King Fahd University of Petroleum & Minerals
Electrical Engineering Department
EE573: Digital Communications II (112)

Major Exam II

April 24st, 2012
4:45 PM-6:15 PM
Building 59-1007

Name: KEY

ID: 0

Question	Mark
1	10 /10
2	12 /12
3	12 /12
Total	34 /~~34~~ 33

Instructions:

1. Read the questions carefully. Plan which question to start with.
2. CLEARLY LABEL ALL SIGNIFICANT VALUES ON BOTH AXIES OF ANY SKETCH
3. Work in your own.
4. Strictly no mobile phones are allowed.
5. Q function table is attached.

Good luck

Dr. Ali Muqaibel

Question 1: Answers should be very clear and to the point (~~8~~ 10 points)

1) What is Welch bound? Is it a lower bound or an upper bound and on what?. **(1 point)**

is a lower bound on the minimum possible cross correlation.

2) Explain why it is unfair to compare *T*/2 fractionally spaced equalizer versus symbol rate equalizer with the same time span? **(1 point)**

FSE

If we keep the same time span the number of taps for the T/2 FSE will be approximatly doubled.
It is unfair to compare in terms of BER performance only?

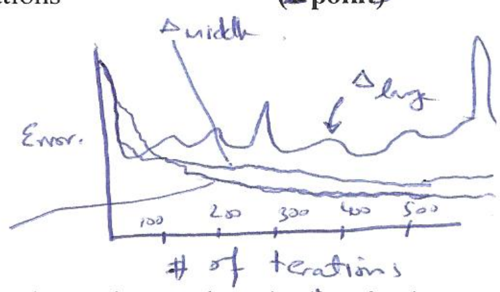
3) In the IS-95 System, the design of the forward link is more relaxed compared with the reversed link. There are two main reasons: **(~~1~~ 2 point)**

a) No power constrains. "No strict power constrains"

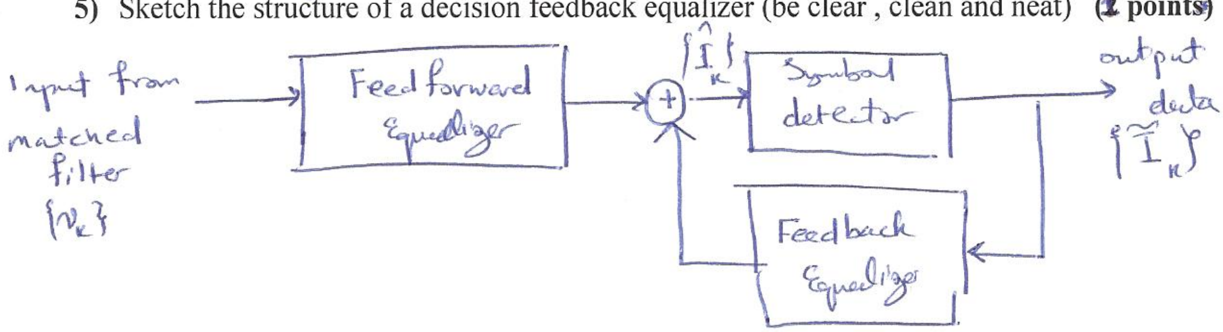
b) Synchronous Communication ⇒ less Interference impact.

4) In adaptive equalization, explain the convergence in terms of the step size. Support your explanation with plots for the output vs. number of iterations **(~~1~~ 2 points)**

There is a trade off
error
if we make step size Δ large, we have faster convergance but we might diverge. and error floor is large.
if we make it small, slower but less error floor (middle)



5) Sketch the structure of a decision feedback equalizer (be clear , clean and neat) **(~~1~~ 2 points)**



6) Which one of the following two codes you would choose for a 4 users CDMA system. *Justify your answer* **(2 points)**

Alam	Naveed
000000	000000
101010	101010
010101	000111
111111	111111

α

one delay
make them the same.

Naveed | Alan

① not linear. | linear code

② $d_{min}=3$ | $d_{min}=3$

③ corross corrlation low | 101010 010101 high

one shift results in high corrlation.
two shifts results in high corrlation.

④ Auto corrlation ~~high~~ low

⑤ → Naveed is better.

Question 2: Equalization (10 points)

Binary PAM is used to transmit information over a bandlimited AWGN channel of zero mean and **variance=0.04** that causes severe ISI with the two adjacent symbols. The transmitted bits of ± 1 are independent and equiprobable. When a "1" is transmitted, the noise-free output of the demodulator is:

$x_m = \begin{cases} 0.95 & m=0 \\ 0.2 & m=\pm 1 \\ 0 & \text{other} \end{cases}$	*Hint: For Binary PAM over AWGN Channel* $P_e = Q\left(\frac{\text{signal amplitude at sampling}}{\sqrt{\text{noise variance}}}\right) = Q\left(\sqrt{\frac{d^2}{\sigma^2}}\right)$ *Assume* d=1.

Mr. Dahiro successfully designed a 3-tap ZFE. The tap coefficients obtained were $[C_{-1}\ \ C_0\ \ C_1] = [~~-2.43~~\ \ 1.16\ \ -2.43]$.
-0.243 $\quad -0.243)$

$\sigma^2 = 0.25$
$\sigma = 0.5$

(a) Calculate the probability of error, p, before equalization. **(4 points)**

Possible amplitude	prob.
0.55	1/4
0.95	1/4
0.95	1/4
1.35	1/4

$$P_e = \frac{1}{4}\left[Q\left(\frac{0.55}{0.5}\right) + 2Q\left(\frac{0.95}{0.5}\right) + Q\left(\frac{1.35}{0.5}\right)\right]$$
$$= \frac{1}{4}\left[Q(1.1) + 2Q(1.9) + Q(2.7)\right]$$
$$= \frac{1}{4}\left[0.1357 + 2(0.0287) + 0.0035\right]$$
$$= 0.04915$$

(b) Calculate the normalized peak distortion before equalization and after equalization and sketch the eye diagrams in the two cases **(4 points)**

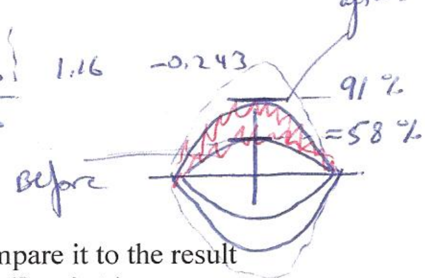
Befor Equalization $= \frac{1}{0.95}(0.2+0.2) = 0.421$

After Equalization, since we have ZFE with 3 taps. The over all response will have $3+3-1=5$ term.

Two residual Components are semetric

0.2 0.95 0.2
-0.243 1.16 -0.243
0.0486

After Equalization $= \frac{2(0.0486)}{1} = 0.0972$



(c) Calculate the probability of error for the equalized channel, p_e, and compare it to the result obtained in (a) and comment. Do not ignore the residual ISI. **(4 points)**

$$P_e = \frac{1}{4}\left[Q\left(\frac{0.9028}{0.592}\right) + 2Q\left(\frac{1}{0.592}\right) + Q\left(\frac{1.0972}{0.592}\right)\right] \quad -1$$

Noise Enhance =

$$\sigma^2_{new} = \sigma^2 \sum_{n=-1}^{1} (C_n)^2 = 0.25\left((1.16)^2 + 2(0.243)^2\right) = 0.25 \times 1.404 = 0.3511 \quad -1$$

$\sigma = 0.592$

$$P_e = \frac{1}{4}\left[Q(1.525) + 2Q(1.69) + Q(1.853)\right] = 0.047$$
$$= \frac{1}{4}\left[0.0630 + 2(0.0455) + (0.0322)\right]$$

The ZFE ... bad because of noise enhancement. It is

Question 3: Spread Spectrum (12 points)

In a fast FH spread spectrum system, the information is transmitted via FSK, with noncoherent detection. Suppose there are $N = 3$ hops/bit, with hard-decision decoding of the signal in each hop. Determine the bit probability of error for this system in an AWGN channel with $E_c/N_0 = 13\ dB$ (SNR per hop). Assume majority decoding.

Hint: probability of chip error with non-coherent detection is $p = \frac{1}{2}e^{-\frac{Ec}{2N_0}}$ **(3 points)**

$$P_c = \frac{1}{2} e^{-20/2} = \frac{1}{2} e^{-10} = 2.27 \times 10^{-5}$$

$$P_b =$$

$$P_e = \sum_{i=2}^{3} \binom{3}{i} P_c^{i} (1-P_c)^{3-i} = 2.3 \times 10^{-9}$$

Mr. Duraibi claimed that DS/SS can achieve higher gain compared with FH/SS at the same given clock rate. Is he right or wrong? Support your decision by finding the required clock rate to obtain a processing gain of 100 with data rate of 1 M bits/s. (in the two cases) **(3 points)**

He is wrong.

$G_p = 100$

① DS/SS

$$G_p = \frac{W}{R} = \frac{1/T_c}{1M} = 100$$

$\Rightarrow R_c = 100$ M chip/sec

② FH SS

$$G_p = 2^{l} \cdot k = 100$$

$l = 6$ & $k = 2$

$G_p = 64 \cdot 2 = 128$ ok > 100

Clock rate $= l \cdot k \cdot R_b$

$= 6 \cdot 2\ (1M) = 12\ M$

clearly DSSS clock rate $>$ FHSS clock rate

A rate 1/2 convolutional code with $d_{min} = 10$ is used to encode a data sequence occurring at a rate of 1000 bits/s. The modulation is binary PSK. The DS spread spectrum sequence has a chip rate of 10 MHz. Determine the coding gain and the processing gain **(2 points)**

Coding Gain $= R_c\, d_{min} = \frac{1}{2}(10) = 5$ (7 dB)

Processing Gain $= \frac{W}{R} = \frac{10^7}{2 \times 10^3} = 5 \times 10^3$ (37 dB)

A CDMA system is designed based on DS spread spectrum with a processing gain of 100 and binary PSK modulation. Determine the number of users if each user has equal power and the desired level of performance is an error probability of 0.0002. Repeat the computation if the error probability is changed to 0.0027. *Comment in the change.*

(4 points)

$$P_e = Q\left(\sqrt{\frac{2W/R}{J_{av}/P_{av}}}\right) = Q\left(\sqrt{\frac{2W/R}{N_u - 1}}\right) = 0.0002 \qquad , \; W/R = 100$$

17.42

$$\Rightarrow \sqrt{\frac{2W/R}{N_u-1}} = 3.49 \Rightarrow N_u = \frac{2(100)}{(3.49)^2} + 1 = \lfloor \quad \rfloor \approx 17$$

if we ~~make~~ allow more error.

26.88

$$\sqrt{\frac{2W/R}{N_u-1}} = 2.78 \Rightarrow N_u = \frac{2(100)}{(2.78)^2} + 1 = \lfloor \quad \rfloor \approx 26$$

if we can tolerate more errors we can take more users.

↑ we round down to guarantee Pe.

TABLE B.1 Complementary Error Function $Q(x) = \int_x^\infty (1/\sqrt{2\pi}) \exp(-u^2/2)\, du$

x	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2168	0.2148
0.8	0.2169	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003
3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002

$$\int_{-\infty}^{\infty} x(t) e^{-j2\pi ft}\, dt \Leftrightarrow \int_{-\infty}^{\infty} X(f) e^{j2\pi ft}\, df$$