University of Oulu
Department of Communications Engineering

WIRELESS COMMUNICATIONS I (521320S)
1. Intermediate exam 31.10.2014 (Based on parts 1-6 of the course, answer in English or in Finnish, no material is allowed)

1. Explain briefly but in detail, what is meant with
   a) Modulator
   b) DPSK
   c) PAM
   d) QAM
   e) You are using 8-level PSK in your system. How many bits you send in one symbol?
   f) Which factors have effect on the spectrum of digitally modulated signal?

2. a) Draw the block diagram of optimal receiver implemented with matched filters in AWGN channel, when the transmitted signals are $s_i(t)$, $i = 1, 2$. Explain in detail, how the receiver works.
   b) Compare roughly the bit error rate performances of coherent binary PSK and FSK modulations both in AWGN channel and in Rayleigh fading channel (no need for equations).

3. a) Assume that bit error probability equation $P_b(\gamma)$ for used modulation method in AWGN channel is known. How it is obtained bit error probability in fading channel?
   b) What means diversity and what methods exist for that?
   c) What kind of combining methods exists and which one has the best performance?

4. For a multipath fading channel let a scattering function $S_c(\tau,\rho)$ is nonzero over $0 \leq \tau \leq 10$ μs and $-3000 \leq \rho \leq 3000$ Hz. Assume that the power of the scattering function is approximately uniform over the range where it is nonzero.
   a) What are the multipath spread and the Doppler spread of the channel? **Explain** what the meaning of these spreads is.
   b) Suppose you input to this channel two identical sinusoids. What is the minimum value of Δf for which the channel response to the first sinusoid is approximately independent of the channel response to the second sinusoid? **Explain** you answer.
   c) For two sinusoidal inputs to the channel $u_1(t) = \sin 2\pi ft$ and $u_2(t) = \sin 2\pi f(t + \Delta t)$, what is the minimum value of Δt for which the channel response to $u_1(t)$ is approximately independent of the channel response to $u_2(t)$? **Explain** you answer.
   d) Will this channel exhibit flat fading or frequency-selective fading for channel with a 2 kHz bandwidth? How about for a channel with a 400 kHz bandwidth? **Explain** you answer.
   e) Assume that $BT_s \approx 1$. Is there fast fading, if we use these bandwidths? **Explain** you answer.

5. You are travelling from Rovaniemi to Helsinki without any hurry in four days. In the map in Fig. 1, you can find the possible routes. You will stay overnight as follows:
   1. night: Oulu or Kuusamo
   2. night: Vaasa or Joensuu
   3. night: Turku or Tampere.

   Select the **shortest** route using **Viterbi** algorithm (4 p). Draw enough intermediate steps so that the Viterbi algorithm idea can be easily seen. What is the length of the route (1 p) and which places you will visit (1 p)?

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WIRELESS COMMUNICATIONS I (521320S)
Final exam 31.10.2014 (Based on all parts of course, answer in English or in Finnish, no material is allowed)

1. Explain briefly but in detail, what is meant with
   a) Modulator
   b) DPSK
   c) PAM
   d) Unbiased estimate
   e) RAKE receiver
   f) Spreading code

2. a) What is phase locked loop and how it is used in synchronization?
   b) Principle of multicarrier transmission

3. a) Assume that bit error probability equation $P_b(\gamma)$ for used modulation method in AWGN channel is known. How it is obtained bit error probability in fading channel?
   b) What means diversity and what methods exist for that?
   c) What kind of combining methods exists and which one has the best performance?

4. A CDMA system consists of 10 equal-power users that transmit information at a rate 20 kbits/s, each using a DS spread spectrum signal operating at a chip rate of 1 MHz. The modulation is binary PSK.
   a) Determine the ε_b/J_0, where J_0 is the spectral density of the combined interference.
   b) What is the processing gain?
   c) How much should the processing gain be increased to allow for doubling the number of users without affecting the output SNR?

5. You are travelling from Rovaniemi to Helsinki without any hurry in four days. In the map in Fig. 1, you can find the possible routes. You will stay overnight as follows:
   1. night: Oulu or Kuusamo
   2. night: Vaasa or Joensuu
   3. night: Turku or Tampere.

   Select the **shortest** route using **Viterbi** algorithm (4 p). Draw enough intermediate steps so that the Viterbi algorithm idea can be easily seen. What is the length of the route (1 p) and which places you will visit (1 p)?

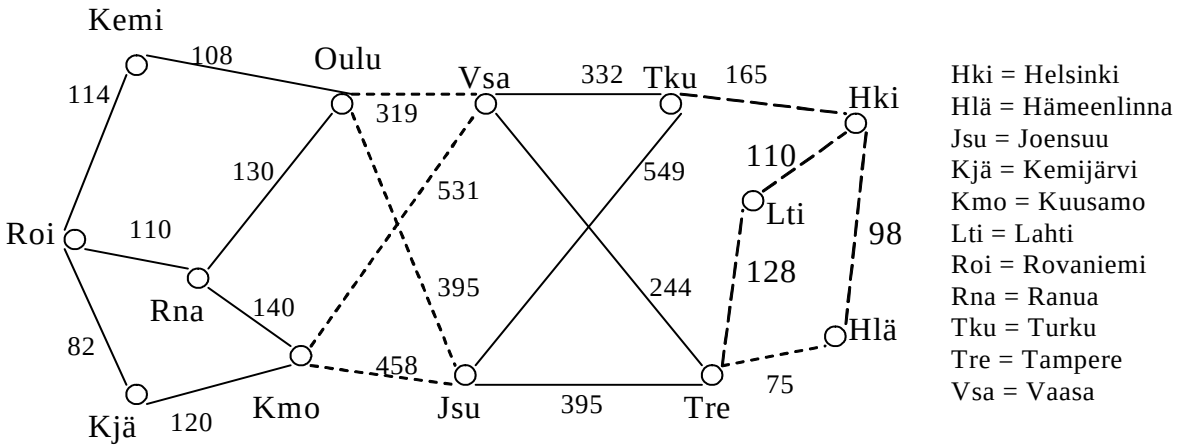
Kemi
108
Oulu
Vsa
332
Tku
165
Hki
114
319
130
531
549
110
Lti
Roi
110
98
128
Rna
140
395
244
Hlä
82
458
75
Kjä
120
Kmo
Jsu
395
Tre
Hki = Helsinki
Hlä = Hämeenlinna
Jsu = Joensuu
Kjä = Kemijärvi
Kmo = Kuusamo
Lti = Lahti
Roi = Rovaniemi
Rna = Ranua
Tku = Turku
Tre = Tampere
Vsa = Vaasa

Fig. 1.

Liite/Appendix: Q-funktion taulukko/Q-function table. Käytä tarvittaessa / Use if needed!

TABLE B.1 Complementary Error Function $Q(x) = \int_x^\infty (1/\sqrt{2\pi}) \exp(-u^2/2)du$

	$Q(x)$									
x	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2168	0.2148
0.8	0.2169	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
3.1	0.0010	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008	0.0007	0.0007
3.2	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
3.3	0.0005	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0094	0.0003
3.4	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002