University of Oulu
Department of Communications Engineering

WIRELESS COMMUNICATIONS I
Final exam 24.1.2014 (Full course)
No material is allowed.

1. Explain briefly but in detail, what is meant with
   a) Modulator
   b) QPSK
   c) Slowly fading channel
   d) Diversity
   e) MRC
   f) Unbiased estimate

2. a) Advantages of spread spectrum systems
   b) Basic idea on multicarrier transmission

3. a) Draw the block diagram of optimal receiver implemented with matched filters for AWGN channel, when the transmitted signals are $s_i(t)$, $i = 1, 2$. Explain in detail, how the receiver works.
   b) Decision feedback equalizer (principle, functioning, block diagram).

4. For a multipath fading channel let a scattering function $S_c(\tau,\rho)$ be nonzero over $0 \le \tau \le 0.1$ ms and $-2000 \le \rho \le 2000$ 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 it the meaning of these spreads.
   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?
   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 $u_2(t)$?
   d) Will this channel exhibit flat fading or frequency-selective fading for channel with a 3 kHz bandwidth? How about for a channel with a 30 kHz bandwidth?
   e) Assume that $BT_s \cong 1$. Is there fast fading, if we use these bandwidths? Explain you answer.

5. Consider an OFDM system with total passband bandwidth $B = 1$ MHz assuming $\beta = \varepsilon = 0$. A single carrier system would have symbol time $T_s = 1/B = 1$ µs. The channel has a maximum delay spread of $T_m = 5$ µs, so there would clearly be severe ISI. Assume an OFDM system with MQAM modulation applied to each subchannel. To keep the overhead small, the OFDM system uses $N = 128$ subcarriers to mitigate ISI. So $T_N = NT_s = 128$ µs. The length of the cyclic prefix is set to $\mu = 8 > T_m/T_s$ to insure no ISI between OFDM symbols. For these parameters, find the subchannel bandwidth, the total transmission time associated with each OFDM symbol, the overhead of the cyclic prefix, and the data rate of the system assuming $M = 16$.

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