E9-251: Signal Processing for Data Recording Channels

Exam #1

Rules and Regulations:

- The paper contains 3 questions. Attempt all the questions with careful reasoning and justifying your approach.
- None of these problems require elaborate investigation.
- You are welcome to refer to your class notes, reference books and anything under the sun. Do not consult/collaborate with any one on any of these problems.
- Turn in your work on Thursday September 20^{th} in class.
- Good Luck!

Question No	Max Points	Actual Score
1	25	
2	25	
3	50	

Total:

1) The following statement assertions are made. State whether they are true or false giving very brief justifications. Random guesses will get zero credit.

(a) We can store data on a para-magnetic medium.

(b) Perpendicular magnetic recording channels have a dc-response.

(c) If we pack more bits within a unit cell of a magnetic medium, we can always boost areal density.

(d) The areal density in current optical recording channels is limited by diffraction.

(e) Group delay of a causal filter is always negative.

(25 pts)

2) Consider two FIR filters characterized by $H_1(z) = \sum_{i=0}^{M} h_i z^{-i}$ and

$$H_2(z) = \sum_{i=0}^{M} h_{M-i} z^{-i} .$$

(a) Comment if the filters $H_1(z)$ and $H_2(z)$ have the same magnitude and phase response. (5 pts)

(b) Suppose, it is known that $H_1(z)$ is minimum phase, and one of the zeros z_1 in $H_1(z)$ is flipped outside the unit circle to $1/z_1$, leaving the rest of the zeros intact to form an alternative filter $H_3(z)$, establish a relationship between the two filters $H_1(z)$ and $H_3(z)$. (5 pts)

(c) Using your result in (b) or otherwise, prove that $H_3(z)$ will not be minimum phase by explicitly computing the partial energies delivered by the two filters in response to an impulse. (15 pts)

3) The impulse response for an optical recording channel is given by $h(t) = \frac{2}{t_0\sqrt{\pi}} e^{-\left(\frac{2t}{t_0}\right)^2}$ $-\infty \le t \le \infty$. Let the density be given by $D = \frac{t_0}{T}$ where T is the symbol spacing. Assume that we have a 4-ary optical recording system where optical pulses are equiprobable with <u>intensities</u> equally spaced within the interval [0 I_{max}], where 0 signifies no intensity and I_{max} signifies maximum intensity. Let the electronic noise from the read back signal be Gaussian distributed $N\left(0, \sigma_w^2\right)$.

(a) Suppose jitter occurs in the position t due to optical fluctuations, assuming that the jitter is characterized by a Gaussian probability density function with mean zero and variance σ_j^2, obtain the noise power due to jitter as a function of symbol density D and jitter variance using a 1st order model. (20 pts)

(b) Obtain an expression for the received signal with interference in amplitude, jitter noise and electronics noise. Show your channel model as a block diagram. (10 pts)

(c) Define the SNR for the system as the ratio of average signal power from the optical pulses to the average noise power (noise is over both electronic noise and jitter noise). Explicitly obtain an expression for the SNR defined in this way as a function of D, I_{max}, σ_j^2 and σ_w^2 . (20 pts)