A
Aalto University
Comnet

S-72.3216 Radio Communication Systems I (5 cr)

Exam (19th December, 2011)

Exc.	Problem 1	Problem 2	Problem 3	Problem 4	Problem 5	**Sum**
max.	6	6	6	6	6	**30**
pts.						

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Problem 1: *(General concepts concerning OFDMA)*

Answer to the following questions:

(a) Describe briefly the principle of *orthogonal frequency division multiplexing* (OFDM) technique.

(b) Why accurate frequency synchronization is important within OFDMA systems?

(c) Identify and justify at least <u>four</u> advantages of OFDMA systems (over systems that use other multiple-access technologies).

(d) Explain what is the *peak-to-average power ratio* (PAPR) of a time domain signal. Why is the PAPR considered a problem in OFDMA systems?

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Problem 2. *(Multiple access techniques)*

Are the following statements right or wrong? Answer just T/F (i.e., True or False). No justification of the chosen alternative is required.

(a) The reuse distance between cells is the distance between centers of any pair of adjacent cells.

(b) Narrow band systems like FDMA are sensitive to fast fading.

(c) Good time synchronization between uplink users is needed in all CDMA system designs.

(d) Time delay budget can be a difficult design problem in FDMA systems.

(e) Discontinuous transmission and reception (DTX/DRX) is one of the advantages of TDMA systems.

(f) Handover measurements can be implemented more easily in CDMA systems, when compared to TDMA systems.

(g) Orthogonal spreading codes are used to randomize the interference between adjacent cells in CDMA systems.

(h) Accurate power control is important for CDMA uplink due to near-far problem.

Evaluation criterion:

8 correct answers → 6 points, 7 correct answers → 5 points,
6 correct answers → 4 points, 5 correct answers → 3 points,
4 correct answers → 2 points, 3 correct answers → 1 points,
less than 3 correct answers → 0 points.

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Problem 3: *(General formulation for co-channel interference)*

Consider the system presented in Fig. 1, composed by two *base stations* (BSs) and one *mobile station* (MS) that operate in the same frequency band. Assume that both BSs apply sectorization using directional antennas. The main direction of the irradiated power in each BS is denoted in the figure by a (black) solid arrow. Mobile station is connected to only one BS at a time (and receives co-channel interference from the other).

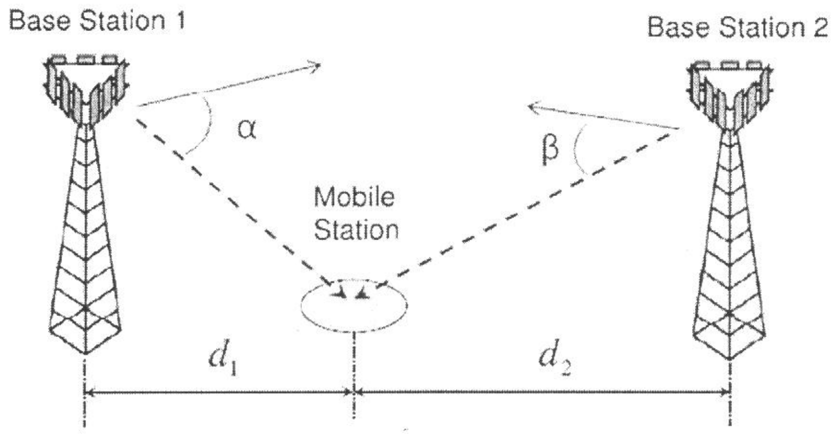

Figure 1: Wireless communication system with two base stations and one mobile station. Base stations apply sectorization, using a directional antennas with pre-defined gain pattern.

(a) Identify all the factors that will determine the *signal-to-interference plus noise* power *ratio* (SINR) that the MS is receiving in this particular case. Give a brief but clear explanation on how these factors affect the quality of the received signal (i.e., no more than 2-3 lines per item).

(b) Give the mathematical formula for the SINR that the MS experiences in reception. Formula should include the impact of (distance dependent) path loss, shadowing, fast fading, and white noise.

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Problem 4: *(Mobility management concepts)*

Answer to the following questions:

(a) What are the *idle mode* and active mode of user terminals? When are they used? Explain the importance of having both modes, when dealing with mobility management issues in a mobile network. How is the *random access procedure* related to *idle mode* and *active mode*?

(b) Describe the different power control types. What are the differences between the different categories that exist? Give some concrete system examples, in which these different power control types are used.

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Problem 5: *(General formulation for co-channel interference)*

Assume that the data rate efficiency (in bits per second per Hertz) in a given wireless communication system can be approximated by the formula

$$R = 0.7 \log_2 (1 + 0.8\,\mathrm{SNR}) \quad [\mathrm{bps/Hz}]. \tag{1}$$

In the latter expression, the *signal-to-noise* power *ratio* (SNR) in decibels is of the form

$$(\mathrm{SNR})_{\mathrm{dB}} = 136 - L_{\mathrm{tot}}, \tag{2}$$

where L_{tot} is the total path loss attenuation factor that includes average (distance dependent) path loss and shadowing.

According to the system definition, it is required that the data rate efficiency is equal to 0.5 [bps/Hz] at the cell edge.

(a) What is the cell range if shadow fading is not considered, and average path loss attenuation (in [dB] scale) is given by

$$L(r) = 133.4 + 35.2 \log_{10}(r) \qquad r > 0, \tag{3}$$

where r is the cell range (i.e., the maximum distance between transmitter and receiver) in kilometers.

(b) Calculate the range of the cell in **(a)** when shadowing is taken into account, with standard deviation $\sigma_s = 6$ [dB]. What is the cell range if it is required that the data rate efficiency of 0.5 [bps/Hz] should be reached at the cell edge with a 90 % probability.

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Appendix Information: *(Formulas and Curves that MAY be required)*

$$f(L_s) = \frac{1}{\sqrt{2\pi}\sigma_s} e^{-\frac{{L_s}^2}{2{\sigma_s}^2}} \tag{4}$$

$$\Pr\{L_s < L_0\} = \int_0^{L_0} f(t)\,dt = 1 - Q\left(\frac{L_0}{\sigma_s}\right) \tag{5}$$

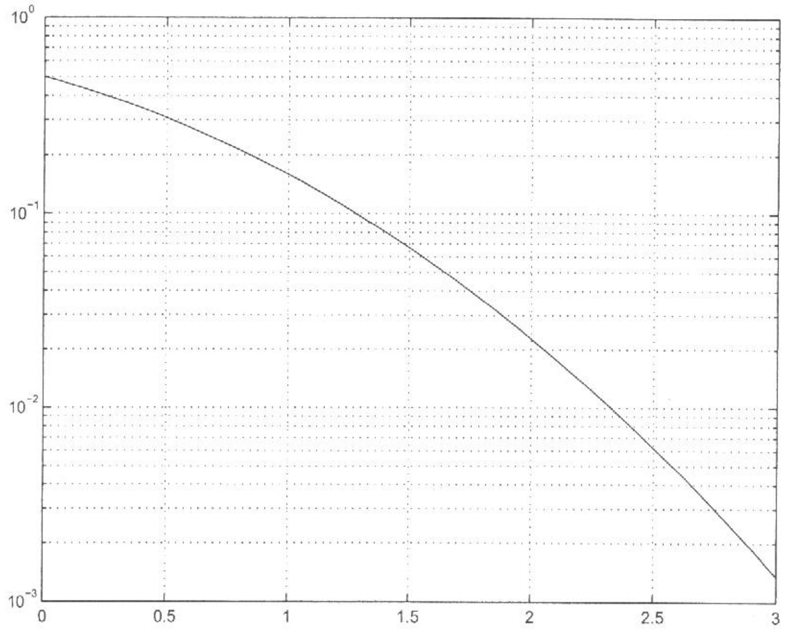

Figure 2: Plot for the Marcum Q-function.

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{+\infty} e^{-\frac{t^2}{2}}\, dt = \frac{1}{2}\,\mathrm{erfc}\left(\frac{x}{\sqrt{2}}\right) \tag{6}$$

$$\left(1 - \frac{1}{z^2}\right) \frac{1}{z\sqrt{2\pi}}\, e^{-\frac{z^2}{2}} \leq Q(z) \leq \frac{1}{z\sqrt{2\pi}}\, e^{-\frac{z^2}{2}} \tag{7}$$

$$\begin{aligned} L_{\mathrm{Hata}}\,[\mathrm{dB}] &= 69,55 + 26,16 \log_{10}(f\,[\mathrm{MHz}]) - 13,82 \log_{10}(h_b\,[\mathrm{mt}]) \\ &- a_i(h_m\,[\mathrm{mt}]) + [44,9 - 6,55 \log_{10}(h_b\,[\mathrm{mt}])] \log_{10}(r\,[\mathrm{km}]), \end{aligned} \tag{8}$$

Large sized city (i.e., $i = 1$):

$$a_1(h_m) = 3,2\,[\log_{10}(11,75\,h_m)]^2 - 5,0 \qquad 200\,\mathrm{MHz} \leq f \leq 1500\,\mathrm{MHz} \tag{9}$$

Medium/small city (i.e., $i = 2$):

$$a_2(h_m) = 0,8 + [1,1\,\log_{10}(f) - 0,7]\; h_m - 1,56 \log_{10}(f) \tag{10}$$

Suburban area (i.e., $i = 3$):

$$a_3(h_m) = a2(h_m) + 2\left[\log_{10}\left(\frac{f}{28}\right)\right]^2 + 5,4 \tag{11}$$

Rural/open area (i.e., $i = 4$):

$$a_4(h_m) = a2(h_m) + 4,78\,[\log_{10}(f)]^2 - 18,3 \log_{10}(f) + 40,9 \tag{12}$$