ABS Seminar no.6

<u>BER analysis and outage analysis</u>

T.1

We assume a mobile channel with NLOS conditions, which we can model by Rayleigh distribution: the density of the probability distribution that the envelope of the received signal will have an amplitude r :

$$p(r) = \frac{r}{\sigma^2}\exp\left(-\frac{r^2}{2\sigma^2}\right)$$, where: σ^2 is dispersion (performance of AC components)

Cumulative distribution function: represents the probability that the envelope of the received signal will reach a value at most equal to R:

$$P_r(r \le R) = 1 - \exp\left[-\frac{R^2}{2\sigma^2}\right]$$

a)
We assume that the average value of the received signal power is -75 dBm. What is the probability of outages (probability that the power of the received signal will be lower than the given threshold value) if the threshold value is:

1. $P_{th} = -95\ dBm$
2. $P_{th} = -92\ dBm$

The probability that the power will be less than a given threshold is given by the CDF value:

$$P_r(\overline{P} < P_{th}) = 1 - \exp\left[-\frac{P_{th}}{\overline{P}}\right]$$

b)
We assume that the application requires a minimum received power threshold of -85 dBm for a 5% probability of outages. Calculate the required average received power value for this application.

T.2
BER analysis

a) We consider a channel with Rayleigh fading - (the received SNR follows the exponential distribution) and a system with uses binary modulation. In the case of binary modulation, the probability of error per bit is given by:

$$P_b = \frac{1}{2}\left(1 - \sqrt{\frac{SNR}{1+SNR}}\right) \quad (1)$$

This relationship can be approximated for high SNR values as: $P_b \approx \frac{1}{4\,SNR}$ (2)

Show how to obtain an approximated relation (2) from an exact relation (1). Hint: use Taylor's expansion for: $\frac{1}{\sqrt{1+x}}$ and use only first two members.

b) By using inequality: $\left(1-\frac{1}{z^2}\right)\frac{1}{z\sqrt{2\pi}}e^{-\frac{z^2}{2}} \le Q(z) \le \frac{1}{z\sqrt{2\pi}}e^{-\frac{z^2}{2}}$ (1) find a suitable approximation for calculating the probability of error per bit in the AWGN channel if the SNR value is large (case of binary modulation).
Hint:
Use limit of (1) for: $z \to \infty$ then both boundaries asymptotically converge and $Q(z)$ can be approximated.

For binary modulation holds:
$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q\left(\sqrt{2SNR}\right)$ (2) if $R_b = W$
Apply an approximate solution of $Q(z)$ in (2)

c) Find the SNR values that are needed to reach the value: $P_b \le 10^{-4}$ in case:
1. AWGN channel
2. Ralyleigh channel

We assume BPSK modulation. Express the results in dB. Use the formulas derived in a) and b).

T.3

LTE throughput can be approximated by the relationship:

$$R = N_{RB} \times W_{RB} \times \gamma \times \log_2\left(1 + B \times SNR\right) \qquad (1)$$

, where:

N_{RB} - is the number of RB
$W_{RB} = 180\,kHz$ - is RB bandwidth
$\gamma = 0{,}88$ - is a parameter taking into account the bandwidth efficiency in LTE
$B = \frac{1}{1{,}25}$ - is a parameter taking into account the efficiency of SNR usage in LTE

a)
We assume that the received SNR inside the cell is 10 dB. How many RBs do we need to achieve a transmission rate of 2Mb/s for a given user?

b)
We need to ensure a transfer rate of at least 700 kbps for each of the 20 users. For LTE band 20MHz there are 96 RB available for users. What must be the minimum SNR in [dB] for the users to achieve the given bit rate?