Department of Electrical Engineering, IIT Madras
EE5141 : Fundamentals of Wireless and Cellular Communications

1. [3+3+3=9 marks] Time-selective Fading: A vehicle is moving with velocity v m/s where the wireless link uses a carrier-frequency of f_c=2GHz and a pass-band message bandwidth of 2W=100KHz. Simulate and plot 5 independent runs of the fading channel (sampled every T_s=1/2W=10μsecs), where each run is over N=8000 samples, using each of the 3 following fading models:
(a) Smith's model (using FFTs) – see Rappaport's book; use N=8192 here.
(b) Sum of sinusoids model – see presentation from TAs
(c) Modified sum of sinusoids model – see presentation from TAs
Repeat the above for 2 choices of velocity, namely (i) v=1m/s; (ii) v=10m/s. Interpret your answer(s) briefly. How does the model in (c) differ from (b) in cross-correlation performance (i.e., over the 5 different runs, what is the mutual correlation?).

2. [2+2=4 marks] Frequency-selective Fading: Consider a wide-band signal with pass-band bandwidth 2W=10MHz, which is transmitted over two multi-path models, defined by their power delay profiles (PDP) as follows:

*Channel Model #**1***

Path Gain σ_i^2(in dB)	0	-3	-8	-15
Path Delay τ_i (in μsecs)	0	0.5	1.7	2.2

*Channel Model #**2***

Path Gain σ_i^2(in dB)	-2	0	-1	-6	-9	-14
Path Delay τ_i (in μsecs)	0	1.8	3.5	5.7	8.1	12.3

Hint: To normalize average channel gain to unity, in each of these models, rescale the (linear value of) the path variance σ_i^2 to ensure that over the L paths, $\sum_{i=0}^{L-1} \sigma_i^2 = 1$.
Each zero-mean path gain a_i, where $E[|a_i|^2]= \sigma_i^2$, is a complex Gaussian random variable with each dimension having a variance of σ_i^2 /2. The impulse-response snap-shot h[n] corresponding to a given PDP is obtained by calling a circular Gaussian rv L times, and scaling the gain based on the power profile. The frequency response snap-shot H[k] is obtained by zero-padding plus FFT (of typically large size to visualize shape easily). For each of the above PDPs, take a 2048 point FFT of the instantaneous h[n] (by appropriate zero-padding) to get H[k]. Plot in dB scale the squared gain, i.e., $10\log_{10}(|H(k)|^2)$, to interpret the coherence band-width of models #1 and #2 and comment. Repeat for each model over 3 different (independent) channel realisations, and plot in the same figure.

3. [6 marks] Now, for 100Hz Doppler, use PDP #2 in Pbm. 2, to generate frequency+time varying fading plots (use 3-D plotting feature in Matlab). Plot the time-varying frequency response, obtained every 5msec, over a duration of 30msecs (i.e., plot 7 consecutive snapshots, obtained at 0msec, 5msec, 10msec,….., up to 30msec).

NOTE: For all the following problems, please read the document from CEWiT titled "BWSIM for Academic Purposes" for more details. Specifically, we will use the parameters described in Table1 extensively. Use only 7 cell (21 sector model with wrap-around). The sub-questions colored in "blue" are perhaps a bit tougher.

4. [2 marks] Consider the 3 different terrains (UMa, UMi, RMa) used in 3GPP-LTE evaluation. For all other parameters as in Table-1, and for the following 2 choices of carrier frequency, generate and plot the SINR cdf and comment. (4a) f_c=800 MHz (b) f_c=2100 MHz

5. [5 marks] For the Urban Macro (UMa) model, we would like to study the impact of changing the Inter Site Distance (ISD) as well as the Antenna tilt. Generate and plot the SINR cdfs for the following cases:
(2a) ISD=300m and tilt varying from 0° to 20° in steps of 5° (all plots on the same graph)
(2b) ISD=800m and tilt varying from 0° to 20° in steps of 5° (all plots on the same graph)
(2c) For ISD=150m and 0° tilt, plot the SINR distribution (scatter-plot) over the $7x3 = 21$ sectors where the SINR is color coded
(2d) For ISD=150m, what choice of tilt (to the nearest degree) will give the "best" SINR distribution? Plot the scatter-plot for this best choice. *Hint*: You may also use the SINR cdf plot to ascertain this.

6. [3 marks] Given a tilt of 12° and with ISD=400m in the UMa model, plot on the same graph both the SINR cdf and the SIR cdf and compare the two for each of the following cases of transmit power P_T:
(5a) $P_T = 40$dBm (5c) $P_T = 45$dBm (5c) $P_T = 50$dBm
Comment on your observation

7. [2 marks] Now we want to plot the SINR cdfs for scenarios where the number of indoor user nodes is changed from 10% to 50% and then to 90%. Assume UMi model and with other parameters as in Table-1. With 90% indoor nodes, what happens when the tilt is changed from 0° to 12° and then to 20°? Comment

8. [2 marks] For the UMi model, generate and plot the path-loss versus distance graph. Compute path-loss assuming that all user nodes are: (8a) Indoor (8b) Outdoor (which is predominantly non-LoS)

9. [3 marks] Consider now the generation of link-level uncoded bit-error rate (BER). Assuming UMa model, generate BER versus SNR plots for QPSK, 16-QAM, and 64-QAM modulation in AWGN channels. Compare these simulation results with the theoretical values (using Q(.) or erfc(.) functions that you would have studied in the digital communications course).

10. [4 marks] We will now study the relative interference levels in a homogeneous network (i.e., only macro nodes and no pico nodes). Assuming UMa model, and with other parameters as in Table-1, plot the cdf for the following signal to interference (S/I) cases:
(a) S/I overall (b) S/I of 1st interferer (c) S/I of 2nd interferer, and (d) S/I of all the weak interferers put together.
(10e) Club all the interferers starting from the 3rd significant interferer to the weak interference, and plot their cdf.

11. [4 marks] Consider now the Het-Net scenario where we want to study the impact of Pico locations and the number of Picos. Use page-28 in the BWSim Tech. Guide, (section 3.6.1), and follow the settings given there both for random pico locations and planned pico locations. Plot both the scatter plot and the cdf for the above cases. Comment on your answer.

12. [6 marks] The aim is to study the effect of pico-power level and the pico-bias (for range extension). Assume 6 picos per sector (randomly distributed). Generate the SINR cdf for the following cases:
(a) Pico-bias = 0dB, and pico-power varied over 20dBm, 30dBm, and 35dBm (in same plot).
(b) Pico-bias = 12dB, and pico-power varied over 20dBm, 30dBm, and 35dBm (in same plot).
(c) Pico power = 35dBm, and pico-bias varied over 0dB, 3dB, 6dB, 10dB, and 18dB (all in same plot).
(d) Which combination of pico-power and pico-bias will give the highest throughput with 6 picos per sector? Defend your result using cdf plots.