S72.3210 Channel Modeling for Radio Communication Systems

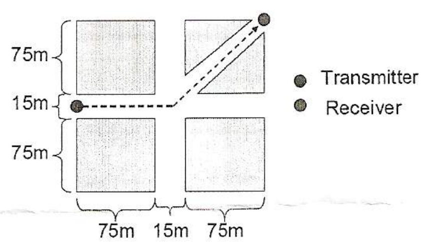
Examination 15.12.2008

Problem 1.

a) Give single slope and dual slope models for average path loss, and name and briefly explain the parameters. What is the path loss exponent in free space propagation?

b) Explain 'reflection from flat ground'-phenomenon. Where does it take place? Why does it impact on the received signal strength and what is the impact? Draw a figure and explain the parameters that impact on the phenomenon.

Problem 2. Use 3GPP microcell model (Berg model) to compute the path loss from the transmitter (blue circle) to the receiver (red circle). Transmitter antenna height is 5 m and receiver antenna height is 1.5 m, carrier frequency is 2 GHz, visibility factor is 0.002 and effective road height is 1m.



Problem 3. Deduce the formula for total path loss on cell edge in terms of average path loss $L_{\max}$, outage probability P_{out} and shadow fading standard deviation σ_s. According to system link budget allowed average path loss is 141.9dB. Using average path loss model

$$L(r) = 137.4 + 35.2\log_{10}(r)$$

compute the number of sites per km^2 when shadow fading standard deviation is 8dB, and 10% and 1% outage probability on cell edge is allowed.

Problem 4. Define (verbally) level crossing rate and average fade duration. Assume a system where channel coding provides best performance if instantaneous signal power crosses (to the positive direction) at least once (in average) the mean power level during an interleaving period of 10 milliseconds. What is the minimum receiver speed that is required for this crossing rate? What is the corresponding average fade duration? Carrier frequency is 2GHz.

Problem 5. Give a definition for average delay and rms delay spread for continuous Power Delay Profile (PDP) of a signal. Define PDP in case of two clusters with delays $\tau_{c,1}$, $\tau_{c,2}$ and powers $P_{c,1}$, $P_{c,2}$ (1p). After averaging over instantaneous values of channel realizations it was found that power angle-delay spectrum is of the form

$$P(\tau,\theta) = \frac{C_0 \cdot e^{-(1+|\theta|)\tau/\sigma}}{1+|\theta|}, \quad -\pi < \theta < \pi, \ \tau > 0,$$

where C_0 and σ are constant parameters. Compute Power Azimuth Spectrum (PAS).

$$L_{\text{Hata}} = 69.55+26.16\log_{10}(f)-13.82\log_{10}(h_{\text{BS}})$$
$$-a_i(h_{\text{MS}})+(44.9-6.55\log_{10}(h_{\text{BS}}))\log_{10}(r),$$

$$a_1(h_{\text{MS}}) = \begin{cases} 8.3(\log_{10}(1.54h_{\text{MS}}))^2-1.1, & 150MHz < f < 200MHz, \\ 3.2(\log_{10}(11.75h_{\text{MS}}))^2-5.0, & 200MHz < f < 1500MHz. \end{cases}$$

$$a_2(h_{\text{MS}}) = 0.8 + (1.1\log_{10}(f)-0.7)\,h_{\text{MS}} - 1.56\log_{10}(f).$$

$$a_3(h_{\text{MS}}) = a_2(h_{\text{MS}}) + 2\left(\log_{10}\left(\frac{f}{28}\right)\right)^2 + 5.4.$$

$$a_4(h_{\text{MS}}) = a_2(h_{\text{MS}}) + 4.78(\log_{10}(f))^2 - 18.3\log_{10}(f) + 40.9.$$

$$L_{\text{Hata},1} = 46.3+33.9\log_{10}(f)-13.82\log_{10}(h_{\text{BS}})$$
$$-a_i(h_{\text{MS}})+(44.9-6.55\log_{10}(h_{\text{BS}}))\log_{10}(r)+C_m,$$

$$C_m = \begin{cases} 3dB, & \text{metropolitan centres} \\ 0dB, & \text{elsewhere} \end{cases}$$

$$L_{\text{Hata},2} = 69.55+26.16\log_{10}(f)-13.82\log_{10}(h_{\text{BS}})$$
$$-a_i(h_{\text{MS}})+(44.9-6.55\log_{10}(h_{\text{BS}}))(\log_{10}(r))^\beta,$$

$$\beta = \begin{cases} 1, & r \le 20km \\ 1+(0.14+1.87\cdot 10^{-4}f+0.00107h_{\text{BS}})\left(\log_{10}\left(\frac{r}{20}\right)\right)^{0.8}, & 20km < r \le 100km \end{cases}$$

$$L_{micro} = \max\{L_{overroof}, L_{street}\},$$

$$L_{overroof} = 24 + 45\log_{10}(r_{\text{Euclidean}}).$$

$$L_{street} = 20\log_{10}\left(\frac{4\pi d_n}{\lambda}D(r)e^{sr}\right), \quad r = \sum_{j=1}^{n} r_{j-1}$$

$$D(r) = \begin{cases} 1, & \text{if } r \le r_{rb}, \\ \frac{r}{r_{bp}}, & \text{if } r > r_{bp}, \end{cases}$$

$$r_{bp} = \begin{cases} r_0 & \text{if } r_0 \le \frac{4(h_{\text{BS}}-h_0)(h_{\text{MS}}-h_0)}{\lambda} \\ \frac{4(h_{\text{BS}}-h_0)(h_{\text{MS}}-h_0)}{\lambda}, & \text{if } r_0 > \frac{4(h_{\text{BS}}-h_0)(h_{\text{MS}}-h_0)}{\lambda}. \end{cases}$$

$$d_j = k_j r_{j-1} + d_{j-1}, \quad k_0 = 1, \; d_0 = 0$$

$$k_j = k_{j-1} + d_{j-1}q_{j-1}, \quad q_j = \left(\frac{\theta_j}{180}\right)^{1.5}$$

$$L = L_0 + L_{\text{ext}} + \Delta L_{\text{ext}}\left(1-\frac{S}{D}\right)^2 + \max\{\Gamma_1, \Gamma_2\},$$

$$\Gamma_1 = nL_{\text{int}}, \quad \Gamma_2 = \alpha(d-2)\left(1-\frac{S}{D}\right)^2$$

$$L = L_{\text{outdoor}} + L_{\text{ext}} + \Delta L_{ext2} + \max\{\Gamma_1, \gamma_3\} - G_{fh}, \quad G_{fh} = \begin{cases} nG_n, \\ hG_h. \end{cases}$$

$$\Gamma_1 = nL_{\text{int}}, \quad \gamma_3 = \alpha d.$$

$$L = L_0 + L_c + \sum_{i=1}^{I} k_{wi}L_{wi} + \sum_{j=1}^{J} k_{fj}L_{fj},$$

$$L = L_0 + L_c + \sum_{i=1}^{I} k_{wi}L_{wi} + k_f^{\left(\frac{k_f+2}{k_f+1}-b\right)} L_f,$$

$$L = L_{\text{crit}} + \alpha(d-d_{\text{crit}}), \qquad d_{\text{crit}} = \frac{D_{\max}^2}{\lambda},$$

$$\sigma(r) = \sigma_\mu\left(1-e^{-|L(r)-L_0(r)|/4}\right)+1.5 \qquad \rho(\Delta x) = e^{-\frac{|\Delta x|}{d_{cor}}\ln 2}$$

$$\rho = \begin{cases} \frac{d_1}{d_2} & \text{for } 0^\circ \le \theta \le \theta_T \text{ and } d_1 \ge \frac{d_c}{2} \\ \left(\frac{\theta_T}{\theta}\right)^\gamma \sqrt{\frac{d_1}{d_2}} & \text{for } \theta_T \le \theta \le \pi \text{ and } d_1 \ge \frac{d_c}{2} \\ \sqrt{\frac{d_c}{2d_2}} & \text{for } d_1 < \frac{d_c}{2} \end{cases} \qquad \theta_T = 2\sin^{-1}\left(\frac{d_c}{2d_1}\right)$$

$$N_R = \int_0^\infty \dot{r}p(R,\dot{r})d\dot{r} \quad p(r,\dot{r}) = p(r)p(\dot{r}) \quad p(\dot{r}) = \frac{1}{\sqrt{2\pi a}}e^{-\frac{\dot{r}^2}{2a}}$$

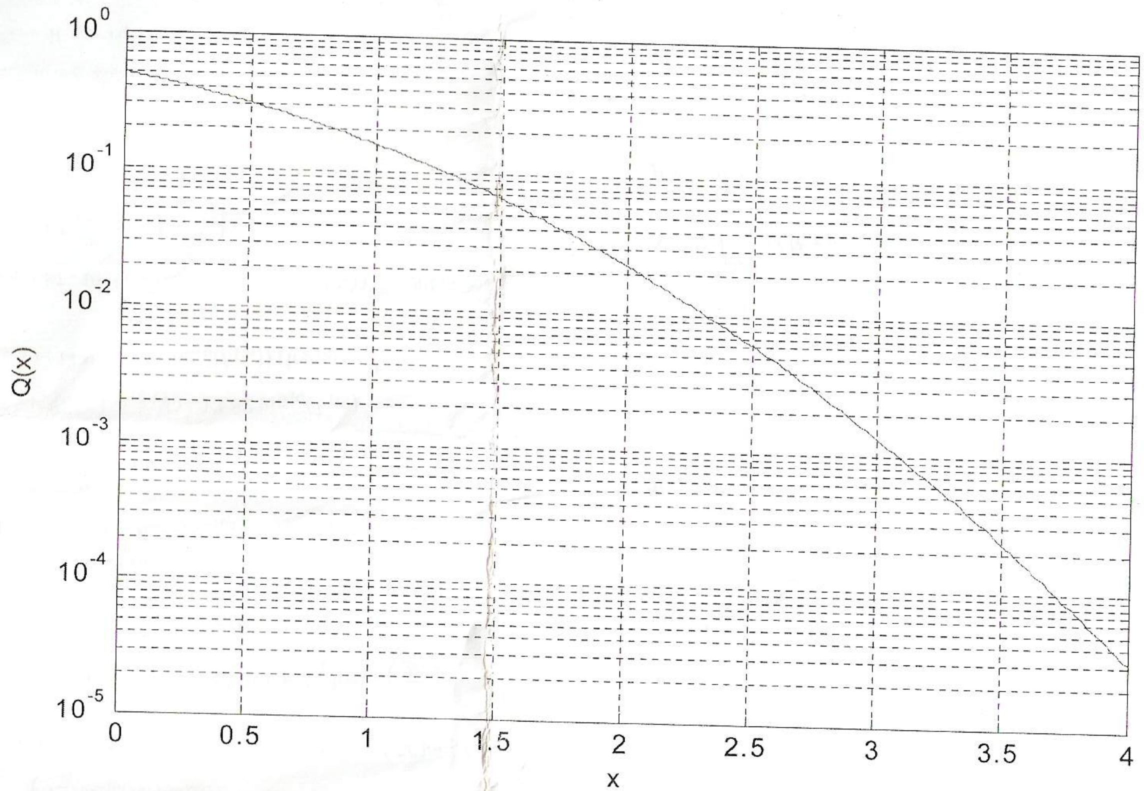
$$p(r,\dot{r},\theta,\dot{\theta}) = \frac{r^2}{4\pi^2\sigma^2 a}e^{-\frac{1}{2}\left(\frac{r^2}{\sigma^2}+\frac{\dot{r}^2}{a}+\frac{r^2\dot{\theta}^2}{a}\right)}, \qquad a = \frac{2\pi^2 v^2\sigma^2}{\lambda^2}$$

$$E\{\tau|r \le R\} = \sqrt{\frac{\sigma^2}{\pi}}\frac{1}{Rf_{d,\max}}\left(e^{\frac{R^2}{2\sigma^2}}-1\right) \quad N_R = \sqrt{\frac{\pi}{\sigma^2}}f_{d,\max}Re^{-\frac{R^2}{2\sigma^2}}$$

$$p_r(r) = \frac{r}{\sigma^2}e^{-\frac{r^2+\nu^2}{2\sigma^2}}I_0\left(\frac{r\nu}{\sigma^2}\right) \quad I_0(x) = \sum_{n=0}^{\infty}\frac{1}{(n!)^2}\left(\frac{x}{2}\right)^{2n}$$

$$p_r(r) = \frac{2}{\Gamma(m)}\left(\frac{m}{\Omega}\right)^m r^{2m-1}e^{-\frac{m}{\Omega}r^2}, \quad m = \frac{E\{r^2\}}{E\{r^2\}-E\{r\}^2}, \qquad \Omega = E\{r^2\}$$

$$\Gamma(m) = \int_0^\infty x^{m-1}e^{-x}dx, \qquad \Gamma(m) = (m-1)!$$



Q(x)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
0
0.5
1
1.5
2
2.5
3
3.5
4
x