University of Oulu
Department of Communications Engineering

WIRELESS COMMUNICATIONS I (521320S)
2. Intermediate exam 19.12.2014 (Based on parts 7-10 of the course, answer in English or in Finnish, no material is allowed)

1. Explain briefly but in detail, what is meant with
   a) Spread spectrum system
   b) MSE
   c) Cyclic prefix
   d) Unbiased estimate
   e) RAKE receiver
   f) Spreading code

2. a) Early-late gate time synchronizer
   b) Decision feedback equalizer

3. a) Maximum likelihood phase synchronizer for unmodulated carrier
   b) Code tracking in spread spectrum system

4. A total of 20 equal-power users are to share a common communication channel by CDMA. Each user transmits information at a rate 15 kbits/s via DS spread spectrum and BPSK. Determine the minimum chip rate obtain a bit error probability of 10^{-3}. Additive noise at the receiver may be ignored in the computation.

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 $M = 8$.

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WIRELESS COMMUNICATIONS I (521320S)
Final exam 19.12.2014 (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) PAM
   c) Frequency non-selective channel
   d) Unbiased estimate
   e) RAKE receiver
   f) Spreading code

2. a) Present the principle of differential PSK. Compare the performance with coherent one.
   b) Explain Alamouti scheme in space-time transmit diversity.

3. a) Maximum likelihood phase synchronizer for unmodulated carrier
   b) Code tracking in spread spectrum system

4. A multipath fading channel has a multipath spread of T_m = 1 s and a Doppler spread B_D = 0.01 Hz. The total channel bandwidth at bandpass available for signal transmission is W = 10 Hz. To reduce the effects of intersymbol interference, the signal designer selects a pulse duration T = 10 s.
   a) Determine and calculate the coherence bandwidth and the coherence time.
   b) Is the channel frequency selective? Explain.
   c) Is the channel fading slowly or rapidly? Explain.
   d) Suppose that the channel is used to transmit binary data via (antipodal) coherently detected PSK in a frequency diversity mode. Explain how you would use the available channel bandwidth obtain frequency diversity and determine how much diversity is available.

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 = 8.

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