S-72.610 Home exercises 2004

Return your solutions before the first exam after the course (17.12.2004)

Home task 1.

In a homogenous hexagonal cell structure the preferred reuse factors are $M = i^2 + i \cdot j + j^2, i, j$ are positive integers, and for these M-values the normalised reuse distance is $D/R = \sqrt{3M}$. D is the distance between base stations and R is the cell radius. For other M-values the reuse distance will not be larger than that of the next smallest of the above values. A service area, that can be exactly covered by 756 equally sized and equally equipped cells, is considered.

a) Determine the preferred M-values for M<50.

b) Determine the reuse factor, when the path loss exponent of the single slope average path loss model is i) 2, ii) 3, iii) 4, and iv) 5, and the worst case average carrier to average interference power ratio is 10. The worst case is defined by the distance R to the host base station, and distance $D - R$ to the 6 nearest interfering base stations. Possible service area border effects are not considered.

c) Determine for the four cases of path loss exponent the network capacity, when this is defined as the possible number of simultaneous on-going calls in the service area.

Home task 2.

In a cell the average radio path loss (dB) as function of the distance r *is* $L = L_o + 10n \cdot \log r_{km}$, where L_o is the loss at 1 km distance, n is the path loss exponent, and the standard deviation of the slow log-normal fading is σ = 6 dB. The cell is first dimensioned for 50% coverage probability at the cell border. How many percent is the new coverage area of the original area, if the coverage probability target at the cell border is first increased from 50% to 90%, and then further to 99%, when n gets the values 2, 3, 4, and 5? Fast fading is not considered. Give the results as a table.
(Q(0) = 0.5 and Q(1.28) = 0.1 ja Q(2.33) = 0.01)

Home task 3.

We consider a narrow-band mobile communication system, where the receiver uses M independent and identically distributed diversity branches.

Based on the cumulative fade distributions, determine the diversity improvement for 20 dB fades, and the diversity gain defined as the fade depth (dB) relative to average level that will be exceeded for 1% of the time. Two cases are investigated: i) 2-branch diversity, and ii) 4-branch diversity, both with selection combining.

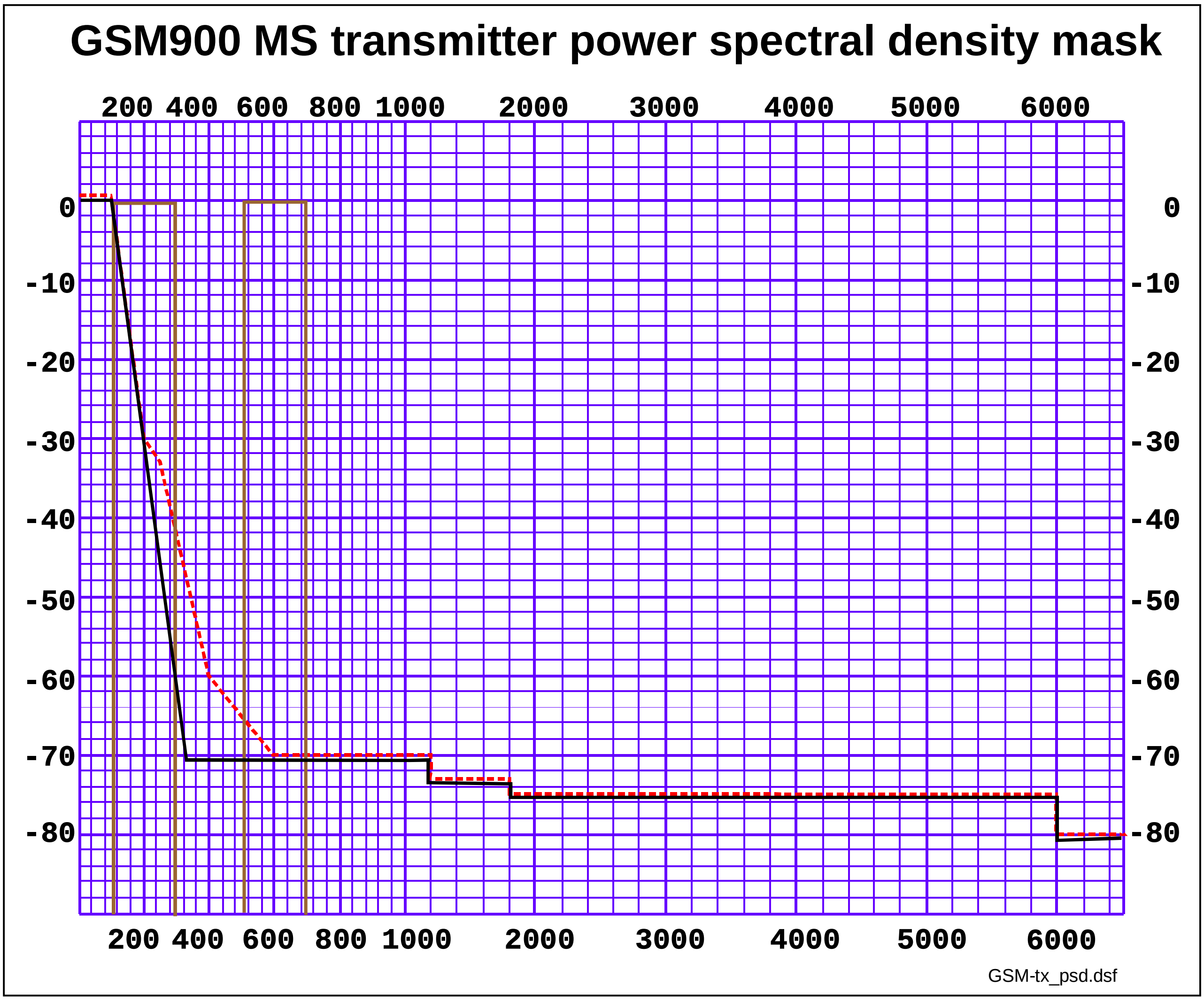
Home task 4.

Compare selection combining and maximum ratio combining of two identically and independently Rayleigh distributed diversity branches in terms of diversity gain at the average bit error probability (BEP) levels 10^{-2} and 10^{-4} when the modulation method is differential BPSK, instantaneous BEP: $P_b(\gamma) = 0.5\exp(-\gamma)$.

Home task 5.

In the highest power classes the GSM900 BTS power spectrum must be below a spectrum mask shown with a dashed line in the figure. The implemented power spectrum is shown with a solid line, whose right part above the carrier is defined by the corner points: (100 kHz, +0.5 dBc), (330 kHz, -70 dBc), (330 – 1200 kHz, -70 dBc), (1200 – 1800 kHz, -73 dBc), (1800 – 6000 kHz, -75 dBc), (>6000 kHz, -80 dBc).

a) Give the piecewise expression of the absolute valued spectral power density defined above and in the figure in logarithmic units.
b) In the mobile phone an ideal bandpass filter with 250 kHz bandwidth is assumed to be used. In the figure this filter is shown shifted to the 1st and 3rd adjacent channels. Under the assumption that BTS transmits the same power on all carriers calculate the signal to interference ratio (dB) on the three first adjacent carriers in the filter output. The absolute-valued signal and interference powers are defined as the integral $P_o = \int_{-\infty}^{\infty} \left|H_{rx}(f)\right|^2 S_{tx,i}(f - n\Delta f_c)\,df$, where i stands for either signal or interference, n is the order of the adjacent channels (n = 0 for the signal channel), and Δf_c is the carrier spacing.



Home task 6.

Power control is introduced in the down-link to reduce the average transmit power level in the cell.

a) Give the expression of the BS transmit power as a function of MS - BS distance r > rmin, when the power used when MS is at the cell border (distance R) is Pmax,

b) The least transmit power level is Pmin. At which distance this is achieved?

c) Give the integral expression of the BS transmit power averaged over all possible MS positions in the cell, amd

d) How many dB would power control reduce the total transmit power in a cell?

Following conditions are fulfilled:

- ideal power control compensating exactly distance depending path loss is used,
- the cell is dimensioned for 50 % coverage probability at cell border,

- the users are uniformly distributed in the cell,
- the power control range is i) 10 dB, ii) 20 dB, iii) 30 dB, iv) 40 dB
- the average path loss model is single-slope with the following path loss exponents: 2; 2.5;3; 3.5; 4; 4.5; and 5.

Home task 7.

The user rate and EGPRS900-BTS receiver sensitivity requirements for different modulation and coding classes in different propagation environments are given in the table below.

Coding class	User net rate kbit/s	BTS-receiver sensitivity/dBm				
		static	TU50	TU50FH	RA250	HT100
MCS1	8.8	–104	–102.5	–103	–103	–102
MCS2	11.2	–104	–100.5	–101	–100.5	–100
MCS3	14.8	–104	–96.5	–96.5	–92.5	–95.5
MCS4	17.6	–101.5	–91	–91	–	–
MCS5	22.4	–101	–96.5	–97	–96	–95
MCS6	29.6	–99.5	–94	–94.5	–91	–91
MCS7	44.8	–96	–89	–88.5	–87	–86
MCS8	54.2	–93	–84	–84	–	–81.5
MCS9	59.2	–91.5	–80	–80	–	–

a) Calculate for the up-link the distances from the BTS where switching from one MCS state to another takes place. Calvulate then the average bearer rate when the user is moving along a cell diameter in TU50 propagation environments, when cell size is dimensioned based on –104 dBm sensitivity, and the path loss exponent is 3.5. .

b) Calculate under the same conditions the average bit rate, if the cell is dimensioned based on the sensitivity value – 90 dBm

Hints: The change in sensitivity will change the effective coverage area of each MCS-state. Use the radio link budget to calculate the coverage area radius of each MCS-state, and then the distance along the diameter where each MCS-state will be used to give the highest rate. In the calculation of the average it can be assumed that the time to change MCS can be neglected.

Home task 8.

a) How long time will the transmitted and received symbols overlap in the 3+1 multi-slot EDGE mobile station, when it transmits and receives normal bursts with maximum timing advance?

b) Determine the theoretical degradation of receiver sensitivity at symbol error probability 0.01 of the uncoded symbols in i) the static AWGN-channel, and ii) the single-tap Rayleigh-fading channel, when link adaptation switches from MCS1 to MCS5?

Home task 9.

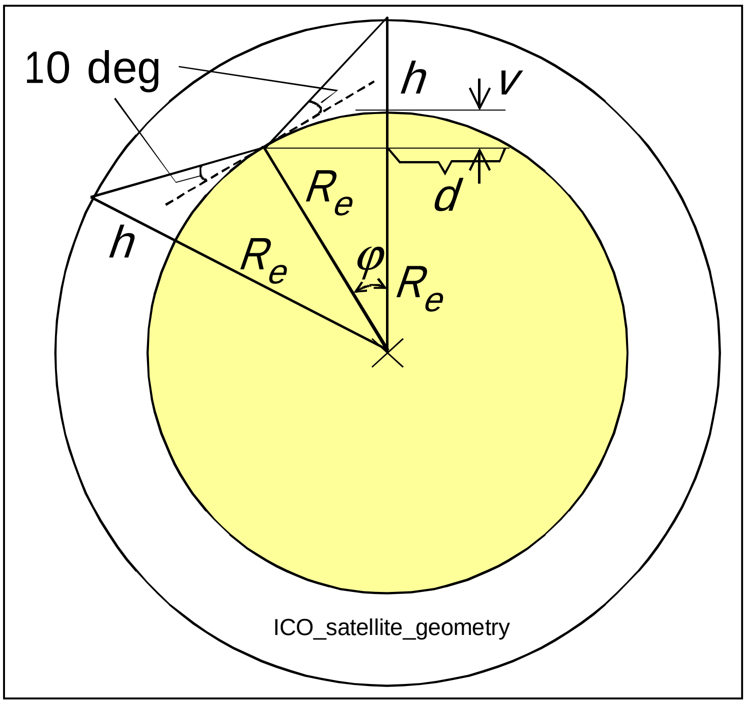
The maximum processing gain in the WCDMA-system is 512.

a) How many simultaneous users with the activity factor 0.4 can coexist in theory (pole capacity) in a single-cell network, if a sufficient performance requires a signal to interference ratio of 3 dB. The up-link is investigated and all users are received with the same power at the base station (ideal power control).

b) The power control is malfunctioning for one user, which is transmitting with constant power corresponding to that required at the cell border. How near to the base station (measured in cell radius) this user can come without reducing the total number more than half of the number in sub-task b? The path loss exponent is 3.5, and slow and fast fading are not considered.

Home task 10.

A mobile satellite system uses satellites in circular orbits at 1500 km altitude.



a) How large is the coverage area of a satellite, if this is defined as the area from which the satellite elevation (angle above the tangential plane in the observation point) is more than 10 degrees at a given time instant?

b) During how long time will the satellite be observed with more than 10 degree elevation, if it passes through zenith in the observation point?

Area of a spherical segment $A = 2\pi R_e v$

Full orbit time: $T = \frac{2\pi}{\sqrt{\mu}} r^{1.5}$, $\mu = 3.986 \cdot 10^{14}\ \mathrm{m^3/s^2}$