S-72.231 Mobile Communication Systems (3 ov)
Exam 9.6.1999

1. **Give short answers to the subtasks (a - j), use figures when appropriate**

a) Explain the following functions of a cellular network: roaming, handover.
b) List two 1st generation and two 2nd generation mobile communication systems.
c) What is the cause of following phenomena in the mobile radio channel: Doppler-shifts, frequency-selective fading?
d) Which criteria start the handover in GSM?
e) How many input and output bits are there in a 20 ms block of the GSM full rate speech encoder?
f) Which modulation method is used in DAMPS?
g) Which duplexing method is used in DECT to separate the transmission directions?
h) List two radio paging systems.
i) List the needed data and the results of cellular radio network capacity planning.
j) List different possibilities to improve the radio link budget when the distance and frequency are given..

Answer four freely chosen tasks of the six following tasks.

2. The COST231-Hata propagation model gives the follwing expression for the average radio path loss: $L_c = 157{,}3 - 13{,}82\lg(h_{bs}) + \left(44{,}9 - 6{,}55\lg(h_{bs})\right)\lg(d)$ on the frequency 1880 MHz. How many times does the possible path length increase with 100 m base station antenna height if the radio path loss is allowed to increase 6 dB, when other system losses are decreased?

3. In a Rayleigh-fading channel the probability density function of the instantaneous signal to noise ratio is $p(\gamma) = \begin{cases} \exp(-\gamma/\gamma_m)/\gamma_m, & \gamma \geq 0 \\ 0 & \gamma < 0 \end{cases}$. The planning target is that the signal to noise ratio should be below 8 dB no more than 1 % of the time.

a) Determine the necessary average signal to noise ratio in dB.
b) Determine the necessary average signal to noise ratio in dB when two independently fading and on average equally strong diversity branches with selection combining is used.

4. Explain the channel encoding used for full rate speech in GSM and how the encoded bits are distributed to the bursts (interleaving).

5. TETRA-system radio interface:
   - frequency ranges
   - frequency duplex spacing in the different frequency ranges
   - carrier spacing
   - number of timeslots/carrier
   - modulation method

6. One radio interface solution of UMTS is WCDMA. How is the 2 Mbit/s bearer service implemented on the radio path, i.e. explain how channel encoding and spreading is planned to be done in the downlink.

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7. 504 traffic channels are allocated for a mobile communication system. The number of traffic channels in the cells (N) is dimensioned for a blocking probability B=2%. The Erlang B-formula is assumed to be valid. $$B = \frac{T^N / N!}{\sum_{n=0}^{N} T^n / n!}$$

a) What is the total capacity/cell if there are 1, 2, 3, or 4 operators equally sharing the frequency resource, and the reuse factor is 7 or 3. It is assumed that the cell size is the same for all operators.

a) How many subscribers/cell can these operators (1, 2, 3, or 4) together serve if the characteristic traffic of one subscriber is 20 mErlang?

Blocking B = 2 %, Number of channels/cell = N, Maximum traffic = T Erlang

N	T	N	T	N	T	N	T	N	T
1	0,02	41	31,92	81	69,65	121	108,39	161	147,6
2	0,22	42	32,84	82	70,61	122	109,37	162	148,6
3	0,60	43	33,76	83	71,57	123	110,35	163	149,6
4	1,09	44	34,68	84	72,53	124	111,32	164	150,6
5	1,66	45	35,61	85	73,49	125	112,30	165	151,6
6	2,28	46	36,53	86	74,45	126	113,28	166	152,6
7	2,94	47	37,46	87	75,42	127	114,25	167	153,6
8	3,63	48	38,39	88	76,38	128	115,23	168	154,5
9	4,34	49	39,32	89	77,34	129	116,21	169	155,5
10	5,08	50	40,26	90	78,31	130	117,19	170	156,5
11	5,84	51	41,19	91	79,27	131	118,17	171	157,5
12	6,61	52	42,12	92	80,24	132	119,15	172	158,5
13	7,40	53	43,06	93	81,20	133	120,12	173	159,5
14	8,20	54	44,00	94	82,17	134	121,10	174	160,4
15	9,01	55	44,94	95	83,13	135	122,08	175	161,4
16	9,83	56	45,88	96	84,10	136	123,06	176	162,4
17	10,66	57	46,82	97	85,07	137	124,04	177	163,4
18	11,49	58	47,76	98	86,04	138	125,02	178	164,4
19	12,33	59	48,70	99	87,00	139	126,00	179	165,4
20	13,18	60	49,64	100	87,97	140	126,98	180	166,4
21	14,04	61	50,59	101	88,94	141	127,96	181	167,4
22	14,90	62	51,53	102	89,91	142	128,94	182	168,3
23	15,76	63	52,48	103	90,88	143	129,92	183	269,3
24	16,63	64	53,43	104	91,85	144	130,90	184	170,3
25	17,50	65	54,38	105	92,82	145	131,88	185	171,3
26	18,38	66	55,33	106	93,79	146	132,86	186	172,3
27	19,26	67	56,27	107	94,76	147	133,84	187	173,3
28	20,15	68	57,23	108	95,73	148	134,82	188	174,3
29	21,04	69	58,18	109	96,71	149	135,80	189	175,3
30	21,93	70	59,13	110	97,68	150	136,78	190	176,3
31	22,83	71	60,08	111	98,65	151	137,7	191	177,2
32	23,72	72	61,04	112	99,62	152	138,8	192	178,2
33	24,63	73	61,99	113	100,60	153	139,8	193	179,2
34	25,53	74	62,94	114	101,57	154	140,7	194	180,2
35	26,43	75	63,90	115	102,54	155	141,7	195	181,2
36	27,34	76	64,86	116	103,52	156	142,7	196	182,2
37	28,25	77	65,81	117	104,49	157	143,7	197	183,2
38	29,17	78	66,77	118	105,47	158	144,7	198	184,2
39	30,08	79	67,73	119	106,44	159	145,7	199	185,2
40	31,00	80	68,69	120	107,42	160	146,6	200	186,2

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Exam 21.5.1999

1. **Give short answers to the subtasks (a - j), use figures when appropriate**

a) Name two analog and two digital cellular standards.
b) Which physical phenomena cause time and frequency variability in the mobile radio channel?
c) Which system parameters are included in the Hata average radio path loss model?
d) When is maximum ratio combining used?
e) Which modulation method is used in GSM?
f) What is the carrier spacing and number of timeslots/carrier in TETRA?
g) Which multiple access methods and duplexing methods are specified for UMTS
h) Which extensions of the GSM-standard will give higher data rates than the basic GMS? (Give the abbreviations and the corresponding functional principle)
i) Which multiple access method and duplexing method are used in DECT?
j) In which five phases can the cellular radio network planning be divided?

Answer four freely chosen tasks of the six following tasks.

2. The average loss of an outdoor radio path as a function of distance is described by $L = L_o + 10n\log r$. The average loss of an outdoor-indoor radio path as a function of distance is described by $L = L_o + 10n\log r + L_{pen}$, where L_o is the loss at a reference distance, n is the path loss exponent, and L_{pen} is the average wall penetration loss. When the other parameters are constant the allowed average loss is the same for both cases.

a) What is the ratio between the cell radii for outdoor and indoor coverage, when an outdoor base station is used, and n = 3.56 and L_{pen} = 17 dB?
b) How many times more base stations are needed to get indoor coverage in a given area compared to the number needed to get outdoor coverage in the same area with the same coverage probability?

3. The error probability of a DPSK-receiver in a non-fading AWGN-channel with the signal to noise ratio γ is $P_b = 0.5\exp(-\gamma)$.

a) Derive the expression of the average error probability of the same receiver in the slowly Rayleigh-fading AWGN-channel, where the probability density function of the signal to noise ratio is $p(\gamma) = \gamma_m^{-1}\exp(-\gamma/\gamma_m)u(\gamma)$, where γ_m is the average signal to noise ratio and $u(\ )$ is the unit step function. Note: the average of a function $f(x)$ is $E\{f(x)\} = \int_{-\infty}^{\infty} f(x)p(x)dx$.
b) How many dB will the Rayleigh-fading change the receiver sensitivity (received power level for $P_b = 10^{-3}$)?

4. The channel bit rate in GSM is 270.33 kbit/s. The user net rate is 13 kbit/s. Explain the reasons why the channel rate is not 8×13 kbit/s.

5.

a) Which are the standardised spreading ratios in WCDMA for UMTS?
b) To which bit rates do the highest and lowest spreading ratios correspond in the downlink? Show the calculations.

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6. In a digital mobile communication system 4QAM modulation is used, which gives a theoretical bit error probability in the Rayleigh-fading channel without and with two-branch selection combining diversity:

$$P_b = \frac{1}{2}\left[1 - \sqrt{\frac{\gamma_o}{2+\gamma_o}}\right] \le \frac{1}{2\gamma_o} \quad P_{b,div} = \frac{1}{2} - \sqrt{\frac{\gamma_o}{2+\gamma_o}} + \frac{1}{2}\sqrt{\frac{\gamma_o}{4+\gamma_o}} \le \frac{1{,}5}{\gamma_o^2}$$

The upper bound is rather tight when the average signal to noise ratio of each branch $\gamma_o >$ 30. Derive the diversity gain expression (the SNR-difference in dB for obtaining the same bit error probability) as a function of the bit error probability and determine the numerical value when $P_b = 10^{-3}$.

7. Twenty companies using separate privat mobile radio networks, each having 1 traffic channels, decide to establish a trunked radio network by putting their traffic channels in a common pool, from which everybody can use any free channel. How many times will this increase the capacity of the used frequency resource if a 1 % blocking probability is allowed both in the separate radio networks and in the trunked network. The traffic model is Erlang B which gives the blocking probability $\boldsymbol{B} = \dfrac{\boldsymbol{T}^{\boldsymbol{N}}/\boldsymbol{N}!}{\sum_{\boldsymbol{n}=\boldsymbol{0}}^{\boldsymbol{N}} \boldsymbol{T}^{\boldsymbol{n}}/\boldsymbol{n}!}$. Use the attached graph to estimate the traffic corresponding to the given blocking probability for several traffic channels.