Radio Engineering Exam

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1. Consider a LTE system on the downlink with the following parameters:

   - eNB Tx power: 23 dBm
   - eNB cable losses: 6dB
   - eNB antenna gain: 6dB
   - UE RX noise figure: 7dB
   - bandwidth: 20MHz
   - carrier frequency: 2.6GHz

   Model the path loss using the two-path model with a eNB (TX) height of 10m and UE (RX) height of 1.5m. Further add a fading margin of 10dB.

   LTE allows to adjust the throughput as a function of the SNR using adaptive coding and modulation. The minimum modulation and coding scheme (MCS) requires an SNR of 0dB and results in a throughput of approximately 2.5Mbps, while the highest MCS requires 28dB of SNR and results in a throughput of 75Mbps[1].

   (a) Compute the range of the cell for the highest and the lowest MCS. 2Pts

   (b) How can the rate at the cell edge be increased? 1Pt

2. The small scale fading is assumed to follow a Rayleigh fading distribution. Compute the available fading margin for an outage probability of 10% for one and for two antennas (using RSSI selection diversity). 2Pts

3. Assume that a system needs a $C/I = 0$dB to work at an acceptable quality. Further assume that the path loss decays with a path loss exponent $\eta = 4$ and the system requires a fading margin of 10 dB.

   (a) Compute the necessary reuse factor and the minimum cluster size. 1Pt

   (b) How do you achieve a reuse factor of 1? Give an example parameter set that would achieve this result. 1Pt

[1] in a 20MHz FDD configuration

4. Assume an isotropic Rayleigh fading environment.

   (a) Write down the formula describing the correlation coefficient of the amplitude between two antennas as a function of their distance d. 1Pt

   (b) How far do two antennas need to be apart (in terms of wavelength) such that their signals are practically uncorrelated (correlation coefficient is smaller that 0.5). 1Pt

   (c) If the fading is no longer isotropic, i.e., the angular spread of the incoming signals is much smaller than 2π, does the correlation increase or decrease (at the same distance)? 1Pt

5. (a) What is a geometry based stochastic channel model? Give an example. 2Pts

   (b) Describe the Kronecker MIMO model (model category, formula + description, pros + cons). 2Pts

   (c) What is the coherence bandwidth and the rms delay spread of a channel? What is their relationship? 1Pt

   (d) What is the definition of wideband and narrowband channels? What effect can be observed in wideband channels? Give an example for a wideband channel model. 1Pt

   (e) Some modern LTE networks employ a frequency reuse of one. This is possible because[2] 1Pt

      i. LTE creates less interference,
      ii. LTE works at 0dB SINR,
      iii. LTE makes use of intercell interference coordination,
      iv. LTE uses multiple antennas.

   (f) Some other LTE parameters still need careful planning. Which ones? 1Pt

   (g) What is the definition of the diversity exponent? What is the diversity exponent in a 2x2 MIMO system that employs (a) Alamouti coding and (b) spatial multiplexing. 1Pt

   (h) How can diversity be exploited using multiple antennas? 1Pt

Total: 20Pts

Good luck!

[2] This is a multiple choice question, please choose the correct one.