KFUPM - COMPUTER ENGINEERING DEPARTMENT

COE-543 – Mobile Computing and Wireless Networking

Assignment 1 – Due May 3rd, 2009.

Problem 1: Describe briefly each of the following mobile systems: UMTS, LTE, and UMB. The description should include the main characteristics and the base technology and service features of the system. Not more than one page per system is required.

Problem 2: Rayleigh fading channels

The envelope of the received signal in a multipath channel can be modeled using a Rayleigh or Rician distributions. Specify each of the distributions and identify the corresponding parameters and their physical meaning. Show that the Rayleigh distribution is a special case of the Rician distribution.

Textbook Problems: 2.2, 2.4 (but for 90% coverage and 12 dB standard deviation), 2.7, 2.13, and 3.3.

For Problem 1 – refer to the introductory material covered at the beginning of the course and the slides package by Brough Turner from NMS Communications covered in class.

For Problem 2 – was covered in class and in notes – should discuss it from RF point of view.

Problem: 2.2 (30 points):

At 900 MHz we use the Okumura – Hata model:

P_t-P_r (dB) = 69.55 +26.16log(f_c) – 13.82log(h_b) –a(h_m) + (44.9-6.55log(h_b))log(d)

At 1900 MHz we use the COST-231 model:

P_t-P_r (dB) = 46.3 +33.9log(f_c) – 13.82log(h_b) –a(h_m) + (44.9-6.55log(h_b))log(d) +C_m

Where a(h_m) = 3.2(log11.75h_m)^2 – 4.97 dB for f_c > 300 MHz

Plug in the following parameters in above models:

h_b = 30 m, h_m= 2 m and C_M = 0.

Then a(h_m) = 1.045 dB. P_t-P_r (dB) = 130 dB.

@ *900 MHz,* Okumura – Hata model (designed for frequencies less than 1500MHz):

(44.9-6.55log(30))log(d) = 130 – (69.55 +26.16log(900) – 13.82log(30) – 1.045)

35.225log(d) = 4.626

d = $10^{(4.626/35.225)}$ = $10^{0.131}$ = **1.353 Km**

@ *1900 MHz,* COST-231 model (designed for frequencies more than 1800MHz)::

(44.9-6.55log(30))log(d) = 130 – (46.3 +33.9log(1900) – 13.82log(30) – 1.045)

35.225log(d) = -5.991

d = $10^{(-5.991/35.225)}$ = $10^{-0.170}$ = **0.676 Km**

Problem: 2.4 (30 points):

The solution to the fading margin is obtained by equating the tail probability to 0.1 (90% of the cell edge is adequately covered). If F_{LS} is the shadow fading component and F is the fading margin, this means:

$$\int_F^\infty F_{LS}(x).dx = 0.1$$

The shadow fading component is normally distributed with mean zero and standard deviation σ = 12 dB. We can thus rewrite the equation as:

$$\int_F^\infty \frac{1}{\sigma\sqrt{2\pi}} \exp(\frac{-x^2}{2\sigma^2}).dx = 0.1$$

We make a substitution of variables, and let $y = x/\sigma$. This results in the equation:

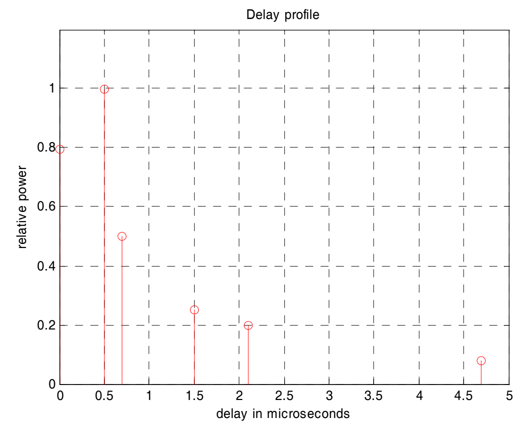
$$\int_{\frac{F}{\sigma}}^\infty \frac{1}{\sigma\sqrt{2\pi}} \exp(\frac{-y^2\sigma^2}{2\sigma^2}).\sigma.dy = 0.1 \Rightarrow \int_{\frac{F}{\sigma}}^\infty \frac{1}{\sqrt{2\pi}} \exp(\frac{-y^2}{2}).dy = 0.1$$

This is nothing but the Q function with the argument of the function being F/σ. This equates to $Q(\frac{F}{\sigma}) = 0.1$. Since $\sigma = 12$, $Q(\frac{F}{12}) = 0.1$ and from the Q-table, this gives $\frac{F}{12} = 1.2816$. So the fade margin, is $F = 15.3786$ dB**.**

Problem 2.7 (20 points):

The delay profile for the channel is given by the following table:

Relative delay (μsec)	Average relative power, σ^2 (dB)	Average relative power σ^2
0.0	-1.0	0.7943
0.5	0.0	1.0000
0.7	-3.0	0.5012
1.5	-6.0	0.2512
2.1	-7.0	0.1995
4.7	-11.0	0.0794



The channel multipath profile is as shown in figure above.

Total excess delay spread = $\tau_L - \tau_1$ = 4.7- 0 = 4.7 μs

$E[\tau] = \bar{\tau} = \frac{\sum_{\forall i} \tau_i \sigma_i^2}{\sum_{\forall i} \sigma_i^2} = 0.7149$ μsec, $E[\tau^2] = \frac{\sum_{\forall i} \tau_i^2 \sigma_i^2}{\sum_{\forall i} \sigma_i^2} = 1.3078$ (μs)^2, and therefore,

$\tau_{rms} = \sqrt{E[\tau^2] - E[\tau]^2} = 0.8926$ μs

Coherence bandwidth = 1/(5*τ_{rms}) = 224 kHz

Because the 25 kbps data rate is less than 224 kHz, this channel is NOT considered wideband

Problem 2.13 (20 points):

(a) RMS delay spread

$$\overline{\tau} = \frac{\sum_{1}^{N} \tau_i |\beta_i|^2}{\sum_{1}^{N} |\beta_i|^2} = \frac{50 \times 0.4 + 100 \times 0.4 + 200 \times 0.2}{0.4 + 0.4 + 0.2} = 100 \text{ ns}$$

$$\overline{\tau^2} = \frac{\sum_{1}^{N} \tau_i^2 |\beta_i|^2}{\sum_{1}^{N} |\beta_i|^2} = \frac{50^2 \times 0.4 + 100^2 \times 0.4 + 200^2 \times 0.2}{0.4 + 0.4 + 0.2} = 13{,}000 \text{ ns}^2$$

$$\tau_{rms} = \sqrt{\overline{\tau^2} - \overline{\tau}^2} = \sqrt{13{,}000 - (100)^2} = 54.8 \text{ ns}$$

(b) RMS Doppler spread

$$\overline{\lambda} = \frac{\int_{-\infty}^{\infty} \lambda D(\lambda) d\lambda}{\int_{-\infty}^{\infty} D(\lambda) d\lambda} = \frac{\int_{-5}^{5} 0.1\, \lambda \; d\lambda}{\int_{-5}^{5} 0.1 \; d\lambda} = \frac{0.1 \left[\frac{\lambda^2}{2} \right]_{-5}^{5}}{1} = 0 \text{ Hz}$$

$$\overline{\lambda^2} = \frac{\int_{-\infty}^{\infty} \lambda^2 D(\lambda) d\lambda}{\int_{-\infty}^{\infty} D(\lambda) d\lambda} = \frac{\int_{-5}^{5} 0.1\, \lambda^2 \; d\lambda}{\int_{-5}^{5} 0.1\, d\lambda} = \frac{0.1 \left[\frac{\lambda^3}{3} \right]_{-5}^{5}}{1} = 25 \text{ Hz}^2$$

$$\lambda_{rms} = \sqrt{\overline{\lambda^2} - \overline{\lambda}^2} = \sqrt{25 - (0)^2} = 5 \text{ Hz}$$

(c) Coherence bandwidth of the channel

$$\frac{1}{5\, \tau_{rms}} = \frac{1}{5 \times 54.8\, ns} = 3.7 \text{ MHz}$$

Problem 3.3 (30 points):

(a) From Table 3A.1 in the case of QPSK (M = 4, m = 2) in Flat Rayleigh Fading channels, we have

$$Pe = \frac{2^{m-1}}{M-1}\left(1-\sqrt{\frac{\sin^2\left(\frac{\pi}{m}\right)m\gamma_b}{1+\sin^2\left(\frac{\pi}{m}\right)m\gamma_b}}\right) = \frac{2}{3}\left(1-\sqrt{\frac{\sin^2\left(\frac{\pi}{2}\right)2\gamma_b}{1+\sin^2\left(\frac{\pi}{2}\right)2\gamma_b}}\right) = \frac{2}{3}\left(1-\sqrt{\frac{2\gamma_b}{1+2\gamma_b}}\right)$$

and for a BER of 10^{-3}, we have $\gamma_b = \frac{1}{2}\frac{\left[1-\frac{3}{2}Pe\right]^2}{1-\left[1-\frac{3}{2}Pe\right]^2} = \frac{1}{2}\frac{\left[1-\frac{3}{2}Pe\right]^2}{1-\left[1-\frac{3}{2}Pe\right]^2}$ = 331.13 = 25.2 dB

(b) From Table 3A.1 in the case of QPSK (M = 4, m = 2) in AWGN channels, we have

$$Pe = \frac{2^{m-1}}{M-1}erfc\left(\sqrt{\sin^2\left(\frac{\pi}{M}\right)m\gamma_b}\right) = \frac{2}{3}erfc\left(\sqrt{\sin^2\left(\frac{\pi}{4}\right)2\gamma_b}\right) = \frac{2}{3}erfc\left(\sqrt{\gamma_b}\right) \quad and \quad \gamma_b = erfc^{-1}\left(\frac{3}{2}Pe\right)$$

and for a BER of 10^{-3}, we have $\gamma_b = erfc^{-1}\left(\frac{3}{2}10^{-3}\right)$ = 5.01 = 7.0 dB

(c) Probability of outage

Therefore for an average γ_b = 331.13 = 25.2 dB, and a threshold γ_{th} = 5.01 = 7.0 dB

$$P_{out} = 1-e^{-\frac{\gamma_{th}}{\gamma_b}} = 1-e^{-\frac{5.01}{331.13}} = 1.5\times10^{-2}$$