

ECE 741 MidTerm Exam

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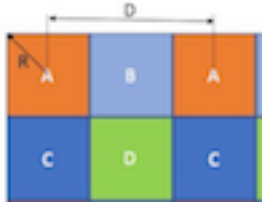
Question 1

(a) Slow fading is the variation of signal power around the average value measured at relatively long distances caused by large obstacles like buildings and hills, while fast fading is variation of signal when the receiver moves at the orders half λ , caused due to multi-pathing. Slow fading is modeled as log-normal distribution while fast fading is modeled as Rauleigh distribution for macrocells, or Ricean distribution for microcells.

(b) It implies a channel bandwidth requirement with enough room to avoid Inter-Symbol Interference due to multipathing by a factor of 5.

(c) Channel coherence time is inversely related to Doppler spread.

(d) $D = 2\sqrt{2}R$



(e) OFDM addresses frequency selective fading problem by inserting guard intervals between symbols.

(f) Because it doesn't specify the number of channels in a single cell, channel reuse factor must be specified in order to truly represent capacity.

(g) $T_{channel-occupancy} = \min\{T_{cell-dwell}, T_{call-duration}\}$, channel occupancy time is either the time spent until the mobile moves to another cell (cell dwell time) or the time until the channel is released.

(h) Directed retry means mobile receivers located in overlapping area of cells may be redirected to other cells if all channels are occupied in the primary cell, with or without handoff mechanism.

(i) The doppler spread (factor of v/λ , v =speed) caused by the speed of the receiver should be much less than the bitrate to have good performance and avoid spectrum modification.

(j) Fade margin for a network providing 99 percent successful service at the fringe of coverage with zero mean and $\sigma = 6\text{dB}$

$$\int_{F/\sigma}^{\infty} e^{-y^2/2} dy = 0.01$$

$Q(F/\sigma) = 0.01$, From Q table $F/\sigma = 2.3$, $F = 2.3 \times 6 \text{ dB} = 13.8 \text{ dB}$

Question 2

$f = 1.8\text{GHz}$, $h_b = 20\text{ m}$, $h_m = 1\text{ m}$, $P_T = 20\text{ dBm}$, $G_T = G_R = 3\text{ dB}$,
 $P_I = -110\text{ dBm}$, $SIR_{min} = 12\text{ dB} = 42\text{ dBm}$

(a) Two Ray Model

$d = 2\text{ km}$

Minimum received power

$$P_{Rmin} = P_I + SIR_{min} = -110\text{ dBm} + 42\text{ dBm} = -68\text{ dBm}$$

Two Ray Model Power loss,

$$P_L = 40\log(d) - 20\log(h_m) - 20\log(h_b) - G_T - G_R$$

$$P_L = 100.02\text{ dB} = 130.02\text{ dBm}$$

Maximum loss to satisfy the minimum SIR, $L_{max} = P_T - P_{Rmin}$

$$L_{max} = 20\text{ dBm} + 68\text{ dBm} = 88\text{ dBm}$$

Therefore the maximum acceptable loss at the base station is: $= L_{max} -$

$$P_L = 88\text{ dBm} - 130\text{ dBm} = -42\text{ dBm}.$$

(b) Free space loss model

$$P_L = 20\log 4\pi d - 20\log \lambda - G_T - G_R$$

$$P_L = 97.57\text{ dB} = 127.97\text{ dBm}$$

The maximum acceptable loss at the base station is: $= L_{max} - P_L = 88$

$$\text{dBm} - 127.97\text{ dBm} = -39.97\text{ dBm}$$

Question 3

(a) $R = 270$ Kbps with QPSK (each symbol carrying two bits = 2 bits/symbol),
 $\sigma_\tau = 1$ microseconds
Bandwidth of transmitted signal (W)

$$W = \frac{270Kbps}{2bits/symbol} = 135KHz$$

50% correlation bandwidth is :

$$B_c = \frac{1}{5\sigma_\tau} = \frac{1}{5 * 10^{-6}} = 200KHz$$

Here, we have $W < B_c$, this channel exhibits flat fading and there will be no Inter-Symbol Interference (ISI).

(b) $R = 11$ Mbps BPSK (each symbol carrying one bit = 1 bits/symbol)
, $\sigma_\tau = 0.05$ microseconds

$$W = \frac{11Mbps}{1bits/symbol} = 11MHz$$

$$B_c = \frac{1}{5\sigma_\tau} = \frac{1}{5 * 0.05 * 10^{-6}} = 4MHz$$

$W > B_c$, channel will exhibit frequency selective fading and there will be ISI.

(c) $R = 11$ Mbps with 64QAM (each symbol carrying 6 bits = 6 bits/symbol),
 $\sigma_\tau = 0.05$ microseconds

$$W = \frac{11Mbps}{6bits/symbol} = 1.833MHz$$

$$B_c = \frac{1}{5\sigma_\tau} = \frac{1}{5 * 0.05 * 10^{-6}} = 4MHz$$

$W < B_c$, this channel exhibits flat fading and there will be no Inter-Symbol Interference (ISI).

Question 4

(a) $P_{av} = -10\text{dBm}$ at 100m distance , lognormal distribution with $\sigma = 6\text{dB}$
Since the power is normalized gaussian around the average power, the probability that the received power at this distance is greater than -10dBm is 0.5

(b) $\Pr\{ P > -40 \text{ dBm} \}$ at 1 Km distance, with $\sigma = 6 \text{ dB}$ and taking path loss factor $n = 4$

$$P_o - P_{av} = 10n\log(r/R)$$

where $r = 100 \text{ m}$, $R = 1 \text{ km} = 1000 \text{ m}$

$$P_o - P_{av} = 10 * 4 * \log\left(\frac{100}{1000}\right) = -40\text{dBm}$$

Again , power is normalized gaussian around -40 dBm, therefore

$$\Pr\{ P > -40 \text{ dBm} \} = 0.5$$

Question 5

Hexagonal cells with $R = 1.5$ Km , Channel reuse factor = $1/7$, Spectrum = 350 full duplex channels, $\mu = 0.01 \text{ sec}^{-1}$, $P_B = 0.01$

(a) Each subscriber generates 10 mErlangs = 10×10^{-3} Erlangs/customer

$$N = \text{Number of Channels per cell} = \frac{350}{7} = 50$$

$$P_B = \frac{\frac{A^N}{N!}}{\sum_{n=0}^N \frac{A^n}{n!}} = 0.01$$

From ErlangB table for $P_B = 0.01$ and $N = 50$, $A = 37.90$

$$\begin{aligned} \text{Number of customers per cell} &= 37.9 \text{ Erlangs/cell} \bigg/ 10 \times 10^{-3} \text{ Erlangs/customer} \\ &= 3790 \text{ customers/cell} \end{aligned}$$

$$\begin{aligned} \text{Number of customers per cluster} &= 3790 \text{ customers/cell} \times 7 \text{ cells/cluster} \\ &= 26530 \text{ customers/cluster} \end{aligned}$$

$$\begin{aligned} \text{(b) Channel efficiency} \\ &= 37.90 \text{ Erlangs} / 50 \text{ Channels} = 0.758 \text{ Erlangs per Channel} \end{aligned}$$

(c) Assuming blocked calls are delayed, i.e. $P_C = 0.01$

From Erlang C table for $P_C = 0.01$ and $N = 50$, $A = 34.80$ Erlangs

$$\begin{aligned} \text{Number of customers per cell} &= 34.80 \text{ Erlangs/cell} \bigg/ 10 \times 10^{-3} \text{ Erlangs/customer} \\ &= 3480 \text{ customers/cell} \end{aligned}$$

$$\begin{aligned} \text{Number of customers per cluster} &= 3480 \text{ customers/cell} \times 7 \text{ cells/cluster} \\ &= 24360 \text{ customers/cluster} \end{aligned}$$

$$\begin{aligned} \text{(d) Channel efficiency} \\ &= 34.80 \text{ Erlangs} / 50 \text{ Channels} = 0.696 \text{ Erlangs per Channel} \end{aligned}$$

Question 6

V = 60 km/hr , Cell Radius = r = 1 Km , N channels per cell , $\lambda = 0.2 \text{ sec}^{-1}$, $\mu = 0.01 \text{ sec}^{-1}$, Channel reuse factor = 1/13 , Spectrum = 260 full duplex channels in a cluster

(a) P_B , with mobility ignored

$$N = \frac{260}{13} = 20 \text{ channels per cell, } A = \frac{\lambda}{\mu} = \frac{0.2}{0.01} = 20 \text{ Erlangs}$$

$$P_B = \frac{\frac{A^N}{N!}}{\sum_{n=0}^N \frac{A^n}{n!}} = \frac{\frac{20^{20}}{20!}}{\sum_{n=0}^{20} \frac{20^n}{n!}} = 0.159$$

(b) Cell dwell time

$$\text{cell cross over rate } \eta = \frac{VL}{\pi S} = \frac{60 \cdot 1000 \cdot 6 \cdot 1000}{\pi \cdot 2.6 \cdot 1000^2} = 0.01225 \text{ sec}^{-1}$$

$$\text{cell dwell time} = \frac{1}{\eta} = 81.62 \text{ sec}$$

(c) Channel occupancy time

$$\tau = \frac{1}{\mu + \eta} = \frac{1}{0.01 + 0.01225} = 44.94 \text{ sec}$$

(d) Probability of handoff

$$P_h = \frac{\eta}{\mu + \eta} = \frac{0.01225}{0.01 + 0.01225} = 0.551$$

(e) Probability of a call going through no handoff before completion

$$1 - P_h = 1 - 0.551 = 0.449$$

(f) Probability of call blocking

Handoff traffic rate

$$\lambda_h = \frac{P_h}{1 - P_h} \lambda = \frac{\eta}{\mu} \lambda = \frac{0.01225}{0.01} 0.2 = 0.245$$

Total traffic load $\rho = A$

$$\rho = \rho_i + \rho_h = \frac{\lambda}{\mu + \eta} + \frac{\lambda_h}{\mu + \eta} = \frac{0.2 + 0.245}{0.01 + 0.01225} = 20$$

$$P_B = \frac{\frac{A^N}{N!}}{\sum_{n=0}^N \frac{A^n}{n!}} = \frac{\frac{20^{20}}{20!}}{\sum_{n=0}^{20} \frac{20^n}{n!}} = 0.159$$