EE4-03
EE9SO10

IMPERIAL COLLEGE LONDON

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DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2011

MSc and EEE/ISE PART IV: MEng and ACGI

MOBILE RADIO COMMUNICATION

Monday, 23 May 10:00 am

Time allowed: 3:00 hours

There are FOUR questions on this paper.

Answer THREE questions.

All questions carry equal marks. The maximum mark for each subquestion is shown in brackets.

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible	First Marker(s) :	M.K. Gurcan
	Second Marker(s) :	K.K. Leung

Instructions to Candidates
Useful equations

Scattering path loss model

$$\frac{P_r}{P_t} = \left[\frac{\lambda\sqrt{G\,\sigma}}{(4\pi)^{\frac{3}{2}}\;S\,S'}\right]^2$$

where σ is the radar cross section and S and S' are distances between the source-scaterrer and the scatterer-receiver.

Reflection path loss model

$$\frac{P_r}{P_t} = \left(\frac{R\sqrt{G}}{S+S'}\right)^2 \left(\frac{\lambda}{4\pi}\right)^2$$

The terms have their usual meaning.

1. Answer the following sub-questions.

(a) Find the re-use distance D for the channel reuse shown in Figure 1.1 for both the diamond and hexagonally shaped cells as a function of cell radius R. [4]

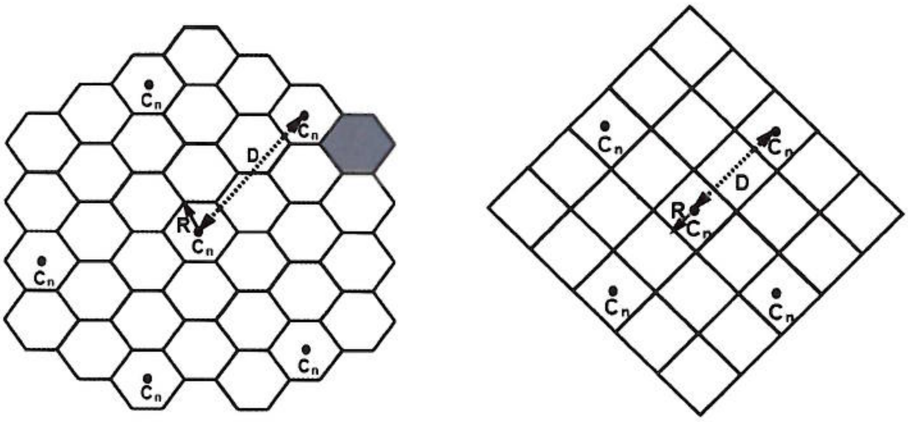


Figure 1.1. Cellular structures.

(b) Consider a system with a transmitter, receiver, and scatterer as shown in Figure 1.2.

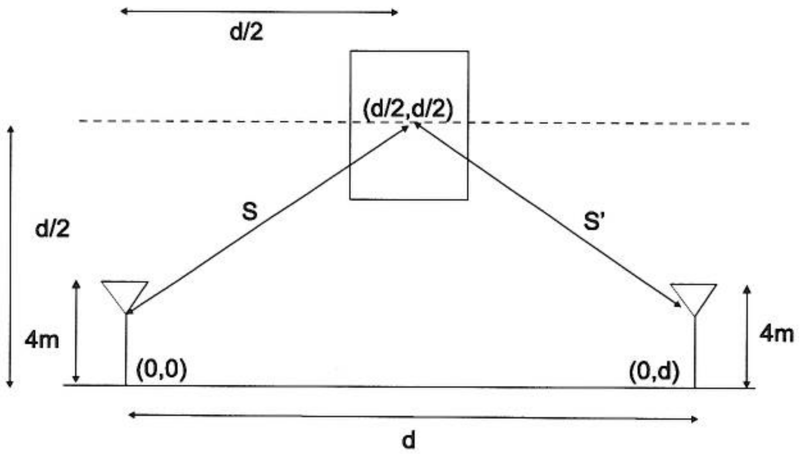


Figure 1.2 Scattering diagram.

Assume the transmitter and receiver are both at heights $h_t = h_r = 4$m and are separated by distance d, with the scatterer at distance $.5d$ along both dimensions in a two-dimensional grid of the ground, i.e. on such a grid the transmitter is located at $(0, 0)$, the receiver is located at $(0, d)$ and the scatterer is located at $(.5d, .5d)$. Assume a radar cross section of 20 dB $m^2$and $f_c = 900$ MHz. Find the path loss of the received signal for $d = 1$, 10, 100, and 1000 meters for scattering and reflection cases. Compare these path loss with the path losses at the same distances if the signal is just reflected with reflection coefficient R = -1 [6]

(c) Consider the set of empirical measurements of $\frac{P_r}{P_t}$ given in the table below for an indoor system at 900 MHz.

Distance from transmitter	$\frac{P_r}{P_t}$
10 m	-70 dB
20 m	-75 dB
50 m	-90 dB
100 m	-110 dB
300 m	-125 dB

Answer the following sub-questions.

i. Find the path loss exponent γ that minimizes the Mean-Square-Error between the simplified model and the empirical dB power measurements, assuming that $d_0 = 1$ m and K is determined from the free space path gain formula at this d_0. [3]

ii. Find the received power at 150 m for the simplified path loss model with this path loss exponent and a transmit power of 1 mW (0 dBm). [3]

iii. Assuming the simplified path loss model with the path loss exponent and the same K given in part (c).i, find the variance, σ^2, of log-normal shadowing about the mean path loss based on these empirical measurements. [3]

(d) Find the outage probability for a micro-cellular system where path loss follows the simplified model (with $\gamma = 3$, and $K = 0$ dB) and there is also log-normal shadowing with $\sigma = 4$ dB. Assume a cell radius of 100 m, a transmit power of 80 mW, and a minimum received power requirement of $P_{\min} = -100$ dBm. [6]

2. Answer the following sub-questions.

(a) Using the indoor attenuation model, determine the required transmitter signal power for a desired received power of -110 dBm for a signal transmitted over 100 m that goes through 3 floors with attenuation 15 dB, 10 dB, and 6 dB, respectively, as well as 2 double plasterboard walls with the partition loss 3.4 dB. Assume a reference distance $d_0 = 1$, path loss exponent $\gamma = 4$ and constant $K = 0$ dB. [5]

(b) Consider a wideband channel characterized by the autocorrelation function

$$A_c(\tau, \Delta t) = \begin{cases} \text{sinc}(W\Delta t) & 0 \le \tau \le 10\mu s, \\ 0 & \text{else,} \end{cases}$$

where $W = 100$Hz and $sinc(x) = sin(\pi x)/(\pi x)$.

i. Does this channel correspond to an indoor channel or an outdoor channel, and why? [3]

ii. Sketch the scattering function of this channel. [2]

iii. Compute the channel's average delay spread, rms delay spread, and Doppler spread. [3]

iv. What is the approximate range of dat rates over which a signal transmitted over this channel will exhibit frequency selective fading? [2]

(c) Let a scattering function $S(\tau, \rho)$ be nonzero over $0 \le \tau \le 0.1$ ms and $-0.1 \le \rho \le 0.1$ Hz. Assume that the power of the scattering function is approximately uniform over the range where it is nonzero.

i. What is the multipath spread and the Doppler frequency spread of the channel? [2]

ii. If the input to this channel is two identical sinusoidal signals separated in time by Δt, what is the minimum value of Δf for which the channel response to the first sinusoidal signal is approximately independent of the channel response to the second sinusoidal signal? [3]

iii. For two sinusoidal inputs to the channel $u_1(t) = \sin 2\pi ft$ and $u_2(t) = sin 2\pi f(t + \Delta t)$, what is the minimum value of Δt for which the channel response to $u_1(t)$ is approximately independent of the channel response to $u_2(t)$? [3]

iv. Will this channel exhibit flat fading or frequency-selective fading for a typical voice channel with 3 KHz bandwidth? [2]

3. Answer the following sub-questions.

(a) Consider a flat-fading channel with three possible received SNRs and associated probabilities: $\gamma_1 = .8333$ with $p(\gamma_1) = .1$, $\gamma_2 = 83.33$ with $p(\gamma_2) = .5$, and $\gamma_3 = 333.33$ with $p(\gamma_3) = .4$ respectively. Assume that both the transmitter and receiver have the instantaneous channel-side-information (CSI).

i. Consider a system with a "variable rate with equal-power loading" policy. Find the Shannon capacity and compare it to the capacity of an AWGN channel with the same average SNR. [3]

ii. Consider a system with a "capacity-with-outage" policy scheme.

A. Find the capacity versus outage for this channel. [2]

B. Find the average rate correctly received for outage probabilities $p_{out} < .1$, $p_{out} = .1$ and $p_{out} = .6$. [2]

iii. Consider a system with an "optimal power adaptation" policy and find the ergodic capacity for the system. [3]

iv. Consider a system with a "channel-inversion-power allocation" policy.

A. Find the zero-outage capacity of this channel. [2]

B. Find the outage capacity of this channel and the associated outage probabilities for cut-off values $\gamma_0 = .84$ and $\gamma_0 = 83.4$. Which of these cut-off values yields a larger outage capacity? [2]

(b) Consider a wireless channel where power fall-off with distance follows the formula $P_r(d) = P_t(d_0/d)^3$ for $d_0 = 10$ m. Assume the channel has bandwidth $B = 30$ KHz and AWGN with noise power spectral density of $N_0 = 10^{-9}$ W/Hz. For a transmit power of 1W, find the capacity of this channel for a transmit receive distance of 100 m and 1 Km. [4]

(c) Consider two users simultaneously transmitting to a single receiver in an AWGN channel. Assume the users have equal received power of 10 mW and total noise at the receiver in the bandwidth of interest of 0.1 mW. The channel bandwidth for each user is 20 MHz.

i. Suppose that the receiver decodes one of the users' signal (signal 1) and the second user's signal acts as AWGN. What is the capacity of the channel associated with the decoded signal 1? [4]

ii. Suppose that after decoding signal 1, the decoder re-encodes it and subtracts it from the received signal, what is the Shannon capacity of the second user's channel? [3]

4. Answer the following sub-questions.

(a) Consider a High Speed Downlink Packet Access (HSDPA) system, with a multi-code CDMA transmission, operating over a frequency selective multi-path channel. Answer the following questions.

i. Explain why the equal-rate, equal-SNR energy allocation policy produces a capacity higher than the equal-rate, equal-energy loading energy allocation policy when using Minimum-Mean-Square-Error (MMSE) equalizer receivers. [4]

ii. Explain why the performance of Rake receiver is worse than the performance of the MMSE receiver which deals with the Multiple-Access-Interference (MAI) and Inter-Symbol-Interference (ISI) effects. [4]

iii. Explain how the transmission energy and the covariance matrix are iteratively adjusted to achieve a target signal-to-noise (SNR) ratio at the output of MMSE receivers when implementing the equal-rate, margin-adaptive loading policy. [4]

iv. Explain how the margin-adaptive and rate-adaptive optimal rate allocation policies are used consecutively to optimize the total transmission rate when using the two-group resource allocation algorithm. [3]

(b) Consider the third generation UTRAN architecture and describe

i. how the soft-handover operates; [2]

ii. how the random access channel and acquisition indicator channels are used to provide access control; [3]

iii. why femto cell systems are introduced and how they operate; [2]

iv. how Long Term Evolution systems are planned to be introduced for next generation mobile radio systems. [3]

1.a *Solution:* For the diamond shaped cells, there is $N_I = 1$ cell between co-channel cells. Thus, $D = 2R(N_I + 1) = 4R$. For the hexagonal cells shown in Figure 1.1 the reuse pattern moves 2 cells along the u axis and then 1 cell along the v axis. Thus, $D = \sqrt{3}R\sqrt{2^2 + 1^2 + 2} = 4.58R$.

1.b

$f_c = 900MHz$
$\lambda = 1/3m$
$G = 1$ radar cross section $20dBm^2 = 10\log_1 0\sigma \Rightarrow \sigma = 100$
d=1 , $s = s' = \sqrt{(0.5d)^2 + (0.5d)^2} = d\sqrt{0.5} = \sqrt{0.5}$
Path loss due to scattering

$$\frac{P_r}{P_t} = \left[\frac{\lambda\sqrt{G\sigma}}{(4\pi)^{3/2}ss'}\right]^2 = 0.0224 = -16.498dB$$

Path loss due to reflection (using 2 ray model)

$$\frac{P_r}{P_t} = \left(\frac{R\sqrt{G}}{s+s'}\right)^2\left(\frac{\lambda}{4\pi}\right)^2 = 3.52\times 10^{-4} = -34.54dB$$

$d = 10$ $P_{scattering} = -56.5dB$ $P_{reflection} = -54.54dB$
$d = 100$ $P_{scattering} = -96.5dB$ $P_{reflection} = -74.54dB$
$d = 1000$ $P_{scattering} = -136.5dB$ $P_{reflection} = -94.54dB$
Notice that scattered rays over long distances result in tremendous path loss

Solution: We first set up the MMSE error equation for the dB power measurements as

$$F(\gamma) = \sum_{i=1}^{5}[M_{\text{measured}}(d_i) - M_{\text{model}}(d_i)]^2.$$

1.c where $M_{\text{measured}}(d_i)$ is the path loss measurement in Table 2.3 at distance d_i and $M_{\text{model}}(d_i) = K - 10\gamma\log_{10}(d)$ is the path loss based on (2.40) at d_i. Using the free space path loss formula, $K = 20\log_{10}(.3333/(4\pi)) = -31.54$

$$\begin{aligned} F(\gamma) &= (-70 + 31.54 + 10\gamma)^2 + (-75 + 31.54 + 13.01\gamma)^2 + (-90 + 31.54 + 16.99\gamma)^2 \\ &+ (-110 + 31.54 + 20\gamma)^2 + (-125 + 31.54 + 24.77\gamma)^2 \\ &= 21676.3 - 11654.9\gamma + 1571.47\gamma^2. \end{aligned}$$

Differentiating $F(\gamma)$ relative to γ and setting it to zero yields

$$\frac{\partial F(\gamma)}{\partial\gamma} = -11654.9 + 3142.94\gamma = 0 \rightarrow \gamma = 3.71.$$

To find the received power at 150 m under the simplified path loss model with $K = -31.54$, $\gamma = 3.71$, and $P_t = 0$ dBm, we have $P_r = P_t + K - 10\gamma \log_{10}(d/d_0) = 0 - 31.54 - 10 * 3.71 \log_{10}(150) = -112.27$ dBm. Clearly the measurements deviate from the simplified path loss model: this variation can be attributed to shadow fading.

1.d $\gamma = 3$
$d_0 = 1$
$k = 0dB$
$\sigma = 4dB$
$R = 100m$
$P_t = 80mW P_{min} = -100dBm = -130dB$

$$\overline{P_\gamma}(R) = P_t K \left(\frac{d_0}{d}\right)^\gamma = 80 \times 10^{-9} = -70.97dB$$

$$a = \frac{P_{min} - \overline{P_\gamma}(R)}{\sigma} = 14.7575$$

P_{out}=1-Q(a).

2.a $P_r = P_t - P_L(d) - \sum_i^3 FAF_i - \sum_j^2 PAF_j$
FAF =(5,10,6), PAF =(3.4,3.4)

$$P_L(d)K\left(\frac{d_0}{d}\right)_0^{\gamma} = 10^{-8} = -8dB$$

$$-110 = P_t - 80 - 5 - 10 - 6 - 3.4 - 3.4$$

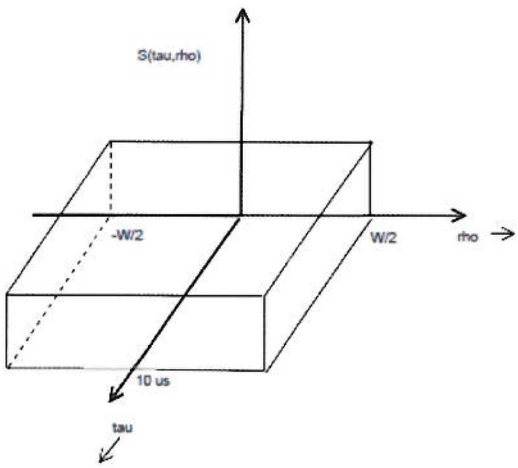
$$\Rightarrow P_t = -2.2dBm$$

Outdoor, since delay spread $\approx$ 10 μsec.
Consider that 10 μsec $\Rightarrow$ d = ct = 3km difference between length of first and last path

2.b Scattering function

$$S(\tau,\rho) = F_{\Delta t}[A_c(\tau,\Delta t)]$$

$= \frac{1}{W} rect\left(\frac{1}{W}\rho\right)$ for $0 \leq \tau \leq 10\mu sec$



Avg Delay Spread $= \dfrac{\int_0^\infty \tau A_c(\tau)d\tau}{\int_0^\infty A_c(\tau)d\tau} = 5\mu$sec

RMS Delay Spread $= \sqrt{\dfrac{\int_0^\infty (\tau - \mu_{Tm})^2 A_c(\tau)d\tau}{\int_0^\infty A_c(\tau)d\tau}} = 2.89\mu$sec

Doppler Spread $= \frac{W}{2} = 50$ Hz

$\beta_u >$ Coherence BW $\Rightarrow$ Freq. Selective Fading $\approx \frac{1}{T_m} = 10^5 \Rightarrow \beta_u >= 10^5$ kHz
Can also use μ_{Tm} or σ_{Tm} instead of T_m

2.c $T_m \approx .1\text{msec} = 100\mu\text{sec}$

$B_d \approx .1\text{Hz}$

Answers based on μ_{T_m} or σ_{T_m} are fine too. Notice, that based on the choice of either T_m, μ_{T_m} or σ_{T_m}, the remaining answers will be different too.

$B_c \approx \frac{1}{T_m} = 10\text{kHz}$

$\Delta f > 10\text{kHz}$ for $u_1 \perp u_2$

$(\Delta t)_c = 10\text{s}$

$3\text{kHz} < B_c \Rightarrow$ Flat

$30\text{kHz} > B_c \Rightarrow$ Freq. Selective

3.a.i

$$C = \sum_i B \log_2(1+\gamma_i)p(\gamma_i) = 30000(.1\log_2(1.8333) + .5\log_2(84.333) + .4\log_2(334.33)) = 199.26 \text{ Kbps}.$$

The average SNR for this channel is $\overline{\gamma} = .1(.8333) + .5(83.33) + .4(333.33) = 175.08 = 22.43$ dB. The capacity of an AWGN channel with this SNR is $C = B\log_2(1 + 175.08) = 223.8$ Kbps. Note that this rate is about 25 Kbps larger than that of the flat-fading channel with receiver CSI and the same average SNR.

3.a.ii

Solution: For time-varying channels with discrete SNR values the capacity versus outage is a staircase function. Specifically, for $p_{out} < .1$ we must decode correctly in all channel states. The minimum received SNR for p_{out} in this range of values is that of the weakest channel: $\gamma_{min} = \gamma_1$, and the corresponding capacity is $C = B\log_2(1+\gamma_{min}) = 30000\log_2(1.833) = 26.23$ Kbps. For $.1 \leq p_{out} < .6$ we can decode incorrectly when the channel is in the weakest state only. Then $\gamma_{min} = \gamma_2$ and the corresponding capacity is $C = B\log_2(1+\gamma_{min}) = 30000\log_2(84.33) = 191.94$ Kbps. For $.6 \leq p_{out} < 1$ we can decode incorrectly if the channel has received SNR γ_1 or γ_2. Then $\gamma_{min} = \gamma_3$ and the corresponding capacity is $C = B\log_2(1+\gamma_{min}) = 30000\log_2(334.33) = 251.55$ Kbps. Thus, capacity versus outage has $C = 26.23$ Kbps for $p_{out} < .1$, $C = 191.94$ Kbps for $.1 \leq p_{out} < .6$, and $C = 251.55$ Kbps for $.6 \leq p_{out} < 1$.

For $p_{out} < .1$ data transmitted at rates close to capacity $C = 26.23$ Kbps are always correctly received since the channel can always support this data rate. For $p_{out} = .1$ we transmit at rates close to $C = 191.94$ Kbps, but we can only correctly decode these data when the channel SNR is γ_2 or γ_3, so the rate correctly received is $(1-.1)191940 = 172.75$ Kbps. For $p_{out} = .6$ we transmit at rates close to $C = 251.55$ Kbps but we can only correctly decode these data when the channel SNR is γ_3, so the rate correctly received is $(1-.6)251550 = 125.78$ Kbps. It is likely that a good engineering design for this channel would send data at a rate close to 191.94 Kbps, since it would only be received incorrectly at most 10% of this time and the data rate would be almost an order of magnitude higher than sending at a rate commensurate with the worst-case channel capacity. However, 10% retransmission probability is too high for some applications, in which case the system would be designed for the 26.23 Kbps data rate with no retransmissions.

3.a.iii

Solution: We know the optimal power allocation is water-filling, and we need to find the cutoff value γ_0 that satisfies the discrete version of (4.15) given by

$$\sum_{\gamma_i \geq \gamma_0} \left(\frac{1}{\gamma_0} - \frac{1}{\gamma_i}\right) p(\gamma_i) = 1. \tag{4.17}$$

We first assume that all channel states are used to obtain γ_0, i.e. assume $\gamma_0 \leq \min_i \gamma_i$, and see if the resulting cutoff value is below that of the weakest channel. If not then we have an inconsistency, and must redo the calculation assuming at least one of the channel states is not used. Applying (4.17) to our channel model yields

$$\sum_{i=1}^{3} \frac{p(\gamma_i)}{\gamma_0} - \sum_{i=1}^{3} \frac{p(\gamma_i)}{\gamma_i} = 1 \Rightarrow \frac{1}{\gamma_0} = 1 + \sum_{i=1}^{3} \frac{p(\gamma_i)}{\gamma_i} = 1 + \left(\frac{.1}{.8333} + \frac{.5}{83.33} + \frac{.4}{333.33}\right) = 1.13$$

Solving for γ_0 yields $\gamma_0 = 1/1.13 = .89 > .8333 = \gamma_1$. Since this value of γ_0 is greater than the SNR in the weakest channel, it is inconsistent as the channel should only be used for SNRs above the cutoff value. Therefore, we now redo the calculation assuming that the weakest state is not used. Then (4.17) becomes

$$\sum_{i=2}^{3} \frac{p(\gamma_i)}{\gamma_0} - \sum_{i=2}^{3} \frac{p(\gamma_i)}{\gamma_i} = 1 \Rightarrow \frac{.9}{\gamma_0} = 1 + \sum_{i=2}^{3} \frac{p(\gamma_i)}{\gamma_i} = 1 + \left(\frac{.5}{83.33} + \frac{.4}{333.33}\right) = 1.0072$$

Solving for γ_0 yields $\gamma_0 = .89$. So by assuming the weakest channel with SNR γ_1 is not used, we obtain a consistent value for γ_0 with $\gamma_1 < \gamma_0 \le \gamma_2$. The capacity of the channel then becomes

$$C = \sum_{i=2}^{3} B \log_2(\gamma_i/\gamma_0) p(\gamma_i) = 30000(.5 \log_2(83.33/.89) + .4 \log_2(333.33/.89)) = 200.82 \text{ Kbps}.$$

Comparing with the results of the previous example we see that this rate is only slightly higher than for the case of receiver CSI only, and is still significantly below that of an AWGN channel with the same average SNR. That is because the average SNR for this channel is relatively high: for low SNR channels capacity in flat-fading can exceed that of the AWGN channel with the same SNR by taking advantage of the rare times when the channel is in a very good state.

3.b *Solution:* The received SNR is $\gamma = P_r(d)/(N_0 B) = .1^3/(10^{-9} \times 30 \times 10^3) = 33 = 15$ dB for $d = 100$ m and $\gamma = .01^3/(10^{-9} \times 30 \times 10^3) = .033 = -15$ dB for $d = 1000$ m. The corresponding capacities are $C = B \log_2(1+\gamma) = 30000 \log_2(1+33) = 152.6$ Kbps for $d = 100$ m and $C = 30000 \log_2(1 + .033) = 1.4$ Kbps for $d = 1000$ m. Note the significant decrease in capacity at farther distances, due to the path loss exponent of 3, which greatly reduces received power as distance increases.

3.c $P_{noise} = 0.1mW$

$B = 20MHz$

(a) $C_{user1 \rightarrow \text{base station}} = 0.933B = 18.66Mbps$

(b) $C_{user2 \rightarrow \text{base station}} = 3.46B = 69.2Mbps$

Examinations :	**Mobile Radio Communication**	**Session**	**May 2011**
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MODEL ANSWERs and MARKING SCHEME

First Examiner: Gurcan, M.K.	**Paper Code :** E4.03, SO10, ISE4.3
Second Examiner: Leung, K.K..	**Question** **Page** 7 ***out of*** 9

Question labels in left margin **Marks allocations in right margin**

4a.i let H be channel matrix

S be the spreading sequence matrix $S = [\vec{s}_1, \dots \vec{s}_K]$

X symbol matrix, $X = [\vec{X}_1^T, \dots \vec{X}_K^T]^T$

$\vec{w}_k$, $k = 1, \dots K$ the despreading filter.

The matched filter matrix for the receiver is

$Q_e = [\,(J^T)^N HS \quad HS \quad J^N HS\,]$ and the matched filter Rake receiver is

$\vec{q}_k = H\vec{s}_k$

The SNR at the output of the mmse receiver is

$$\gamma_k = \frac{E_k \vec{q}_k C^{-1} \vec{q}_k}{1 - E_k \vec{q}_k^H C^{-1} \vec{q}_k}$$

where E_k is the energy allocated to channel k.

For equal energy loading $E_k = \frac{E_T}{K}$ for $k = 1, \dots K$.

Hence the SNR is

$$\gamma_k = \frac{\frac{E_T}{K} \vec{q}_k^H C^{-1} \vec{q}_k}{1 - \frac{E_T}{K} \vec{q}_k^H C^{-1} \vec{q}_k}$$

Rate is allocated to each channel to satisfy

$$\Gamma\,(2^{b_p} - 1) \leq \min_k (\gamma_k) \leq \Gamma\,(2^{b_{p+1}} - 1)$$

where there is wasted SNR problem. With SNR and equal rate loading we update energy and covariance matrix such that all SNRs at the output of despreading filters are the same hence the wasted SNR problem is eliminated

///

4.a.ii For the Rake receiver the SNR at the output of the matched filter receiver is

$$\gamma_k = \frac{E_k\, |\vec{q}_k^H q_k|^2}{\sum E_j\, |\vec{q}_j^H \vec{q}_k| + 2\sigma^2 \vec{q}_k^H \vec{q}_k}$$

The signal at the output of the Rake receiver suffers from ISI and MAI and using an mmse receiver both ISI and MAI are both eliminated.

$$\gamma_k = \frac{E_k \vec{q}_k^{\,H} C^{-1} \vec{q}_k}{1 - E_k \vec{q}_k^{\,H} C^{-1} \vec{q}_k}$$

—//—

4.a.iii The received signal covariance matrix at the output of the chip matched filter is

$$C_i = Q_e A_i^2 Q_e^H + 2\sigma^2 I_{N+2\alpha}$$

$$E_{k,i+1} = \frac{\gamma^*(y_k)}{1+\gamma^*(y_k)} \left(\vec{q}_k^{\,H} C_i^{-1} \vec{q}_k \right)^{-1}$$

energy and the covariance matrix are iteratively adjusted until $E_{k,i} \simeq E_{k,(i-1)}$

—///—

4.a.iv In the margin adaptive loading $y_k = b_p$ for all $k = 1, \ldots K$. In the rate adaptive loading $y_k = b_p$ for $(k-m)$ channels and $y_k = b_{p+1}$ for m channels such that the total rate per symbol period is

$$R_T = b_p (k-m) + b_p m.$$

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Examinations : **Mobile Radio Communication** **Session** **May 2011**

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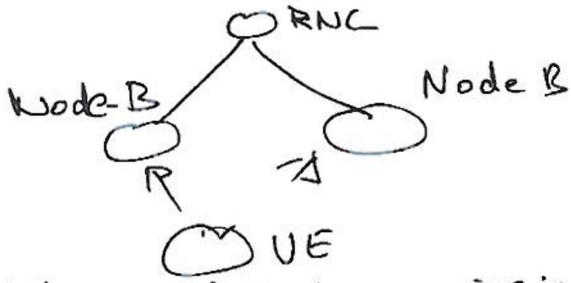
MODEL ANSWERs and MARKING SCHEME

First Examiner: **Gurcan, M.K.** **Paper Code : E4.03, SO10, ISE4.3**

Second Examiner: **Leung, K.K.** **Question** **Page** 9 ***out of*** 9

Question labels in left margin **Marks allocations in right margin**

4.b.i soft-Hand over



We receive transmissions from a single UE via two node B's and use the best.

4.b.ii A number of spreading channelization codes and a specific scrambling code per Node B are allocated. Each user selects one of the available codes. If the transmission is sucessful the acquisitron indicator channel is used to inform the user.

4.b.iii) Fento cells are introduced to provide a radio access over the internet for the 3G mobile networks. They provide short range coverage and are being rapidly deployed.

4.b iv) LTE systems will provide OFDM transmission and introduce frequency and time multiplexing to achieve very high downlink data rates.