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IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2003

MSc and EEE/ISE PART IV: M.Eng. and ACGI

MOBILE RADIO COMMUNICATION

Thursday, 8 May 10:00 am

Time allowed: 3:00 hours

There are FOUR questions on this paper.

Answer THREE questions.

Corrected Copy

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

Examiners responsible   First Marker(s) : M.K. Gurcan
                         Second Marker(s) : D.B. Ward

Special Instructions for Invigilators: None

Information for candidates:

1. a) Assume that a receiver is located at a distance $d_0 = 1$ km from a base station transmitting at a power of 10 W. If the carrier frequency is 900 MHz, free space propagation is assumed and the transmitter and receiver gains are $G_T = 1$, and $G_R = 2$ respectively, at the receiver antenna find

i) the free-space power, $P_{FSR}(d_0)$, and [3]

ii) the magnitude of the electric field, $E_{FSR}(d_0)$. [2]

b) Assume that in a mobile radio system, the area-mean-power, $P_{am}(R_1)$, at the cell boundary is 6.57×10^{-11} W, and $R_1 = 6$ km. The interference signal power, $6\,P_{am}(D)$, in the radio cell is constant and equal to 9.1×10^{-13} W. A mobile user is located R_2 km away from the base station and the received signal is subjected to randomly fluctuating shadowing losses as the mobile moves. The standard deviation, σ, of the log-normal shadowing loss is $\sigma = 3$ dB. The probability that the local-mean-power, $P_{lm}(R_2)$, will exceed a certain value γ is calculated from the cumulative distribution function using

$$\Pr\left(P_{lm}(R_2) > \gamma\right) = 1 - \frac{1}{2\sqrt{\pi}} \exp\left\{ -\left(\frac{10\log_{10} \frac{P_{am}(R_2)}{\gamma}}{\sigma\ \sqrt{2}} \right)^2 \right\}.$$

Find the maximum transmitter-receiver separation, R_2, that will ensure that a local-mean-power to interference-power ratio of 13 dB is provided for 95% of the time. [4]

c) Assume that in a narrow-band mobile radio system, the shadowing loss is 0 dB and the mobile is R_1 metres away from the base station and is moving at a steady speed of v m/s and receiving a signal with wavelength λ metres.

i) Describe how the statistical time varying nature of the received signal envelope can be expressed using the Rayleigh fading probability density function (PDF). [3]

ii) Show how the actual signal power, $P_i(R_1)$, can be related to the area mean power, $P_{am}(R_1)$, and the Rayleigh fading amplitude R. [3]

Question continued over

d) A narrow-band mobile radio system, subject to Rayleigh fading, uses differential binary phase-shift-keying modulation. As a function of the signal-to-noise ratio, X_a, the bit error probability, $P_e(X_a)$, is given by $P_e(X_a)=\frac{1}{2}\exp(-X_a)$. Show that the bit-error-probability is given by $P_e(X_R)=\frac{1}{2+2X_R}$ as a function of wanted-signal-area-mean power to total-interference-signal-power ratio, X_R. [5]

2. a) Describe

i) how the performance of a slotted Aloha multiple access scheme is stabilised by controlling the re-transmission probabilities of back-logged users, [2]

ii) why it is necessary to estimate the number of backlogged users in order to stabilise slotted Aloha systems, and [2]

iii) how the offered load-drift, dG, given by $dG = \dfrac{dn - G\,ds}{S_{k+1}}$ can be used to stabilise a slotted Aloha system at the optimum offered load. Assume that N_k and S_k respectively are the real and estimated numbers of backlogged users and that $G_k = \dfrac{N_k}{S_k}$. Assume also that the terms dn and ds correspond to the real and estimated drifts respectively. [3]

b) Assume that the joint-drift, dj, is related to the offered-load-drift by $dj = S_{k+1}\,dG$. State the limiting values of the joint drift equation $dj(G)$ for $G = 0$ and $G = \infty$. Comment on the results if the control parameter u_c (i.e the number of corrections applied to the estimated number of users when there is a collision), satisfies the condition $u_c > \lambda$. [5]

c) If the joint drift equation $dj(G) = 0$ has three roots, discuss under what condition the largest root might result in an unstable Aloha system. Comment on the real number of users in the system for this case. [4]

d) In a mobile radio system a circular radio cell of radius 450m is used. There are 1600 mobile users in an area of 20000 m^2 and 12 percent of the mobile users are active during a one hour period. Determine

i) the call arrival rate per second for the access control scheme, and [2]

ii) the call arrival rate per slot, assuming a slotted Aloha system with packet duration of 100 ms is used. [2]

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3. a) Explain

i) why equalisers are required in wideband radio transmission systems, and [2]

ii) how the equaliser coefficients are calculated using training sequences employed in a GSM radio system. You may assume that the channel introduces intersymbol interference and suffers from additive white Gaussian noise. [2]

b) Discuss the advantages and disadvantages of using

i) *linear equalisers,* [2]

ii) *decision feedback equalisers* and [2]

iii) *maximum likelihood sequence detectors.* [2]

in wideband mobile radio systems.

c) The cell radius of a mobile radio system is $R_1 = 1000$ m. When a narrow-band radio system is used the system operates with the required signal-to-noise ratio $X_R(R_1)$=875 and provides 20 simultaneous conversations in each cell. The narrow-band system will be replaced with a wide-band system that is time-shared between eight users and covers eight times the transmission bandwidth of the narrow-band system. Both the wide-band and the narrow-band systems have the same transmitter powers, the same transmitter and receiver antenna gains of unity, and the same desired signal-to-noise ratios $X_D(R_2)$=13 dB. Assuming that the wideband system achieves the desired signal-to-noise ratio at $R_2 = 970$ m when the equaliser gain, c_0, is 0.8 find

i) the total number of channels available with the narrow-band system, [2]

ii) the number of simultaneous conversations the wide-band system can provide for the same total number of physical channels. [3]

Question continued over

d) In a wide-band mobile radio system, the base-station transmits uncorrelated data signals. A channel, with an impulse response $\boldsymbol{h} = [0.845 \quad 0.507 \quad 0.169]^T$, introduces intersymbol interference for the received signal. The ratio of area-mean-power-to-total-interference-power is equal to 13 dB at the cell boundary. A minimum-mean-square-error decision-feedback-equaliser (DFE) is used to equalise the received signal. The equaliser feedforward and feedback coefficients are $\boldsymbol{c} = [-0.0094 \quad 0.0477 \quad 1.081]^T$ and $\boldsymbol{b} = [-0.5561 \quad -0.1827]^T$ respectively. Find the signal-to-noise ratio at the output of the equaliser and the corresponding equaliser gain c_0. [5]

4) a) In connection with the Global Systems Mobile (GSM) radio system, describe

i) the framing structure for the control channels, [2]

ii) how the network switching subsystem is modified to handle packet transmission for use in the General Packet Radio Service (GPRS). [2]

b) Describe how new sets of logical channels are used as part of GPRS in the phase-two GSM specifications in the case of

i) the packet common control channel, [1]

ii) the packet broadcast control channel, [1]

iii) the packet data traffic channel. [1]

c) For the third generation wideband UTRA/FDD radio system, outline

i) the orthogonal variable spreading factor codes, [1]

ii) the physical layer structure, paying particular attention to:

- how the uplink modulation and scrambling are organised to minimise the audible interference from the terminal transmission, [2]
- the transport channels:
  - ♦ the dedicated transport channel, [1]
  - ♦ the downlink shared common transport channel. [1]

iii) The downlink frame structure, paying particular attention to the DPCCH / DPDCH structure. [2]

iv) the downlink multiplexing and channel coding, paying particular attention to

- the transport block concatenation, [1]
- the downlink channel coding, [1]
- the frame equalisation, [1]
- the interleaving, [1]
- the radio frame segmentation, [1]
- the rate matching. [1]