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

COE-543 – Mobile and Wireless Networks
May 18th, 2009 – 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	40	
2	40	
3	50	

Total: 130

Q.1) (40 points) On the subject of RF propagation

a) Microcellular RF pathloss models are widely used for characterizing environments for outdoor mobile cellular networks.

a.1) **(10 points)** sketch a typical signal-power versus distance relation for **microcellular** RF pathloss models.

a.2) **(10 points)** List the input parameters that typically influence the **microcellular** path loss models?

b) Consider an RF channel whose wideband impulse response function, $h(t)$, is given by $h(t) = \sum_{i=0}^{L} \alpha_i \delta(t - \tau_i) \exp(j\phi_i)$

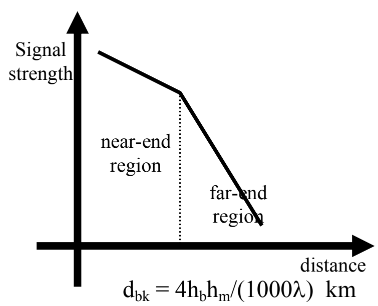
The above function defines the multipath delay spread for the RF link.

b.1) **(10 points)** Define the quantities α_i, τ_i, and ϕ_i indicating their characteristics (randomness, distribution, units, etc)?

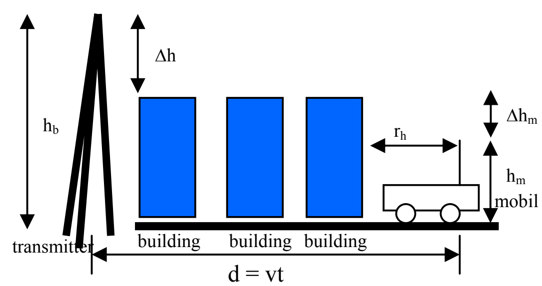
b.2) **(10 points)** Such channels suffer from a phenomenon called "irreducible error rate". Briefly (in not more than few sentences), explain this phenomenon and outline its principle cause?

Solution

a.1) typical signal-power versus distance relation is as follows



a.2) Input parameters:

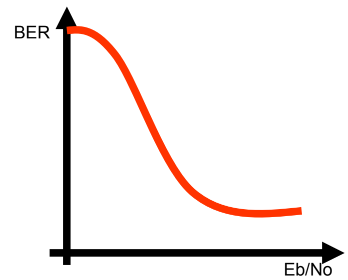


b.1) Parameters for the delay-spread function:

α_i ~ Rayleigh distributed signal amplitude – power of multipath component = $E[\alpha_i^2] = 2\sigma_i^2$

φ_i ~ the phase of signal associated with i^{th} multipath - uniform random variable $(0, 2\pi)$

τ_i ~ multipath arrival time in seconds b.2) Irreducible error rate: caused by the intersymbol interference (ISI) resulting from the multipath nature of the channel – multiple copies of the same symbol interfere and cause ISI. Increasing the transmit power per symbol does not reduce the error floor since it increases both the desired signal and the interfering copies. A typical BER curve is as shown.



Q2) (**40 points**) on the subject of physical layer issues for wireless communications:

a) (**20 points**) Using the figure shown, answer the following questions:

a.1) Which modulation scheme is most bandwidth efficient? Why?

a.2) Which modulation scheme in best in terms of adjacent channel interference? Why?

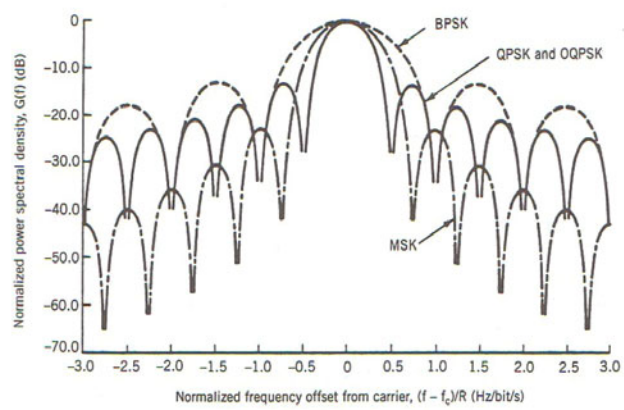
a.3) How are QPSK and OQPSK schemes similar or different?

b) **(20 points)** The side lobes for QPSK can be further improved if a pulse shaping filter is used.

b.1) What is the ideal pulse shape that can be used? Is it practical and why?

b.2) One can utilize a raised cosine pulse (RCP) shape as well. The RCP shape is controlled using a parameter 0<= β <= 1. Draw the frequency representation for the RCP filter and show the effect of β.

Solution:



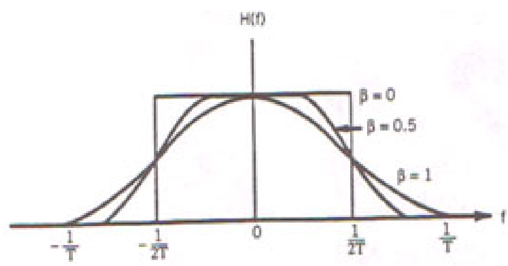
a.1) QPSK (and OQPSK) is the most bandwidth efficient since it has the narrowest main lobe (half the width for other schemes). This is because QPSK sends two bits per symbol while the other schemes (BPSK and MSK) send one bit per symbol.

a.2) In terms of adjacent channel interference, MSK is the best since it has the lowest side-lobes.

a.3) OQPSK is the identical to QPSK except that in the Q-branch one-bit delay is introduced to prevent 180-degrees phase shifts.

b.1) The ideal pulse shape is the sinc function – since it corresponds to an ideal LPF in the frequency domain. That is it has ZERO adjacent channel transmissions. Not practical – has significant side lobes in the time domain and non-causal.

b.2) Frequency BW: Min BW = $1/(2T)$ for $\beta=0$ ➔ Maximum time-domain side lobes, Max BW = $1/T$ for $\beta=1$ ➔ minimum time-domain side lobes – See figure.



Q3) (**50 points**) We have an installed cellular system with 100 sites, a frequency reuse factor of N = 7, and 500 overall two-way channels:

a) **(10 points)** Give the number of channels per cell, total number of channels available to the service provider, and the minimum carrier-to-interference ratio (C/I) of the system in dB. Assumes a pathloss exponent of 4.

b) To expand the network, we decide to create an underlay-overlay system where the new system uses a frequency reuse factor of N = 3.

b.1) **(10 points)** If R_0, D_0 are the cell radius and reuse distance for the underlay system, respectively, while R_1 and D_1 are the cell radius and reuse distance of the overlay system, respectively. Draw the frequency plan on the figure below? (i.e. put down the channel set number for both underlay and overlay systems). Indicate on the figure the quantities R0, D0, R1, and D1.

b.2) **(5 points)** Using the figure of b.1 - show that $D_1 = 3\ R_0$?

b.3) **(10 points)** What is the quantity D_1/R_1 equal to? Why?

b.4) **(15 points)** Give the number of channels assigned to inner and outer cells to keep a uniform density over the entire coverage area.

a) Number of channels per cell = 500 / 7 = 71 channels
Total number of channels available to the provider = 71 x 100 = 7100 channels
Minimum carrier-to-interference ratio with frequency reuse factor N = 7

$$\left(\frac{C}{I}\right)_{dB} = 10\log\left[\frac{1}{6}\left(\frac{D}{R}\right)^4\right] = 10\log\left[\frac{1}{6}\left(\sqrt{3N}\right)^4\right] = \text{ 18.7 dB}$$

b.1) (See figure – one possible plan)

b.2) Reuse distance for overlay network, D_1 is equal to 3 X underlay cell radius, R_0 – Refer to figure

b.3) D_1/R_1 should be set to D_0/R_0 = sqrt(3X7) = 18.7 dB to guarantee that the overlay network provides equal or better C/I for its subscribers/channels.

b.4) Number of cells assigned to inner and outer cells

$$\frac{D_0}{R_0} = \sqrt{3\times 7} = 4.6 = \frac{D_1}{R_1} \text{ and } D_1 = 3\ R_0 \text{ so that } \frac{3R_0}{R_1} = 4.6 \text{ and } R_0 = 1.53\ R_1$$

$$Area = K\ R^2 \text{ and } \frac{A_0}{A_1} = \frac{KR_0^2}{KR_1^2} = (1.53)^2 \quad and \quad A_1 = 0.43\ A_0$$

If X is the number of channels, then

$$3\,(0.43\ X) + 7\,(0.57X) = 500 \quad and \quad X = 94.7$$

For the inner cells: 0.43 X = 0.43 (94.7) = 40 channels
For the outer cells: 0.57 X = 0.57 (94.7) = 54 channels

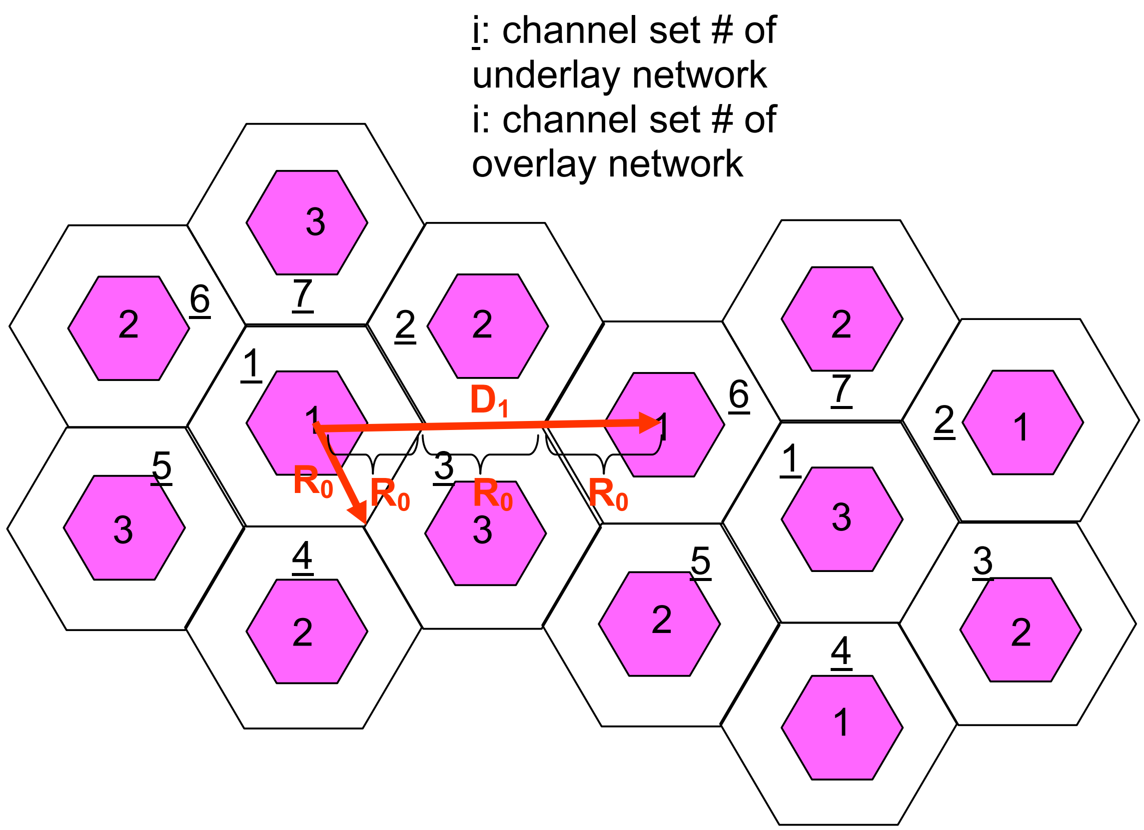


Figure for Q3 – b.1 – underlay-overlay network