GLASGOW COLLEGE UESTC

Final Exam Paper

Mobile Communications (UESTC 4017)

Date: Jan.6th, 2022
Time: 0930-1130am

Attempt all PARTS. Total 100 marks

Use one answer sheet for each of the questions in this exam.
Show all work on the answer sheet.

Make sure that your University of Glasgow and UESTC Student Identification Numbers are on all answer sheets.

An electronic calculator may be used provided that it does not allow text storage or display, or graphical display.

All graphs should be clearly labelled and sufficiently large so that all elements are easy to read.

The numbers in square brackets in the right-hand margin indicate the marks allotted to the part of the question against which the mark is shown. These marks are for guidance only.

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Q1 (a) 5G network has three use case categories, i.e., enhanced mobile broadband (EMBB), massive machine type communication (MMTC) and ultra-reliable and low latency (URLLC), respectively. At the same time, there are several key capabilities required to 5G new radio, i.e., peak data rate, spectrum efficiency, mobility, connection density, energy efficiency, latency, etc.

(i) Assume a scenario that users at different places take the advantage of 5G virtual reality (VR) equipment to attend a concert simultaneously, clarify what kind of the use case this scenario belongs to. List at least two key capabilities/features with the relatively high importance required for this 5G scenario, and give your reasons. [6]

(ii) Assume a scenario that a doctor takes the advantage of 5G augmented reality (AR) service to control a remote surgical machine for the patient. List at least two key capabilities/features with the relatively high importance required for this 5G scenario, and give your reasons. [4]

(b) Multiple input multiple output (MIMO) system can achieve either spatial-diversity gain (i.e., better BER performance) or spatial-multiplex gain (i.e., higher data rate) compared to the single input single output (SISO) system.

(i) What kind of the performance gain for the space-time block code (STBC) system can achieve? Give the reason why this system can achieve this performance gain compared to SISO system. [4]

(ii) What kind of the performance gain for the Bell lab layered space time (BLAST) system can achieve? Give the reason why this system can achieve this performance gain compared to SISO system. [4]

(c) Assume a π/4−DQPSK modulator with an initial phase $\theta_0 = 0$ as the initial constellation state S_0. The bit mapping rule for π/4−DQPSK modulation is shown in ***TableQ1.*** If the input bits for the modulator are [-1, 1, 1, -1, -1, 1] (the first and last input bit as -1 and 1, respectively).

(i) Determine the output phase/state sequence of the above input bits. [3]

(ii) Draw the constellation state transition path on the constellation diagram of ***Fig. Q1***. [2]

(iii) Find the maximum phase shifting of the output state sequence. [2]

Table Q1

Input bits (S_I, S_Q)	+1, +1	-1,1	-1, -1	+1, -1
Phase difference ψ_k	$\pi/4$	$3\pi/4$	$-3\pi/4$	$-\pi/4$

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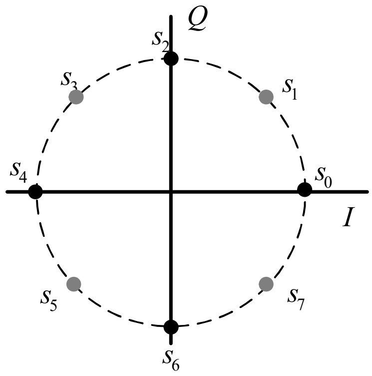

Figure Q1 . Constellation diagram of π/4-DQPSK

Q2 Figure Q2 shows a scaled power delay profile of the 3-tap multipath channel measured with carrier frequency of $f_c = 900MHz$.

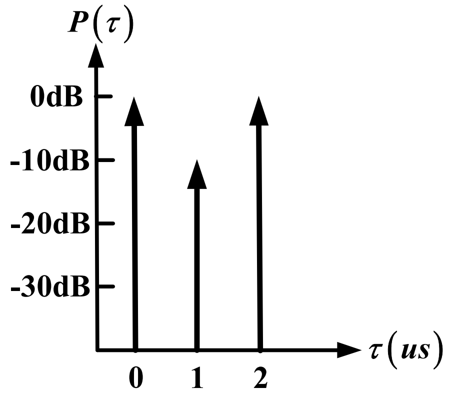

Figure Q2 Power delay profile of the multi-path channel

(a) If a single-carrier signal with bandwidth of $B_s = 500$ KHz is transmitted over this channel, discuss whether this signal will be distorted by the multi-path channel. [10]

(b) If a mobile terminal moving with a speed of 30 km/hr receives a signal through the above channel, discuss the time-domain sampling interval (or sampling rate) to ensure the adjacent samples highly correlated. [7]

(c) If an *M*-QAM OFDM signal with $N = 32$ subcarriers and $\Delta f = 156.25KHz$ subcarrier interval is transmitted over this multi-path channel.

(i) Find the bandwidth of the OFDM signal and discuss the length of cyclic prefix (CP) required here to avoid ISI. [4]

(ii) Discuss the modulation order (i.e., the value of *M*) to ensure the bit rate $R_b \geq 20Mbps$. [4]

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Q3 Assume a communication system shown in Fig.Q3, where at position A, a transmitter is transmitting signals with power $P_t = 3000$ W, the antenna gain $G_t = G_r = 1$, and the carrier frequency $f_c = 1000$ MHz. The path loss from A to B is 50dB, and the average receiving power at position B is 14.8dBm.

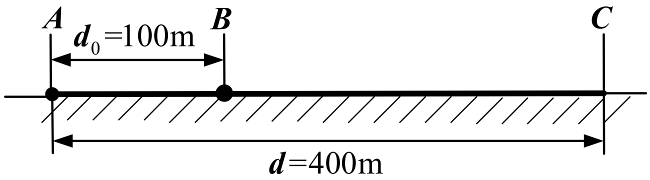

Figure Q3 The location of transceivers

(a) Discuss whether the signal experiences free space propagation from transmitter A to receiver B. [6]

(b) If the path loss between position B and position C is exponential growth with propagation exponent $n = 3$, find the average received power at position C and the total path loss from A to C. [8]

(c) Assume the signal bandwidth is $B_s = 30KHz$ and the power spectrum density of addictive white Gaussian noise (AWGN) is $N_0 = 10^{-6}$ mW/Hz.

(i) Determine the received SNR in dB at position C. [5]

(ii) If the transmitting signal at position A is 16-QAM symbols, determine the E_s, $\frac{E_b}{N_0}$ and $\frac{E_s}{N_0}$ of the transmitting signal, respectively. [6]

Q4 Assume a cellular system is transmitting single-carrier signals with system spectrum of 890-940MHz, where the system spectrum is divided into multiple sub-channels which are assigned to a cluster of cells so that co-channel interference is minimized. The bandwidth of each sub-channel is 250kHz.

(a) Assume the system is with edge-excited cells, which uses three sectored (or directional) antennas of 120° to cover each cell area. If the *C/I* should be larger than 12dB, the propagation factor *n*=3, please calculate the cluster size *N* to satisfy the *C/I* requirement. Note: *C/I* is the carrier-to-interference ratio, where *C* is the desired signal power from the desired base station at the desired carrier frequency, *I* is the sum of the interference's power caused by co-channel cell/base stations at the same carrier frequency. [8]

(b) Draw a cell allocation pattern according to your selected cluster size in question Q4(a). At least three adjacent clusters should be shown here. You can use the capital letters (like A, B, C, D, E…, etc.) to label the co-channel cells. [7]

(c) If this cellular system is adopted with frequency division duplex (FDD) mode that the uplink channels and downlink channels are allocated on the spectrum of 890-

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905MHz and 915-940MHz, respectively. Find the number of total channels (i.e., the available channels per cluster), the uplink capacity (i.e., the available channels per cell) and downlink capacity (i.e., the available channels per cell), respectively. [6]

(d) If the system in (c) further splits each channel into 4 time slots, find the number of total sub-channels per cluster, the uplink capacity (i.e., the available sub-channels per cell) and downlink capacity (i.e., the available sub-channels per cell), respectively. [4]

End of question paper