CITY UNIVERSITY OF HONG KONG

Course code & title	:	EE3008 Principles of Communications
Session	:	Semester A 2020/21
Time allowed	:	Two hours

This paper has SEVEN pages (including this cover page).

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1. This is Part I of the exam, which consists of 4 questions.
2. Answer <u>ALL</u> questions.
3. Please carefully read the instructions on the next page.

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*This is an **open-book** examination.*

Candidates are allowed to use the following materials/aids:

Approved calculator and course materials

Materials/aids other than those stated above are not permitted. Candidates will be subject to disciplinary action if any unauthorized materials or aids are found on them.

Please call the departmental hotline 3442-7740 for emergent issues.

Please note that the final exam of EE3008 has two parts:

1. Part I starts at 6:30pm and ends at 8:12pm. Part II starts at 8:12pm and ends at 8:30pm.
2. The question list of Part I will be released on the canvas course website under \Files\Exam_Q.pdf at 6:30pm. Please submit your solution on the canvas course website under \Assignments\Exam before 8:40pm.
3. The question list of Part II will be released on the canvas course website under \Quizzes\Exam -- Part II at 8:12pm. Please finish answering 15 multiple-choice questions within 18 minutes.
4. Please clearly write down your steps. Showing only the final result without any justification will receive zero marks.
5. Please do NOT share your solution with others. Identical answers will lead to disciplinary actions to ALL the involved parties.
6. About the online submission of your solution to Part I:
    a. Please submit your solution in a single pdf or jpeg file.
    b. At the end of the exam, you'll have 10 minutes for uploading your solution. The website will be closed at 8:40 pm.
    c. No email submission will be accepted. Late submission will receive zero marks.

Please review the following honor pledge statement. Submit the honor pledge statement with your name, signature and date along with the answer sheet.

Honor Pledge

I pledge that the answers in this exam are my own and that I will not seek or obtain an unfair advantage in producing these answers. Specifically,

1. *I will not plagiarize (copy without citation) from any source;*
2. *I will not communicate or attempt to communicate with any other person during the exam/quiz; neither will I give or attempt to give assistance to another student taking the exam/quiz; and*
3. *I will use only approved devices (e.g., calculators) and/or approved device models.*
4. *I understand that any act of academic dishonesty can lead to disciplinary action.*

So Chuen

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Question 1 (28 marks)

A sinusoidal test signal is applied to an FM system and the modulated signal is given by:

$$s_{FM}(t) = 100\cos[10^7 \pi t + 2\sin(2000\pi t)].$$

1. Determine the peak frequency deviation, the modulation index, and the effective bandwidth of the modulated signal by using Carson's rule. (6 marks)
2. Determine the output power at 5.05 MHz and 4.998 MHz. (4 marks)
3. Increase the peak amplitude of the sinusoidal test signal until the first sidebands of the modulated signal disappear. Determine the required channel frequency range for including 98% in-band power of the modulated signal. (5 marks)
4. Apply the sinusoidal test signal to an AM-DSB-C modulator. Compared to the FM modulated signal (i.e., given in Q1.3), it is found that the output power of the AM-DSB-C system is twice of that of the FM system, and the magnitude of each sideband in the AM-DSB-C system is equal to that of each second sideband in the FM system.
    1. Determine the modulation index of the AM-DSB-C system. (5 marks)
    2. Specify whether the AM-DSB-C modulated signal can be properly detected by an envelope detector. If yes, sketch and label the output waveform of the envelope detector. If no, determine the minimum dc offset for the envelope detector to properly work. (8 marks)

Question 2 (24 marks)

A full-scale audio signal is sampled at the Nyquist sampling rate and then applied to a 4-bit Midriser with the dynamic range from -4 V to 4 V. The audio signal has a constant power spectral density of 0.5 W/kHz and its peak-to-rms ratio, i.e., the ratio of the peak amplitude to the square root of signal power, is measured to be 3 dB.

1. Determine the step size, the maximum quantization error, the quantization noise power, and the number of quantization levels of the Midriser. (4 marks)
2. Determine the output bit sequence of sampled values (-0.18 V, 1.61 V, 2.12 V) using Gray coding. Show your detailed steps, including the quantized values assigned to each sample. (6 marks)
3. Determine the SQNR in dB. (5 marks)
4. Determine the bit rate of the bit stream. (4 marks)
5. Suppose that 10 such audio signals, each sampled, quantized and modulated, are sent to a central station with time-division multiplexing (TDM) over a channel with frequency range of [0, 200 kHz]. What modulation scheme should be adopted to ensure 90% in-band power? State your reason. (5 marks)

Question 3 (18 marks)

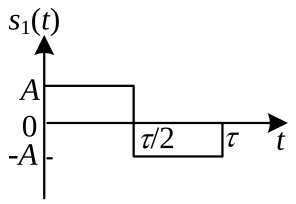
A bit stream is modulated by using QPSK and transmitted over an AWGN channel of bandwidth 200 kHz with 90% in-band power. At the receiver side, the two-sided noise power spectral density is found to be 10^{-6} W/Hz, and the BER is found to be 10^{-5} with the optimal receiver adopted.

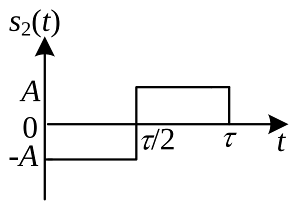
1. Determine the symbol rate, SER and received signal power. (7 marks)
2. If the channel frequency range is allocated to [0, 200 kHz], can the modulated signal pass through the channel with 95% in-band power? State your reason. (3 marks)
3. If your answer to Q3.2 is yes, determine the maximum bit rate that can be supported by the channel. Otherwise, provide one modulation scheme that can achieve it, with justifications. In both cases, determine whether a BER of $5\text{x}10^{-6}$ can be achieved when the received signal power is increased by 4 dB. (8 marks)

Question 4 (15 marks)

Consider the following binary signaling systems where digital waveforms $s_1(t)$ and $s_2(t)$ are used to represent bits "1" and "0", respectively. They operate on an AWGN channel with the two-sided noise power spectral density 10^{-6} W/Hz. Assume τ=1 μs, and A=4 V. For each of them, sketch and label the optimal receiver, and determine the corresponding BER.

1.





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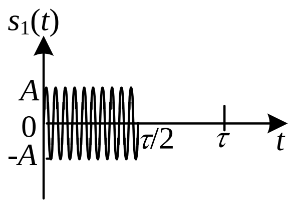

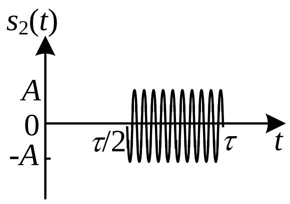

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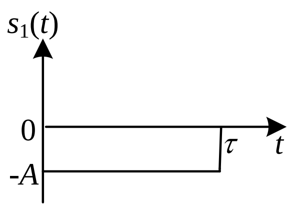

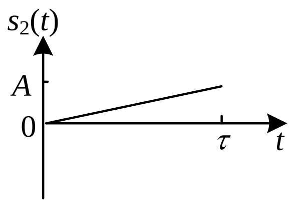

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Appendix I

Table 6-1 Values of Bessel Function of the First Kind $J_n(\beta)$ for Various Values of n and β

n	$\beta = 1$	$\beta = 2$	$\beta = 3$	$\beta = 4$	$\beta = 5$	$\beta = 6$	$\beta = 7$	$\beta = 8$	$\beta = 9$
0	0.7652	0.2239	−0.2601	−0.3971	−0.1776	0.1506	0.3001	0.1717	−0.0903
1	0.4401	0.5767	0.3391	−0.0660	−0.3276	−0.2767	−0.0047	0.2346	0.2453
2	0.1149	0.3528	0.4861	0.3641	0.0466	−0.2429	−0.3014	−0.1130	0.1448
3	0.0196	0.1289	0.3091	0.4302	0.3648	0.1148	−0.1676	−0.2911	−0.1809
4	0.0025	0.0340	0.1320	0.2811	0.3912	0.3576	0.1578	−0.1054	−0.2655
5	0.0002	0.0070	0.0430	0.1321	0.2611	0.3621	0.3479	0.1858	−0.0550
6	*	0.0012	0.0114	0.0491	0.1310	0.2458	0.3392	0.3376	0.2043
7	*	0.0002	0.0025	0.0152	0.0534	0.1296	0.2336	0.3206	0.3275
8	*	*	0.0005	0.0040	0.0184	0.0565	0.1280	0.2235	0.3051
9	*	*	0.0001	0.0009	0.0055	0.0212	0.0589	0.1263	0.2149
10	*	*	*	0.0002	0.0015	0.0070	0.0235	0.0608	0.1247
11	*	*	*	*	0.0004	0.0020	0.0083	0.0256	0.0622
12	*	*	*	*	0.0001	0.0005	0.0027	0.0096	0.0274
13	*	*	*	*	*	0.0001	0.0008	0.0033	0.0108
14	*	*	*	*	*	*	0.0002	0.0010	0.0039
15	*	*	*	*	*	*	0.0001	0.0003	0.0013
16	*	*	*	*	*	*	*	0.0001	0.0004
17	*	*	*	*	*	*	*	*	0.0001
18	*	*	*	*	*	*	*	*	*
19	*	*	*	*	*	*	*	*	*

TABLE I.1 Values of $Q(x)$ versus x.

	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641
0.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
0.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
0.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
0.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
0.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
0.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
0.7	.2420	.2389	.2358	.2327	.2296	.2266	.2236	.2206	.2177	.2148
0.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
0.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
2.3	.0107	.0104	.0102	.00990	.00964	.00939	.00914	.00889	.00866	.00842
2.4	.00820	.00798	.00776	.00755	.00734	.00714	.00695	.00676	.00657	.00639
2.5	.00621	.00604	.00587	.00570	.00554	.00539	.00523	.00508	.00494	.00480
2.6	.00466	.00453	.00440	.00427	.00415	.00402	.00391	.00379	.00368	.00357
2.7	.00347	.00336	.00326	.00317	.00307	.00298	.00289	.00280	.00272	.00264
2.8	.00256	.00248	.00240	.00233	.00226	.00219	.00212	.00205	.00199	.00193
2.9	.00187	.00181	.00175	.00169	.00164	.00159	.00154	.00149	.00144	.00139

TABLE I.2 Values of $Q(x)$ for Large x.

x	10 log x	$Q(x)$	x	10 log x	$Q(x)$	x	10 log x	$Q(x)$
3.00	4.77	1.35E-03	4.00	6.02	3.17E-05	5.00	6.99	2.87E-07
3.05	4.84	1.14E-03	4.05	6.07	2.56E-05	5.05	7.03	2.21E-07
3.10	4.91	9.68E-04	4.10	6.13	2.07E-05	5.10	7.08	1.70E-07
3.15	4.98	8.16E-04	4.15	6.18	1.66E-05	5.15	7.12	1.30E-07
3.20	5.05	6.87E-04	4.20	6.23	1.33E-05	5.20	7.16	9.96E-08
3.25	5.12	5.77E-04	4.25	6.28	1.07E-05	5.25	7.20	7.61E-08
3.30	5.19	4.83E-04	4.30	6.33	8.54E-06	5.30	7.24	5.79E-08
3.35	5.25	4.04E-04	4.35	6.38	6.81E-06	5.35	7.28	4.40E-08
3.40	5.31	3.37E-04	4.40	6.43	5.41E-06	5.40	7.32	3.33E-08
3.45	5.38	2.80E-04	4.45	6.48	4.29E-06	5.45	7.36	2.52E-08
3.50	5.44	2.33E-04	4.50	6.53	3.40E-06	5.50	7.40	1.90E-08
3.55	5.50	1.93E-04	4.55	6.58	2.68E-06	5.55	7.44	1.43E-08
3.60	5.56	1.59E-04	4.60	6.63	2.11E-06	5.60	7.48	1.07E-08
3.65	5.62	1.31E-04	4.65	6.67	1.66E-06	5.65	7.52	8.03E-09
3.70	5.68	1.08E-04	4.70	6.72	1.30E-06	5.70	7.56	6.00E-09
3.75	5.74	8.84E-05	4.75	6.77	1.02E-06	5.75	7.60	4.47E-09
3.80	5.80	7.23E-05	4.80	6.81	7.93E-07	5.80	7.63	3.32E-09
3.85	5.85	5.91E-05	4.85	6.86	6.17E-07	5.85	7.67	2.46E-09
3.90	5.91	4.81E-05	4.90	6.90	4.79E-07	5.90	7.71	1.82E-09
3.95	5.97	3.91E-05	4.95	6.95	3.71E-07	5.95	7.75	1.34E-09