Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
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FACULTY OF SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS

SCHOOL OF ENGINEERING

Electronic and Electrical Engineering

Engineering MSc | **Semester 1, 2023**

Digital Wireless Communications : Sample question paper

DD/MM/YY | **RDS - Simmonscourt** | **14:00–16:00**

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Instructions to Candidates:
Answer all four questions. All questions carry equal marks.

For creating graphs, only consider the essential data points.

Materials permitted for this examination:
Calculator, drawing instruments, and mathematical tables.

Q.1 **[Total: 25 marks]**

(a) Describe the role and importance of a pulse-shaping filter in digital communication systems. Explain how this filter aids in signal transmission and reception. Provide specific examples of situations where the implementation of pulse-shaping filters significantly enhances communication system performance.

[7 marks]

(b) Given a digital stream generating at 8 kbits/second and a system with a maximum transmission rate of 4 ksymbols/second:

(i) Choose an appropriate digital modulation scheme for this transmission scenario.

(ii) Calculate the necessary bandwidth using the chosen modulation scheme, considering two pulse shaping filters:

- An ideal low-pass filter (LPF).
- A raised cosine pulse with 60% excess bandwidth.

(iii) Determine the bandwidth requirement if 16-QAM is utilized with the raised cosine filter mentioned previously.

(iv) Discuss a potential drawback associated with implementing 16-QAM modulation in this context

[12 marks]

(c) Explain the concepts of Inter-symbol interference and cochannel Interference.

[6 marks]

Q.2 **[Total: 25 marks]**

(i) The base station of a CDMA communication system uses maximal-length sequences to perform direct sequence spread spectrum (DSSS) on data transmitted to mobile stations. The base station transmits the information to six mobile stations simultaneously using the same carrier frequency and six different orthogonal maximal-length sequences. The sequences are generated using feedback shift registers of length m = 4. The spreading factor (N) is equal to the length of the spreading sequences. The base station transmits with a power of 30 dBm per user. The channel is considered an AWGN channel with power noise density = ${N_0}/{2} = 10^{-13} W/Hz$ W/Hz. The receiver of each mobile station is a CDMA single-user detector where the Signal-to- Interfere-and-Noise Ratio (SINR) is given by

$$SINR = \frac{GP_n}{GN_0W + \sum_{k \neq n} P_k}$$

where P_n is the power of the received signal of interest, P_k is the received power for the K^{th} user, and G is the processing gain ($G = N$).

a) What is the value of the spreading factor N? **[2 marks]**

b) What is the bandwidth of the signal before and after the spreading action, if each channel has a transmit rate of 750 kbit/s using 8-PSK modulation and a raised cosine filter with 50% excess bandwidth as pulse shape? **[6 marks]**

c) Assuming an attenuation of 25 dB on the received signal for each user, what is the maximum transmit data rate that can be achieved for the down-link communication for each user? For the same spreading factor calculated in 1 a): **[6 marks]**

d) Calculate the maximum number of CDMA users in the down-link to ensure a transmit data rate of 750 kbit/s. **[3 Marks]**

e) Repeat the calculation in 1 d) if 64-QAM is used instead. **[3 Marks]**

(ii) Draw a signal space diagram for the following constellations and their receiver decision areas: a) BPSK b) QPSK c) 4-PAM d) 4-QAM e) 8-PSK f) 16-QAM. **[5 Marks]**

Q.3 **[Total: 25 marks]**

(a) Consider a CDMA system with 3 users transmitting BPSK (i.e. levels -3 -1 and 1) over an AWGN channel. The users are assigned spreading sequences of unit energy corresponding to the following binary sequences shaped as antipodal rectangular pulses:

$$c_1 = [\,1\,,1,1,1,1,1\,],$$

$$c_2 = [\,1,0,1,0,1,0\,].$$

(i) Are the spreading codes c_1 and c_2 orthogonal to each other?
(ii) Find a spreading code orthogonal to c_1 and c_2 for the third user.
(iii) Assuming perfect synchronization, given the sampled sequence at the receiver as

$$r_n = [\,0.01\,,0.03\,,-0.87\,,0.71\,,-0.11\,,0.4]$$

decide the symbols transmitted by each user by using the method of maximum-likelihood.

[25 mark]

Q.4 **[Total: 25 marks]**

(a) Considering simultaneous transmission of a QPSK signal with the rate of 2 bit per second at frequencies $f_1 = 1000\,\mathrm{kHz}$, $f_2 = 2000\,\mathrm{kHz}$, $f_3 = 4\,\mathrm{kHz}$, and $f_4 = 8000\,\mathrm{kHz}$, over a channel with the noise variance of $\sigma^2 = 10^{-3}$ and the following response,

$$|H(f)|^2 = 0.8\left(\sin\left(\frac{(4000 - f)\pi}{4000}\right) + 1\right)$$

(i) Sketch the channel response.

(ii) What is the output SNR (in dB) associated with the maximal-ratio combiner?

(iii) What is the output SNR (in dB) associated with the selection combiner?

(iv) What is the output SNR (in dB) associated with the equal-ratio combiner?

[18 marks]

(b) Define and explain the concepts of coherence time and coherence bandwidth in the context of wireless communication channels, particularly in relation to fading phenomena. **[7 marks]**