The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2013-14 (2.0 hours)

EEE6431 Broadband Wireless Techniques

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

Data Provided: Q-Function on Page 5

1. **a.** Name the main functional blocks of a digital wireless communication system. Use a schematic diagram to illustrate your answer.

Now explain the purpose of the following functions:

i. Channel coding;
ii. Modulation. **(5)**

b. How is received power related to range and carrier frequency in the free-space pathloss model?

A mobile located at 5 km from a base station transmitting on a radio carrier frequency of 2 GHz achieves reliable communication when the received power is 10 dB above the noise floor of -105 dBm. What minimum power in watts is required at the transmitter? Assume a free-space pathloss and the use of isotropic transmit and receive antennas. **(5)**

c. What are the main differences between the 2-ray ground and free space pathloss propagation models?

The dB pathloss formula for the 2-ray ground propagation model is given by:

$$P_L\ (\mathrm{dB}) = 40\log d - 20\log h_t - 20\log h_r - 10\log G_t - 10\log G_r\,,$$

where d, h_t, h_r, G_t and G_r take their normal meanings. Using the transmit power calculated in Part 1(b), would the same mobile achieve reliable communication if the 2-ray pathloss model is used instead of the free-space pathloss model? For your calculations use $h_t = 20$m and $h_r = 2$m. **(5)**

d. What is shadow fading?

Find the outage probability due to shadow fading for the mobile in Part 1(c) for a shadow fading standard deviation of 10 dB. Comment on your answer.

(5)

2. **a.** How does multipath propagation lead to time varying constructive and destructive interference in the mobile radio channel?

The pdf of a narrowband Rayleigh faded signal envelope r is given by:

$$P_R(r) = \frac{2r}{\bar{P}_r} exp\left(-\frac{r^2}{\bar{P}_r}\right)$$

where $\bar{P}_r$ is the average received power. Derive an expression for the pdf of the received signal power. **(5)**

b. The bit error rate (BER) of a narrowband mobile radio system is considered to be acceptable when the received power is greater than one fifth of its average power. What is the probability that the system will experience unacceptable bit errors if the received signal envelope experiences narrowband Rayleigh fading?

Explain why we might expect the probability of error to be less if the received signal envelope experiences narrowband Rician fading. **(5)**

c. What is meant by the coherence bandwidth of a wideband frequency selective channel?

Calculate the 50% coherence bandwidth of the discrete time channel impulse response shown in Table 2(c).

Discrete-Time CIR	
Excess Delay (μs)	Path Power (dBr)
0	0
1	-3
2	0
4	-3
8	-6

Table 2(c)

(6)

d. What is meant by the coherence time of a faded radio signal?

Now calculate the 50% coherence time of a mobile travelling at 50 km/h in a 2 GHz mobile radio system. **(4)**

3. **a.** What is the optimum power adaptation policy to maximise the capacity of a discrete-time channel that has stationary and ergodic time-varying channel power gains $g[i]$ at discrete times i. **(3)**

b. Consider a narrowband discrete-time channel with independent and identically distributed channel power gains $g[i]$, $i = 1, 2, 3$, which can take on the 3 possible values:

$g[1] = 0.2$ with probability $P_1 = 0.2$;

$g[2] = 1.5$ with probability $P_2 = 0.5$;

$g[3] = 0.9$ with probability $P_3 = 0.3$.

If a transmitter and receiver have knowledge of the instantaneous values of $g[i]$, find the ergodic capacity of the channel when the average transmit power is 200 mW, the 1-sided noise PSD is 10^{-9} W/Hz and the channel bandwidth is 20 MHz. **(7)**

c. Compare your answer in Part 3(b) with:

i. The ergodic capacity when the channel power gains are only known at the receiver, and;

ii. The Shannon capacity of an additive white Gaussian noise (AWGN) channel.

Comment on your answers. **(6)**

d. What are the optimal power allocations that achieve the ergodic capacity in Part 3(b)? **(4)**

4. **a.** Why are multicarrier (MC) modulation techniques used in wideband frequency selective fading channels?

Draw and label a schematic diagram of a MC transmitter based on the OFDM (orthogonal frequency division multiplexing) technique.

Now explain the purpose of the cyclic prefix in OFDM. **(5)**

b. The IEEE 802.11a standard for wireless local area networks is based on OFDM. Briefly describe the main physical layer features of this standard.

From your description, show how the data rates of 12, 24 and 54 Mbit/s are realised in the standard. **(5)**

c. Direct sequence spread spectrum (DSSS) typically uses binary spreading sequences in order to combat intersymbol interference (ISI) on a wideband frequency selective fading channel. What properties should a spreading sequence possess in order to minimise the ISI?

Now design a length 3 binary bipolar spreading sequence which has optimal ISI minimising properties. **(5)**

d. What is a RAKE receiver?

Using your length 3 spreading sequence from Part 4(c) design a suitable RAKE receiver for the channel impulse response shown in Figure 4(d). Assume a chipping rate of 1 Mchip/s.

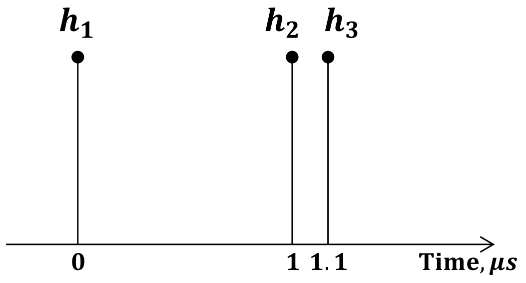


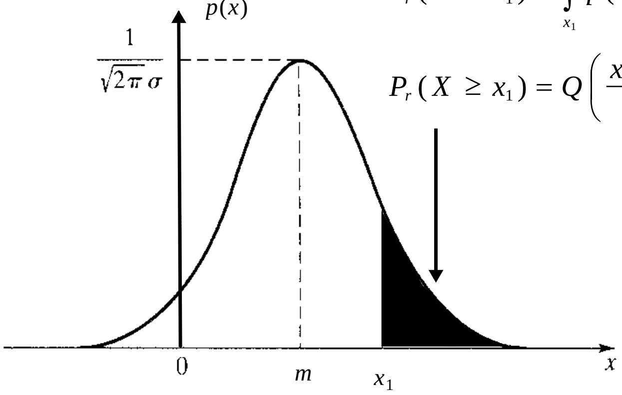
Figure 4(d)

(5)

TOF/GGC

EQUATION SHEET

- **Gaussian pfd and graphical Q-Function:**



$$P_r(X \geq x_1) = \int_{x_1}^{\infty} p(x)\,dx$$

$$P_r(X \geq x_1) = Q\left(\frac{x_1 - m}{\sigma}\right)$$