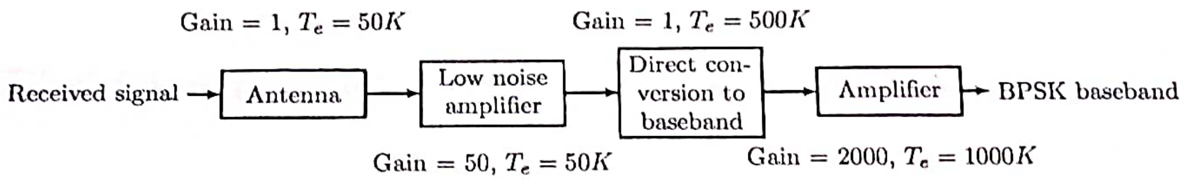


Figure 1: Receiver for the point to point link

Question 3 (10 marks): Consider the 4-PAM digital modulation scheme. Derive an upper bound on the symbol error rate for this scheme. Make and state suitable assumptions on the received signal constellation. Under high signal to noise ratio conditions, can you suggest a method to improve (or tighten) the upper bound.

Question 4 (10 marks): Assume that an independent and identically distributed bitstream $(B_1, B_2, \dots)$, with each bit B_i chosen uniformly, is transmitted over a channel using BPSK with received energy per bit E_b. We assume that the channel adds additive white Gaussian noise (with power spectral density $\frac{N_0}{2}$) to the received signal. The coherent correlation receiver, unfortunately, has been designed as a BFSK correlation receiver (with one frequency being the same as the carrier frequency of the BPSK signal, and the other as an orthogonal frequency) to decode BFSK signals which are assumed to use a received energy per bit of $0.5E_b$. Obtain the average probability of symbol error when this correlation BFSK receiver is used to decode the received BPSK signal. Express your answer in terms of the Q function.

Question 5 (5 marks): Consider the baseband digital communication system shown in Figure 2. The communication system transmits bits which are chosen uniformly at random from $\{0, 1\}$. The bits are converted into a baseband line code, which uses a rectangular pulse of amplitude 1 and duration T_b to transmit a 1, while for transmitting a 0, the transmitter does not transmit anything for a duration of T_b (i.e., a baseband on-off signalling scheme). The line

code is transmitted over an ideal channel which has unit gain, infinite bandwidth, and no delay. The output of the channel is corrupted with zero-mean additive white Gaussian noise with power spectral density of $N_0/2$.
The channel output is connected to the receiver via a connector. This connector can either be connected correctly (direct) or reversed. If the connector is connected correctly then the output signal of the connector is the input itself. If the connector is reversed, the output signal is $-1\times$ the input signal.
The output of the connector is filtered using a low pass filter of two sided bandwidth W which is assumed to pass the line code without any distortion. Since the signalling is on-off, an engineer decided to take the absolute value of the signal using the Abs(.) block before sampling and taking decisions. The receiver is assumed to have perfect symbol timing synchronization so that the received bits can be sampled at the middle of the bit times.

1. Suppose the detector is a threshold detector with a threshold of 0.5. Derive the probability of bit error conditioned on 0 being transmitted
2. Derive the probability of bit error conditioned on 1 being transmitted
3. What is the detection rule that minimizes the probability of bit error for this system?

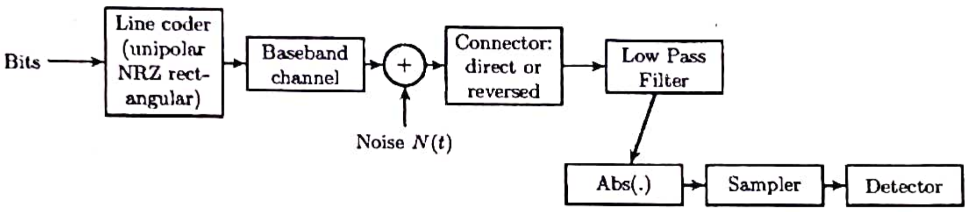
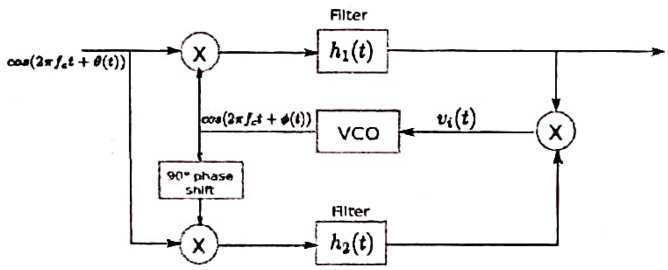


Figure 2: Baseband digital communication system for Question 5

Question 6 (5 marks) In wireless communications, regulations limit the amount of spectrum that a transmitter can use. Assume that a transmitter is allocated a one-sided bandwidth of $2W$ Hz at a center frequency of f_c. The pulse shaping techniques that we discussed in class are also used to make sure that the transmitted signal energy is "limited" to the region of the spectrum that is allocated to the transmitter. For example, "using" a sinc pulse shape, i.e. $sinc(2Wt)$, would ensure that the transmitted signal is bandlimited to $2W$ Hz. However, such pulse shapes cannot be used in practice. Therefore, consider the case where the pulse shape used is $sinc(2Wt) \times rect(t/T)$, where $rect(x) = 1$ for $|x| \leq 1$. Obtain the fraction of signal energy that is outside the allowed bandwidth of $2W$ Hz (an expression is sufficient).

Question 7 (5 marks): Consider the following model for a phase locked loop used for carrier synchronization. The



input signal into the loop is assumed to be $cos(2\pi f_c t + \theta(t))$. The two filters have impulse responses $h_1(t)$ and $h_2(t)$ which can be assumed to be low pass responses. The VCO output is $cos(2\pi f_c t + \phi(t))$ where $\phi(t) = K_v \int_0^t 2\pi v_i(u)du$. Using similar linearization assumptions that you have made before for the analysis of the PLL, find out the steady state behaviour of the signal $v_i(t)$ if the input signal has a $\theta(t)$ which is a step function of amplitude θ_0. Please specify what you have assumed for $h_1(t)$ and $h_2(t)$.

End of question paper.