KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
COLLEGE OF COMPUTER SCIENCES & ENGINEERING

COMPUTER ENGINEERING DEPARTMENT

COE-543 – Mobile and Wireless Networks
November 17th, 2011 – Midterm Exam

Student Name:
Student Number:
Exam Time: 90 mins

- Do not open the exam book until instructed
- The use of programmable and cell phone calculators is not allowed – only basic are permitted
- **Answer ALL Questions**
- All steps must be shown
- Any assumptions made must be clearly stated

Question No.	Max Points	
1	50	
2	50	
3	50	

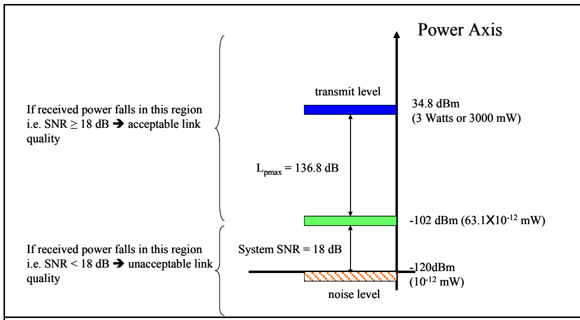
Total: 150

Q.1) On the subject of RF propagation

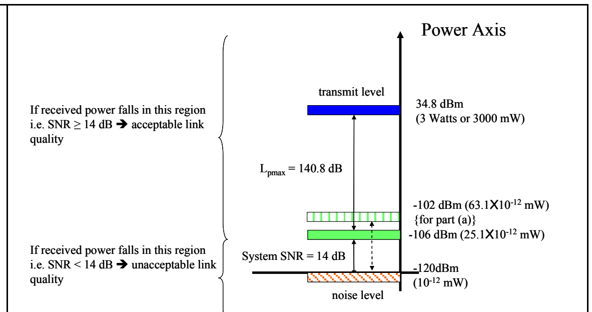
(50 points) The modulation technique used in the existing AMPS is analog FM. The transmission bandwidth is 30 kHz per channel and the maximum transmitted power from a mobile use is 3 W. The acceptable quality of the input SNR is 18 dB, and the background noise in the bandwidth of the system is -120 dBm (120 dB below the 1mW reference power). In the cellular operation we may assume the strength of the signal drops 30 dB for the first meter of distance from the transmitter antenna and 40 dB per decade of distance for distances beyond 1 meter.

1. What is the maximum distance between the mobile station and the base station at which we have an acceptable quality of signal?
2. Repeat (a) for digital cellular systems for which the acceptable SNR is 14 dB
3. For (2) – now assume shadowing is considered. What would be the distance such that 90% of the locations have SNR equal or greater than 14 dB? Assume the shadowing process has a standard deviation of 8 dB.

Solution:



(1)



(2)

(1) Maximum distance for an SNR of 18 dB.

The transmitter power is Pt = 10log(3Watts/1mW) = 34.8 dBm

The minimum acceptable received power is Prmin = -120 dBm + 18 dB = -102 dBm

The maximum allowable path loss is Lpmax = Pt – Prmin = 34.8 dBm - (-102 dBm) = 136.8 dB

The path loss model based on 30 dB in the first meter and 40 dB per decade of distance is

$Lp = 30 + 40*\log_{10}(d)$ ➔ $d = 10^{(Lp-30)/40}$ and $dmax = 10^{(Lpmax-30)/40} = 10^{(136.8-30)/40} = 468$ meters

(2) Maximum distance for an SNR of 14 dB.

The transmitter power is Pt = 10log(3Watts/1mW) = 34.8 dBm

The minimum acceptable received power is Prmin = -120 dBm + 14 dB = -106 dBm

The maximum allowable path loss is Lpmax = Pt – Prmin =34.8 dBm - (-106 dBm) = 140.8 dB

The path loss model based on 30 dB in the first meter and 40 dB per decade of distance is

$Lp = 30 + 40*\log_{10}(d)$ ➔ $d = 10^{(Lp-30)/40}$ and $dmax = 10^{(Lpmax-30)/40} = 10^{(140.8-30)/40} = 589$ meters

(3) Using the standard normal variable tables – zp = 1.282 ➔ X = 8 * 1.282 = 10.26 dB.

Therefore, the new minimum acceptable received power is Prmin = -120 + 14 + 10.26 = -95.74 dB

The maximum allowable path loss is Lpmax = Pt – Prmin = 34.8 dBm – (-95.7) = 130.5 dB

$Lp = 30 + 40*\log_{10}(d)$ ➔ $d = 10^{(Lp-30)/40}$ and $dmax = 10^{(Lpmax-30)/40} = 10^{(130.5-30)/40} = 325.5$ meters

Q.2) On the subject of cellular concept and traffic engineering

(50 points) Consider a cellular system with 395 total allocated voice channels of 30 kHz each. The total available bandwidth in each direction is 12.5 MHz. The traffic is uniform with average call holding time of 120 seconds, and call blocking during the system busy hour is 2%. Assume a cell reuse factor of 7, 3 antenna sectors per cell site, and a slope for the path-loss of 40 dB/decade. Furthermore, assume the there are 10 mobiles/km2 with each mobile generating traffic of 0.02 Erlangs.

a) (5 points) Calculate the calls per cell site per hour the network can support

b) (5 points) Calculate the maximum cell radius the network can support

c) (10 points) Calculate the mean SIR provided by setup

d) (20 points) Calculate the spectral efficiency in Erlangs/km2/MHz

e) (10 points) How would an engineer utilize antenna sectorization to increase the capacity for the above system.

Solution:

The traffic per cell site = V X t X Ac

Where V = no of mobile per km2

t = traffic in Erlangs per mobile

Ac = area of cell = $2.6R^2$ (R is the cell radius)

Therefore, traffic per cell site = $10X0.02X2.6R^2 = 0.52\ R^2$ Erlangs

No of voice channels per sector = 395/(7X3) = 19 channel

Offered traffic per sector = 12.3 Erlangs or 12.3x3 = 36.9 Erlangs per cell site

Carried traffic per cell site = (1-0.02)X36.9 = 36.2 Erlangs

a & b) But carried traffic = No of calls per cell site per hour X 3600/120

- ➔ No of calls per cell site per hour = 1,086
- ➔ Cell radius R =sqrt(36.2/0.52) = 8.3 km

c) Mean SIR = q^a/m, assuming m co-channel interferers all at the reuse distance D

for a = 4 (given), N = 7, q = √(3N) = 4.6, m = 2 (for 3 sectors) ➔ SIR = 223.9 or 23.5 dB

d)

$$\text{The spectral efficiency} = \frac{\text{Traffic carried per cell X Nc}}{\text{Total BW X Total Area}} = \frac{\text{Traffic carried per cell}}{\text{Total BW X } 2.6\ R^2}$$

or

$$= 36.2/(2.6R^2 \text{ X } 12.5) = 0.0162 \text{ Erlangs/km2/MHz}$$

e) To increase capacity utilizing sectorization, the engineer must increase number of sectors per site to say 4 or 6 and at the same time reduce the reuse factor to 4 or 3. Without reducing the reuse factor there will be no capacity improvement.

Q.3) (50 points) On the subject of physical layer for wireless networks

a) Frequency shift keying modulation (FSK)

a.1) **(10 points)** Explain the basic operation FSK modulation – Use drawing if possible.

a.2) **(5 points)** What is relation between Minimum shift keying (MSK) and FSK?

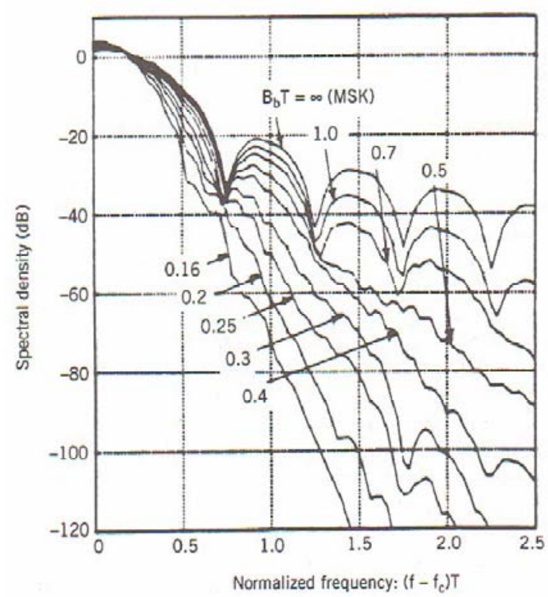
a.3) **(10 points)** How is MSK improved upon in Gaussian minimum shift keying? Draw the block diagram of the GMSK modulator.

b) Consider the spectral density functions of the MSK and GMSK shown in figure.

b.1) **(10 points)** What is referred to by B_bT? Define the term and it implication.

b.2) **(10 points)** In terms of adjacent channel interference, which modulation scheme (MSK or GMSK) is better? And why?

b.3) **(5 points)** What is the disadvantage of a GMSK scheme of small B_bT value (i.e. less than 0.25)?



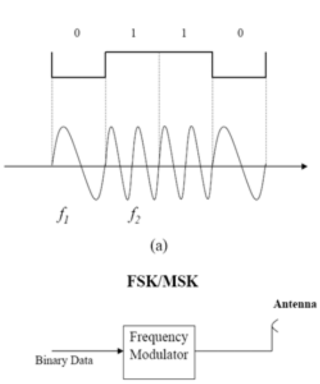
Solution:

a.1) FSK: the following mapping is used: bit 0 ➔ cos(2 $\pi f_1 t$) while bit 1 ➔ cos(2 $\pi f_2 t$). The output is a constant envelope signal (refer to figure)

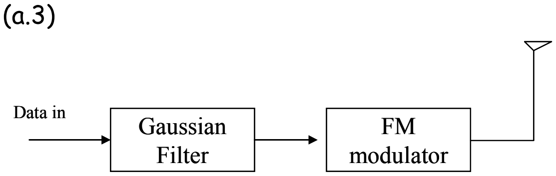
a.2) MSK is an FSK carrier modulation scheme where minimum frequency spacing is chosen such that the signal alphabets are orthogonal. This spacing is 1/(2T) for coherent MSK And 1/T for non coherent MSK. MSK is a constant-envelope continuous-phase modulation where abrupt phase changes at the bit transition times (characteristic of FSK in general) are eliminated.

a.3) To further reduce side lobes of an MSK signal power spectrum, a Gaussian filter is used in front of the MSK/FSK modulator – the resulting scheme is referred to by GMSK. The filter reduces side lobes and therefore reduces adjacent channel interference.

(a.1)



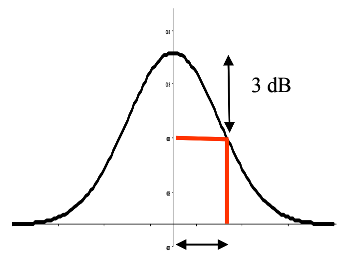
(a.3)



Block diagram of GMSK modulator

b.1) BbT is the Time-bandwidth product for the Gaussian filter used in GMSK. where B_b = 3 dB bandwidth of the Gaussian filter, and T is the bit duration

Implication: an indication of how wide the filter bandwidth – when Bb = ∞ ➔ all pass filter or no filter.



b.2) In terms of adjacent channel interference, MSK has the higher side lobes compared to GMSK. Further more, GMSK with lower B_bT produces lower side lobes and therefore lower adjacent channel interference.

b.3) Low value of B_bT (i.e. narrow low pass filter) produces good signal in terms of adjacent channel interference but a signal with very smooth transitions and therefore error-rate due to thermal noise increase.

<u>Appendix A</u>:

A.2 QUANTITIES OF THE UNIT NORMAL DISTRIBUTION

Table A.2 lists z_p for a given p. For example, for a two-sided confidence interval at 95%, $\alpha = 0.05$ and $p = 1 - \alpha/2 = 0.975$. The entry in the row labeled 0.97 and column labeled 0.005 gives $z_p = 1.960$.

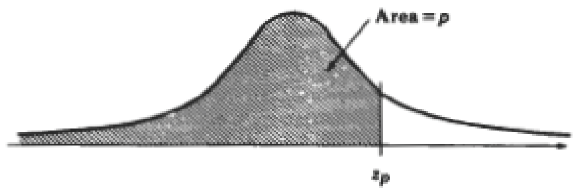


TABLE A.2 Quantiles of the Unit Normal Distribution

p	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.5	0.000	0.025	0.050	0.075	0.100	0.126	0.151	0.176	0.202	0.228
0.6	0.253	0.279	0.305	0.332	0.358	0.385	0.412	0.440	0.468	0.496
0.7	0.524	0.553	0.583	0.613	0.643	0.674	0.706	0.739	0.772	0.806
0.8	0.842	0.878	0.915	0.954	0.994	1.036	1.080	1.126	1.175	1.227

p	0.000	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009
0.90	1.282	1.287	1.293	1.299	1.305	1.311	1.317	1.323	1.329	1.335
0.91	1.341	1.347	1.353	1.359	1.366	1.372	1.379	1.385	1.392	1.398
0.92	1.405	1.412	1.419	1.426	1.433	1.440	1.447	1.454	1.461	1.468
0.93	1.476	1.483	1.491	1.499	1.506	1.514	1.522	1.530	1.538	1.546
0.94	1.555	1.563	1.572	1.580	1.589	1.598	1.607	1.616	1.626	1.635
0.95	1.645	1.655	1.665	1.675	1.685	1.695	1.706	1.717	1.728	1.739
0.96	1.751	1.762	1.774	1.787	1.799	1.812	1.825	1.838	1.852	1.866
0.97	1.881	1.896	1.911	1.927	1.943	1.960	1.977	1.995	2.014	2.034
0.98	2.054	2.075	2.097	2.120	2.144	2.170	2.197	2.226	2.257	2.290

p	0.0000	0.0001	0.0002	0.0003	0.0004	0.0005	0.0006	0.0007	0.0008	0.0009
0.990	2.326	2.330	2.334	2.338	2.342	2.346	2.349	2.353	2.357	2.362
0.991	2.366	2.370	2.374	2.378	2.382	2.387	2.391	2.395	2.400	2.404
0.992	2.409	2.414	2.418	2.423	2.428	2.432	2.437	2.442	2.447	2.452
0.993	2.457	2.462	2.468	2.473	2.478	2.484	2.489	2.495	2.501	2.506
0.994	2.512	2.518	2.524	2.530	2.536	2.543	2.549	2.556	2.562	2.569
0.995	2.576	2.583	2.590	2.597	2.605	2.612	2.620	2.628	2.636	2.644
0.996	2.652	2.661	2.669	2.678	2.687	2.697	2.706	2.716	2.727	2.737
0.997	2.748	2.759	2.770	2.782	2.794	2.807	2.820	2.834	2.848	2.863
0.998	2.878	2.894	2.911	2.929	2.948	2.968	2.989	3.011	3.036	3.062
0.999	3.090	3.121	3.156	3.195	3.239	3.291	3.353	3.432	3.540	3.719

Appendix B: Offered Loads (in Erlangs) for various Blocking Objectives – According to the Erlang-B model

P(B) = Trunks	0.01	0.015	0.02	0.03	0.05	0.07	0.1
I	0.010	0.015	0.020	0.031	0.053	0.075	0.111
2	0.153	0.190	0.223	0.282	0.381	0.471	0.595
3	0.455	0.536	0.603	0.715	0.899	1.057	1.271
4	0.870	0.992	1.092	1.259	1.526	1.748	2.045
5	1.361	1.524	1.657	1.877	2.219	2.504	2.881
6	1.913	2.114	2.277	2.544	2.961	3.305	3.758
7	2.503	2.743	2.936	3.250	3.738	4.139	4.666
8	3.129	3.405	3.627	3.987	4.543	4.999	5.597
9	3.783	4.095	4.345	4.748	5.370	5.879	6.546
10	4.462	4.808	5.084	5.529	6.216	6.776	7.511
11	5.160	5.539	5.842	6.328	7.076	7.687	8.487
12	5.876	6.287	6.615	7.141	7.950	8.610	9.477
13	6.607	7.049	7.402	7.967	8.835	9.543	10.472
14	7.352	7.824	8.200	8.803	9.730	10.485	11.475
15	8.108	8.610	9.010	9.650	10.633	11.437	12.485
16	8.875	9.406	9.828	10.505	11.544	12.393	13.501
17	9.652	10.211	10.656	11.368	12.465	13.355	14.523
18	10.450	11.024	11.491	12.245	13.389	14.323	15.549
19	11.241	11.854	12.341	13.120	14.318	15.296	16.580
20	12.041	12.680	13.188	14.002	15.252	16.273	17.614
21	12.848	13.514	14.042	14.890	16.191	17.255	18.652
22	13.660	14.352	14.902	15.782	17.134	18.240	19.693
23	14.479	15.196	15.766	16.679	18.082	19.229	20.737
24	15.303	16.046	16.636	17.581	19.033	20.221	21.784
25	16.132	16.900	17.509	18.486	19.987	21.216	22.834
26	16.966	17.758	18.387	19.395	20.945	22.214	23.885
27	17.804	18.621	19.269	20.308	21.905	23.214	24.939
28	18.646	19.487	20.154	21.224	22.869	24.217	25.995
29	19.493	20.357	21.043	22.143	23.835	25.222	27.053
30	20.343	21.230	21.935	23.065	24.803	26.229	28.113
31	21.196	22.107	22.830	23.989	25.774	27.239	29.174
32	22.053	22.987	23.728	24.917	26.747	28.250	30.237
33	22.913	23.869	24.629	25.846	27.722	29.263	31.302
34	23.776	24.755	25.532	26.778	28.699	30.277	32.367
35	24.642	25.643	26.438	27.712	29.678	31.294	33.435
36	25.511	26.534	27.346	28.649	30.658	32.312	34.503
37	26.382	27.427	28.256	29.587	31.641	33.331	35.572
38	27.256	28.322	29.168	30.527	32.624	34.351	36.643
39	28.132	29.219	30.083	31.469	33.610	35.373	37.715