Homework for Module 6

Quiz, 12 questions

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1.
(Difficulty ⋆) You need to design a data transmission system where the data symbols come from an alphabet $\mathcal{A}$ with cardinality 32; all symbols are equiprobable. The bandwidth constraint is $F_{\min} = 250$ MHz, $F_{\max} = 500$ MHz.

To meet the bandwidth constraint, the signal is upsampled by a factor of 4 and interpolated at $F_s = 1$ GHz before being converted to the analog domain.

Determine the Baud rate (in symbols/s) and throughput (in bits/s) of the system.

Type the values of Baud rate (in symbols/s) and throughput (in bits/s) separated by a space; write the values as integers (i.e. no exponential notation). For example, if the Baud rate is 10^6 symbols/s and throughput $2 \cdot 10^6$ bits/s, the answer should be written in the following form:

1000000 2000000

Enter answer here

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2.
(Difficulty ⋆) Consider a QAM system designed to transmit over a bandwidth of 3 kHz. The channel's power constraint imposes a maximum SNR of 30 dB. The system can tolerate a probability of error of 10^{-6}.

Determine the maximum throughput of the system in bits per second.

Enter the bit rate in bits/s as an integer (i.e. no exponential notation)

Enter answer here

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3.

(Difficulty ⋆⋆) In the specifications for a data transmission system, you are given the bandwidth constraint $F_{\min} = 400$ MHz, $F_{\max} = 600$ MHz. Assume the sequence of digital symbols to transmit is i.i.d.

From the options below, choose the combinations of upsampling factor K and interpolation frequency F_s that allow you to build an analog transmitted signal meeting the bandwidth constraint.

Select all the answers that apply.

- [ ] $F_s = 1.5$ GHz, $K = 10$
- [ ] $F_s = 2.4$ GHz, $K = 12$
- [ ] $F_s = 1.5$ GHz, $K = 5$
- [ ] $F_s = 1$ GHz, $K = 5$
- [ ] $F_s = 1.9$ GHz, $K = 9$

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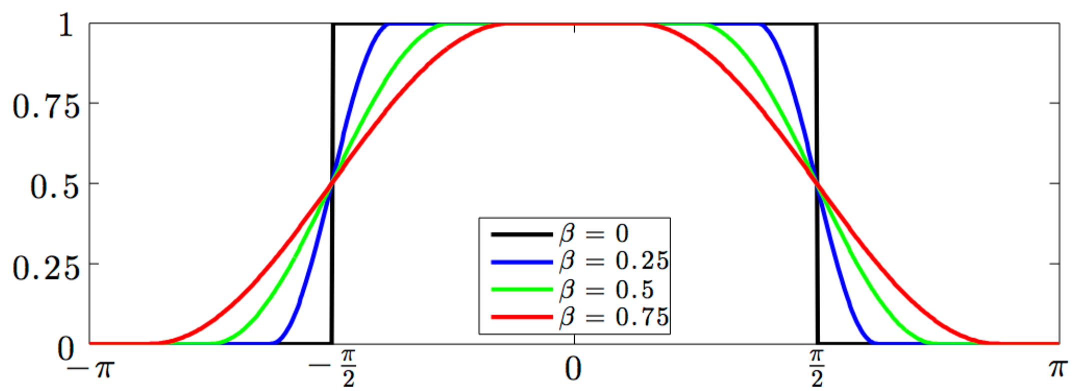
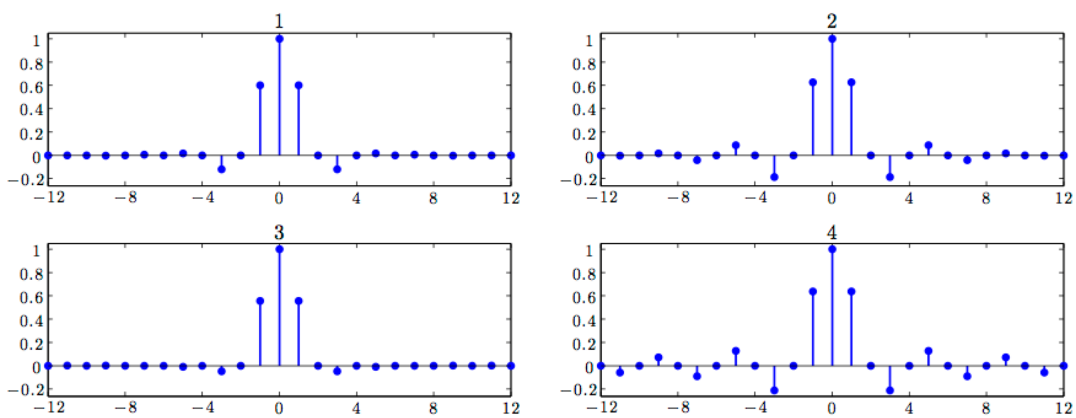
4.
(Difficulty ⋆) Consider the raised cosine spectra given below:



Associate the impulse responses shown in random order below with the associated raised cosine spectra.



Type the impulse response numbers separated by a space, starting from the one corresponding to the raised cosine spectrum with $\beta = 0$ to the one corresponding to $\beta = 0.75$.

Enter answer here

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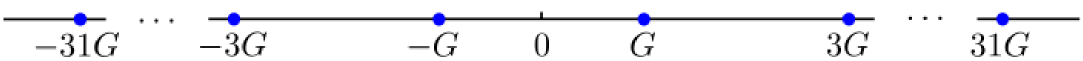
5.
(Difficulty $\star\star\star$) Consider a 32-PAM transmission system, where the signaling symbols are placed on the real line like so:



Assume the transmitted symbols are uniformly distributed and independent. The transmission channel is affected by white noise, whose sample distribution is **uniform** over the interval $[-100,\ 100]$.

Find the **minimum** value for G that guarantees an error probability of at least 10^{-2}.

Type the computed value of G without the use of exponents.

Example: if you found that $G = 10.52$, your answer should be:

10.52

Enter answer here

1
point

6.
(Difficulty $\star$) A transmission channel has a bandwidth of 6 MHz and a SNR of 20 dB.

Check the throughputs below that are **theoretically** possible for the given channel.

Select all the answers that apply.

- [ ] 36 Mbit/s
- [ ] 12 Mbit/s
- [ ] 42 Mbit/s
- [ ] 6.5 Mbit/s
- [ ] 50 Mbit/s

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7.

(Difficulty ⋆) Assume that we are using a QAM signalling scheme to communicate over a given channel; the system is designed to meet the bandwidth and power constraints. If we want to decrease the error rate, which of the following steps can we take?

Select all the answers that apply.

- [ ] Increase the constellation size M
- [ ] Decrease signal power
- [ ] Decrease the bit rate
- [ ] Decrease the constellation size M
- [ ] Increase the baud rate

1
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8.

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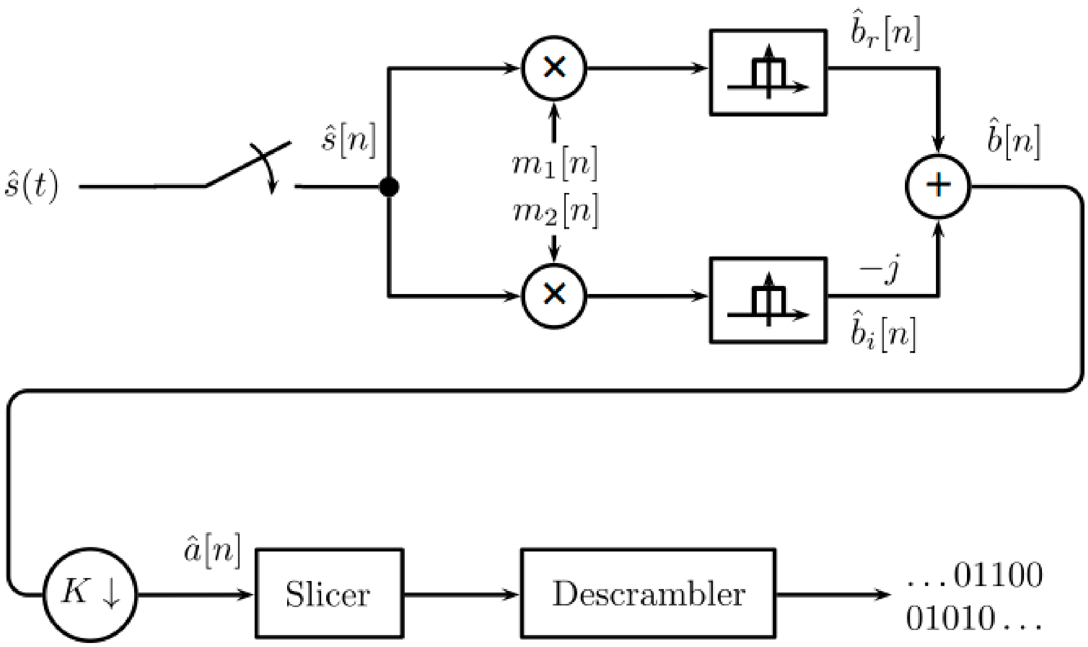
(Difficulty ⋆⋆⋆) With respect to the block diagram of a QAM receiver given below, assume $\hat{s}[n]$ is a real-valued bandpass signal occupying the interval $[\omega_{\min}, \omega_{\max}]$ on the positive frequency axis (and symmetric in magnitude around $\omega = 0$). Assume also that the modulation frequency $\omega_c = (\omega_{\min} + \omega_{\max})/2$ is much larger than the bandwidth, i.e. $\omega_c \gg \omega_{\max} - \omega_{\min}$.



In order to reconstruct the complex baseband signal, the sampled passband signal $\hat{s}[n]$ is demodulated by multiplying it with

two signals, $m_1[n]$ and $m_2[n]$. Select among the choices below the signal pairs that can be used to demodulate $\hat{s}[n]$ in order to get the correct signals $\hat{b}_r[n]$ and $\hat{b}_i[n]$.

Select all the answers that apply.

- [ ] $m_1[n] = 1 + \cos\omega_c n$, $m_2[n] = 1 + \sin\omega_c n$
- [ ] $m_1[n] = \sin\frac{\omega_c n}{2}\cos\frac{3\omega_c n}{2}$, $m_2[n] = \sin\frac{3\omega_c n}{2}\cos\frac{\omega_c n}{2}$
- [ ] $m_1[n] = \cos\omega_c n$, $m_2[n] = \sin\omega_c n$
- [ ] $m_1[n] = \cos\frac{\omega_c n}{2}\cos\frac{3\omega_c n}{2}$, $m_2[n] = \sin\frac{\omega_c n}{2}\cos\frac{3\omega_c n}{2}$
- [ ] $m_1[n] = \cos\frac{\omega_c n}{2}\cos\frac{3\omega_c n}{2}$, $m_2[n] = \sin\frac{\omega_c n}{2}\sin\frac{3\omega_c n}{2}$

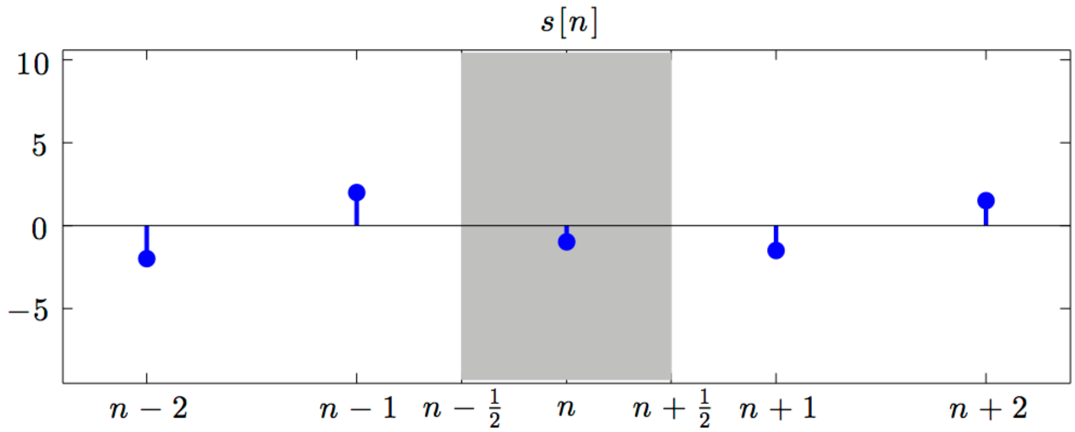
1 point

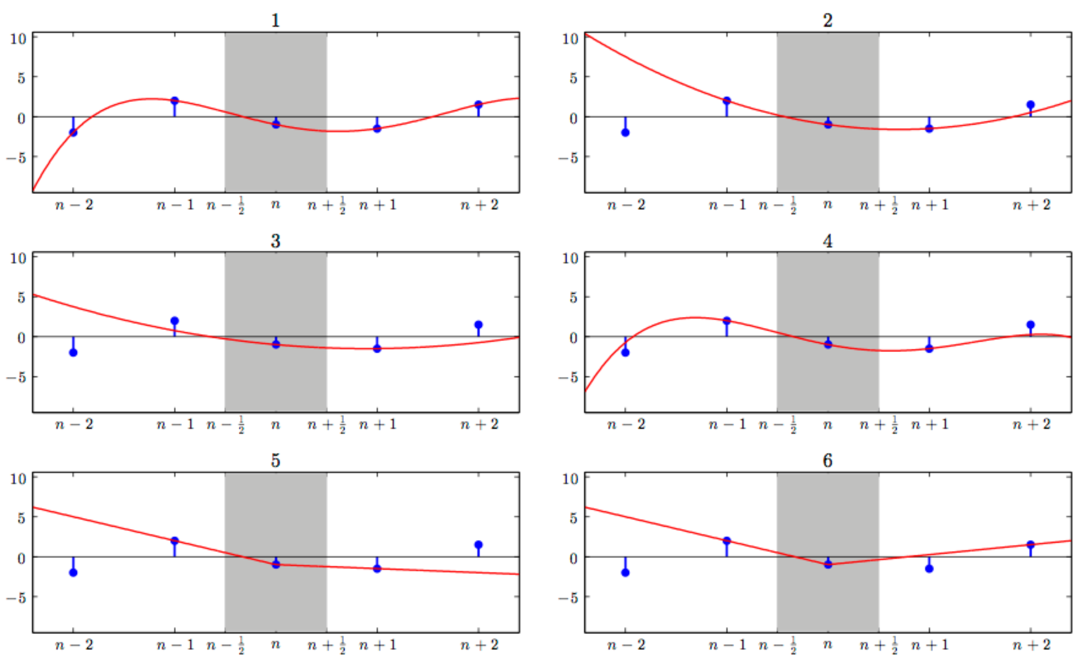
9.

(Difficulty: ⋆⋆⋆) Consider a local interpolation scheme based on Lagrange polynomials. Suppose you want to compute the approximate value of $s_c((n+\tau)T), |\tau| \leq 1/2$ using the discrete-time version of the signal $s[n] = s_c(nT)$. For simplicity, let's set $T = 1$.

Lagrange interpolation of order N will fit an order-N polynomial through the $N+1$ samples that are closest to $s_c(n+\tau)$. For instance, for $N=1$, Lagrange interpolation will fit a straight line between $s[n]$ and $s[n-1]$ if $\tau < 0$ and between $s[n]$ and $s[n+1]$ if $\tau > 0$. For $N=2$, Lagrange interpolation will fit a parabola through $s[n-1]$, $s[n]$ and $s[n+1]$ for all values of τ.

Consider the following signal, showing 5 samples around $s[n]$; the gray area represents the range of the local approximation that we want to perform. Below you will find six plots each one of which shows, in red, a polynomial interpolator passing through $s[n]$. Select the interpolators that are valid Lagrange interpolators for the gray interval.





- [ ] 6
- [ ] 5
- [ ]

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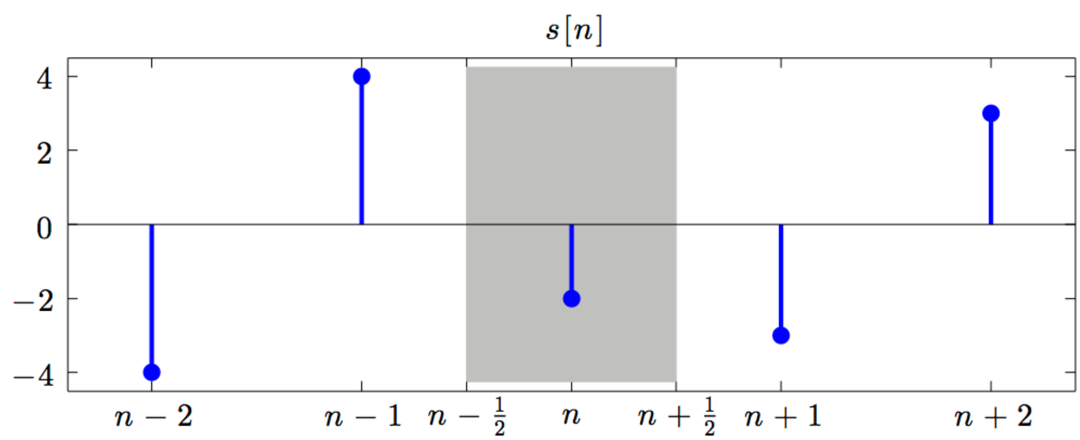
1 point

10.

(Difficulty: ⋆⋆) Consider the same interpolation setup as in the previous question:



The numeric values of the five samples are

$$\begin{aligned} s[n-2] &= -4 \\ s[n-1] &= 4 \\ s[n] &= -2 \\ s[n+1] &= -3 \\ s[n+2] &= 3 \end{aligned}$$

Using Lagrange interpolation, compute the interpolated value $s_c(n+\tau)$ for $\tau_4 = \frac{1}{4}, N_4 = 2$.

Hint: the easiest way to solve the exercise is to write a short program.

Enter answer here

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1 point

11.

(Difficulty ⋆) Consider a simplified ADSL signaling scheme where there are only 8 sub-channels and where the power constraint is the same for all sub-channels. All subchannels have equal width and each sub-channel CH_k is centered at $\omega_k = \frac{\pi k}{N}, N = 8$. Assume further that we are allowed to send only on the last six sub-channels,

CH_2 to CH_7.

We use QAM signalling on each of the allowed sub-channels, and the sub-channels' SNRs in dBs are shown here:

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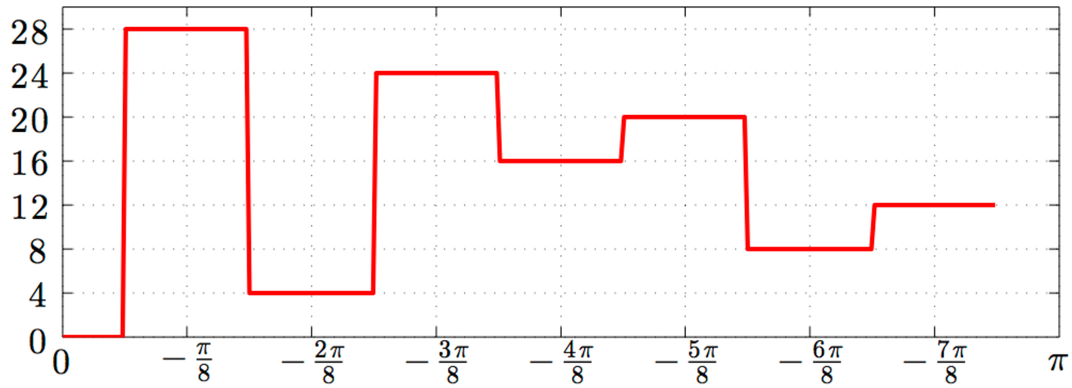
Which sub-channel will have the smallest throughput (in bits/second), and which will have the largest?



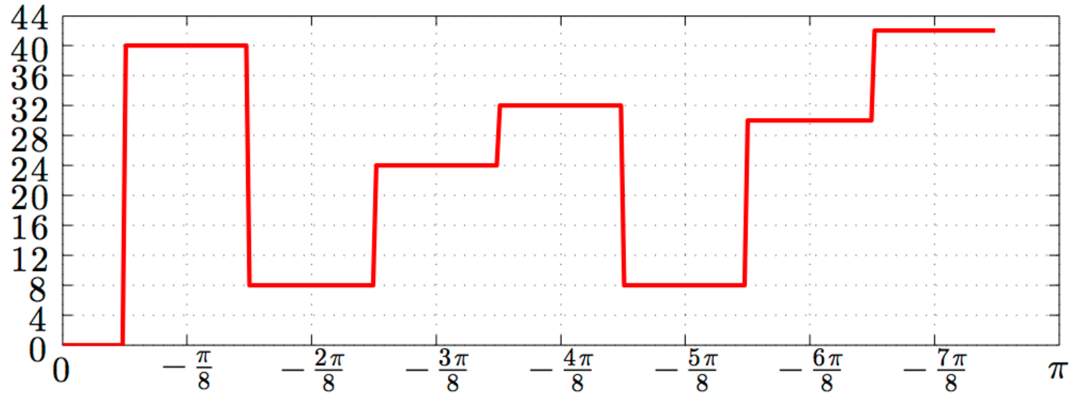
Type the indices of the channel with the lowest and the channel with the highest throughput, separated by a space. Note that the baseband channel (of which we see the $[0, pi/16]$ portion in the plot) is channel number zero.

Enter answer here

1 point

12.

(Difficulty ⋆⋆) We are still working with the simplified ADSL specification from the previous problem $(N = 8)$. The sub-channels' SNRs are slightly different, and they are given below.



To simplify the problem and avoid making calculations,

you are given the error rate curves for different QAM signalling schemes with square constellations (like the ones you saw in the lecture) in the figure below.

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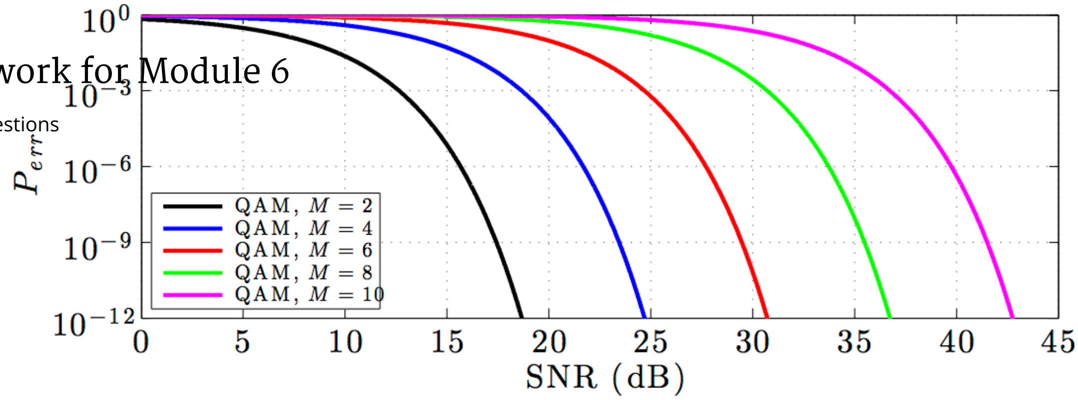

Based on the sub-channels' SNRs shown in the first figure, number of channels $N = 8$, sampling frequency $F_s = 2$ MHz and the used signalling scheme, determine the maximum throughputs of channels CH_3, CH_4 and CH_7.

Assume that we are not willing to accept the error probabilities higher than $P_{err} = 10^{-6}$ on any of the sub-channels.

Type the maximum throughputs on channels CH_3, CH_4 and CH_7 as integers separated by a space.

Enter answer here

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