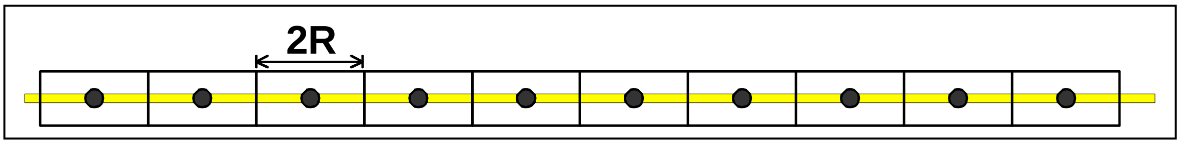
S-72.2211 Home exercises 2008

Deadline for submission of solutions 7.3.2008

Home work 1.

How much will the coverage area increase if a gain term in the radio link budget is improved with 3 dB, and the path loss exponent of the single slope average loss model is i) 3.0, ii) 4.0, and iii) 5.0?

Home work 2.



Consider a 1-dimensional cellular network along a straight highway, as in the figure above. A GPRS system is deployed along the highway. CS1 and CS4 are different coding schemes of GPRS. The CIR-target of GPRS CS1 is 9.5 dB, whereas the CIR-target of GPRS CS4 is 22dB. In CS4 no channel coding is used which is the reason why the CIR target level is higher.

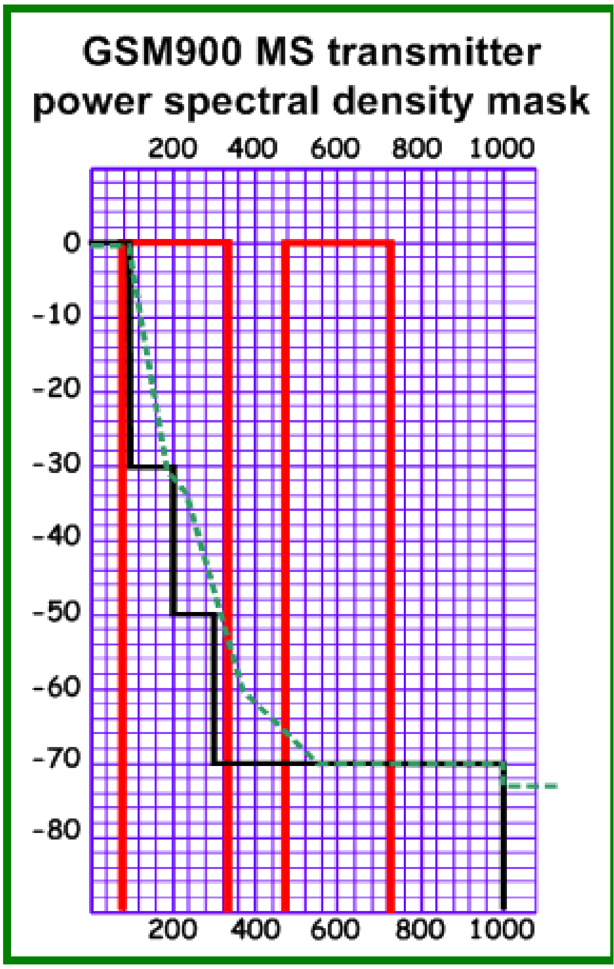
The reuse distance is chosen so that the CIR target of CS1 is reached at the cell border, when a single interferer is considered. The path loss exponent of the average radio path loss is 3.2. All base stations are identical.

a) Determine the minimum normalised reuse distance D/R based on the strongest interferer, i.e. the interferer closest to the cell border under investigation. Use the **target** CIR value to get the minimum distance. Select the reuse factor k. Then calculate the **achieved** CIR based on the strongest interferer. Calculate the achieved CIR-value (dB), when also the interferer in the opposite direction is considered.

b) Check at what distance from the base station GPRS CS4 can be used, when the two strongest interferers are considered.

Home work 3.

In the highest power classes the GSM900 BTS power spectrum must be below a spectrum mask shown with a dashed line in the figure at right. The implemented power spectrum **(right part only)** is shown with a solid line and is defined as:



$$S_{tx}(f)=\begin{cases} +0.0 \text{ dBc}, & 0 \le f \le 100 \text{ kHz} \\ -30.0 \text{ dBc}, & 100 \le f \le 200 \text{ kHz} \\ -50.0 \text{ dBc}, & 200 \le f \le 300 \text{ kHz}, \\ -70.0 \text{ dBc}, & 300 \le f \le 100 \text{ kHz} \\ -\infty \text{ dBc}, & 1000 \le f \le \infty \text{ kHz} \end{cases}$$

In the mobile phone an ideal band-pass 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.

a) Give the piecewise expression of the *absolute valued* spectral power density defined above and in the figure in logarithmic units.

b) Assuming that the BTS transmits the same power and uses the same spectrum mask on all carriers, calculate the signal to interference ratio (dB) caused by the three first adjacent carriers in the filter output. The absolute-valued signal and interference powers are defined as the integral

$P_o = \int_{-\infty}^{\infty} |H_{rx}(f)|^2 S_{tx}(f - n\Delta f_c)df$, where n is the order of the adjacent channels (n = 0 for the channel of the desired signal), and Δf_c is the carrier spacing. $H_{rx}(f)$ is the receive filter which takes the value 1 inside the 250KHz band and is zero elsewhere. Thus for example the interference power from the n'th adjacent channel is $P_{I,n} = \int_{-125kHz}^{125kHz} S_{tx}(f - n\Delta f)df$. The SIR when considering the interference from the n'th adjacent channel is $SIR = 10\log\left(P_S / P_{I,n}\right)$

c) Calculate the overall SIR, where the interference from the adjacent channels with n=-3,-2,-1,1,2,3 is taken into account.

Home work 4.

The user rate and EGPRS900-BTS receiver sensitivity requirements for different modulation and coding schemes (MCS) in different propagation environments are given in the table below. Note that here the effects of the environment (multipath propagation, MS speed) are taken into account directly in the sensitivity, not as margins in the link budget. Consequently there are different sensitivities in different multipath & velocity environments. There is also a different sensitivity when frequency hopping (FH) is used in TU50.

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	–	–

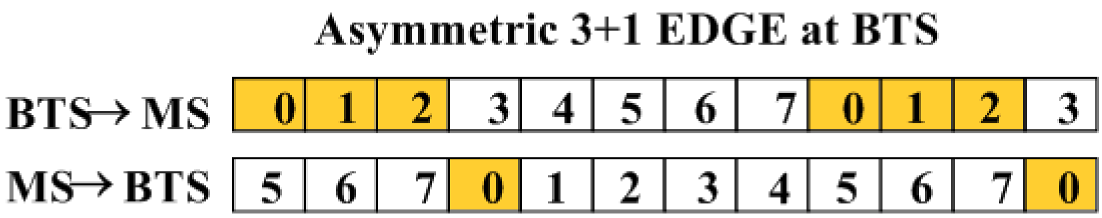
a) Calculate for the up-link the distances from the BTS (relative to the cell radius) where switching from one MCS state to another takes place in the TU50 propagation environment. Dimension the cell so that -104dBm sensitivity is sufficient at the cell edge. Calculate the average bit rate when the user is moving with constant speed along a cell radius from the cell center to the cell edge. Assume a single slope path loss model with path loss exponent 3.5.

b) Calculate 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. 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 work 5.

A mobile station receives three DL slots and one UL slot in an EDGE cell. The timing of the slots at the base station is depicted in the figure below. 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?



Home work 6.

Determine the theoretical degradation of receiver sensitivity when link adaptation switches from EDGE MCS1 to MCS5 at uncoded bit error probability 0.01 in

i) the static AWGN-channel, and

ii) the single-tap Rayleigh-fading channel.

In MCS1 the modulation is GMSK (1 bit per symbol) and in MSC5 it is 8PSK (3 bits per symbol).

Hint: The bit-error probabilities in AWGN are

$P_{b,GMSK} = Q\left(\sqrt{1.78E_b/N_o}\right)$ and $P_{b,8PSK} \approx \frac{2}{3}Q\left(\sqrt{6\cdot\sin^2(\pi/8)E_b/N_o}\right)$, where

the energy per bit is the ratio of the received power and the bit rate, $E_b = P_{rx}/R_b$. Note that the bit rate for GMSK and 8PSK are different. Average error performance in a Rayleigh fading channel is given by the expression

$$P_b = \int_0^\infty p(\gamma)P_b(\gamma)d\gamma = \int_0^\infty \exp(-\gamma/\overline{\gamma})/\overline{\gamma} \quad P_b(\gamma)d\gamma$$

where $\gamma = E_s/N_0$ is the signal-to-noise power ratio (note that the symbol energy is used here), and $\overline{\gamma}$ is the average SNR. You may use the values of the inverse Q-function InvQ(0,01) =2.23 and InvQ(0.015) = 2.17, and the expression for the intergral:

$$\int_0^{\infty} \frac{\exp(-\gamma / \overline{\gamma})}{\overline{\gamma}} Q\left(\sqrt{k\gamma}\right) = \frac{1}{2}\left[1 - \sqrt{\frac{k\overline{\gamma}}{2 + k\overline{\gamma}}}\right]$$

Home work 7.

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

a) How many simultaneous uplink 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. All users are received with the same power at the base station (ideal power control).

b) 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 work 8.

With down-link power control perfectly compensating average path loss, the transmit power is $P_{tx} = \max\left(P_{\min,} P_{\max}\left(r/R\right)^n\right)$ when the mobile station is at distance *r* in a cell with radius *R*, and the path loss exponent is n=3.5. P_{min} is the minimum transmit power which is used when the MS is close to the BS. P_{max} is the maximum transmit power used in the cell. The dynamic range of power control is P_{max}/P_{min}, usually expressed in the decibel domain. The mean transmit power averaged over the spatial distribution of mobile stations is

$$P_{txm} = \int_0^R \int_0^{2\pi} p\left(r,\varphi\right) P_{tx}(r) d\varphi dr \,.$$

If the mobiles are uniformly distributed over the cell the probability density function of the user positions is

$$p_u(r,\varphi) = \frac{2r}{R^2} \cdot \frac{1}{2\pi}, \; r \in \left[0, R\right], \; \varphi \in \left[0, 2\pi\right].$$

Consider a user distribution where the density of users is higher near to the base station, having the p.d.f.

$$p_C(r,\varphi) = \frac{2}{R}\left(1 - \frac{r}{R}\right)\frac{1}{2\pi}.$$

Calculate the reduction in the mean base station transmission power when the users are distributed according to center peaked distribution p_c compared to the case with the uniform user distribution p_u. The power control dynamic range is i) 10 dB, ii) 20 dB, iii) 30 dB, iv) 40 dB.