UNIVERSITY OF SWAZILAND

MAIN EXAMINATION, FIRST SEMESTER DECEMBER 2014

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: TELECOMMUNICATIONS AND WIRELESS SYSTEMS

COURSE CODE: EE544

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:

1. **There are five questions in this paper. Answer any FOUR questions. Each question carries 25 marks.**
2. **If you think not enough data has been given in any question you may assume any reasonable values.**

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THIS PAPER CONTAINS EIGHT (8) PAGES INCLUDING THIS PAGE

QUESTION ONE ***(25 marks)***

(a) (i) Show that the noise temperature of an antenna when effected by rain is given by $T_A = T_m\left(1 - 10^{-\frac{A}{10}}\right) + T_c 10^{-\frac{A}{10}}$ where A is the attenuation due to rain in dB, T_m is the physical temperature of rain in ^0K and T_c is the cosmic noise temperature. Assume that the efficiency of the antenna is 1.

(6 marks)

(ii) Find the noise temperature of an antenna having an efficiency of 0.65 and experiencing a rain attenuation of $6dB$. You may assume that the cosmic noise temperature, physical temperature of the rain and the temperature of the earth are 30 °K, 260 °K and 300 °K respectively.

(7 marks)

(b) A satellite earth station located at an altitude of 45^0, receives $20GHz$ signal when the angle of elevation of the antenna is 50^0. The rain rate exceeded for 0.01% of an average year is 60 $\frac{mm}{hr}$. Estimate the non diversity fade margin required to have a link availability of 99.995% of a year. Assume that the additional losses are of $4dB$.

(12 marks)

QUESTION TWO *(25 marks)*

(a) A geostationary satellite operating at $12GHz$, transmits using an antenna of gain $25dB$. The antenna gain of the earth station receiver is $50dB$. If the received signal strength is $-88dBm$ and the system fade margin is $10dB$, find the transmitter power of the satellite. Also estimate the diameter of the receiver antenna if its efficiency is 0.7.

(9 marks)

(b) The BER required at the output of a digital receiver is 10^{-6}. If the signal has a data rate of $1.5\frac{Mb}{s}$ and QPSK modulated, find the signal power required at the input of the receiver when the signal to noise ratio at the input is $13dB$. Assume the following data,

Receiver noise figure = $5dB$ Bandwidth expansion factor = 1.12

FEC code rate = $\frac{7}{8}$

(10 marks)

(c) A link between two locations on earth is maintained through a satellite transponder. Derive an expression for the $\frac{C}{N}$ ratio at the receive end in terms of the $\frac{C}{N}$ ratios of the uplink and the downlink.

(6 marks)

QUESTION THREE ***(25 marks)***

(a) A mobile service is having a cluster size of 7 and a cell radius of $0.5km$

(i) Find the co-channel distance. (2 marks)

(ii) Calculate the carrier to co-channel interference ratio. (2 marks)

(iii) Assuming 60^0 sectoring, calculate the resulting carrier to co-channel interference ratio. (3 marks)

(b) A $30MHz$ bandwidth is to be used for the forward channels of a mobile service. The cluster size is 7 and the GSM channel bandwidth is assumed. If the expected grade of service of the network is 2%, estimate the number of customers that can be served in a cluster. An average user makes a one call in a hour and the average holding time is $3min$. You may assume blocked calls cleared processing.

(10 marks)

(c) A base station of a mobile service operating in $900MHz$ band covers a large city area. A mobile receiver at a $2km$ distance from the base station receives a power level of $-95dBm$. Estimate the path loss experienced by the mobile receiver. What is the transmitter power of the base station if it uses an omni-directional antenna. You may use,

The height of the base station tower = $25m$

The height of the mobile receiver = $1m$

(8 marks)

QUESTION FOUR *(25 marks)*

(a) An optical fiber consists with a core and cladding having refractive indices of 1.456 and 1.426 respectively.

(i) An incident light ray which makes an angle $\propto$ with the axis of the fiber is propagated throughout the fiber. Calculate the maximum possible value for $\propto$, deriving any formula you use.

(4 marks)

(ii) Find the relative refractive index difference and the numerical aperture.

(2 marks)

(iii) How do you define the coupling efficiency at the source-fiber interface? Calculate the coupling efficiency if the source-fiber interface is filled with a material having a refractive index of 1.11.

(3 marks)

(b) (i) State the factors effecting the losses at the connectors and splices of an optical fiber link.

(2 marks)

(ii) A multimode optical fiber cable of $8km$ length has a model dispersion of $0.6\frac{ns}{km}$. Calculate the maximum transmission bit rate if NRZ line coding is employed.

(4 marks)

(c) An optical link is required for a distance of $100km$ with an access point built at the mid length of the line. Assume that the splicing is done in every10 km. The power of the optical transmitter and the sensitivity of the end point optical receiver are $1.5mW$ and $-20dBm$ respectively. Complete the design of the link giving relevant recommendations with justifications. You may use,

Attenuation loss	$= 0.25\frac{dB}{km}$
Connector loss	= 0.2 dB per connector
Splicing loss	= 0.15 dB per splice
Safety margin	= $6dB$

(10 marks)

QUESTION FIVE (25 *marks*)

(a) (i) Consider a generic $N \times N$, three stage space division switch. Working with usual notations, derive the expressions for the total number of switching elements and the blocking probability using Lee's model.

(6 marks)

(ii) A three stage space switch consists with 128 inlets and 128 outlets. The first and the third stage each use 16 matrices.
Evaluate the number of switching elements in the network if it is non-blocking.
In the busy hours, the occupancy rate of an inlet is 10%. Calculate the blocking probability of the switch if the number of switching elements required for non-blocking operation is reduced by one third.

(12 marks)

(b) A PABX serves 100 internal extensions and 4 external lines which are connected to PSTN. The busy hour calling rate is 2 and the external traffic is 30% of the total. If the average call holding time is three minutes, find the probability that an incoming call from PSTN finds the lines busy.

(7 marks)

SOME SELECTED USEFUL FORMULAE

$L_P = 69.55 + 26.16 \log F_c - 13.82 \log h_b - a(h_m) + (44.9 - 6.55 \log h_b) \log R$

$a(h_m) = 3.2(\log 11.75\, h_m)^2 - 4.97$

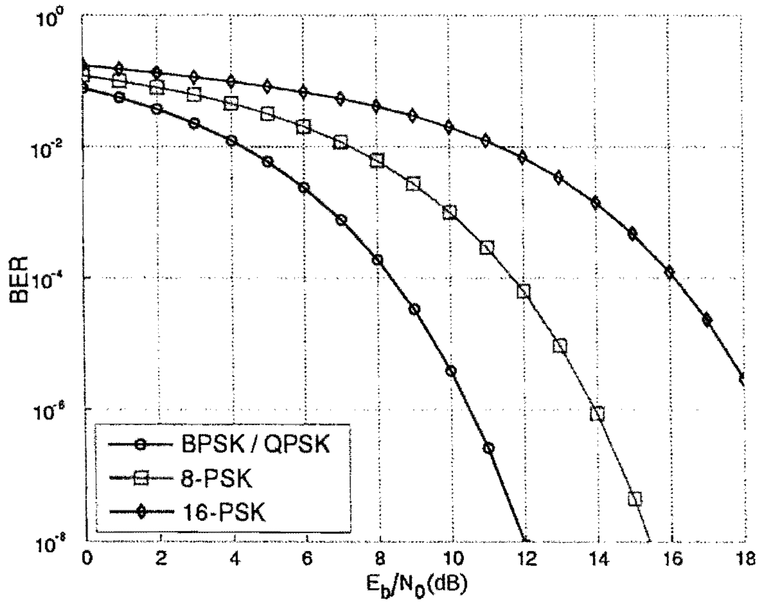
F (GHz)	a	b
1	$3.87\text{x}10^{-5}$	0.912
10	0.0101	1.276
20	0.0751	1.099
30	0.187	1.021
40	0.35	0.939

h_R(km):

$5 - 0.075(\phi - 23)$	$\emptyset > 23^0$
5	$0^0 \leq \emptyset \leq 23^0$
5	$0^0 \geq \emptyset \geq -21^0$
$5 + 0.1(\emptyset + 21)$	$-71^0 \leq \emptyset \leq -21^0$
0	$\emptyset < -71^0$

$$S_{0.01} = \frac{1}{1 + \frac{r_R \sin\theta}{35 \exp(-0.015 R_{0.01})}}$$

$$L_P = L_{0.01} \times 0.12\, P^{-(0.546 + 0.043 \log P)} \quad \text{where } 0.001 < P < 1\%$$



Erlang B Traffic Table

Maximum Offered Load Versus B and N

B is in %

N/B	0.01	0.05	0.1	0.5	1.0	2	5	10	15	20	30	40
1	.0001	.0005	.0010	.0050	.0101	.0204	.0526	.1111	.1765	.2500	.4286	.6667
2	.0142	.0321	.0458	.1054	.1526	.2235	.3813	.5954	.7962	1.000	1.449	2.000
3	.0868	.1517	.1938	.3490	.4555	.6022	.8994	1.271	1.603	1.930	2.633	3.480
4	.2347	.3624	.4393	.7012	.8694	1.092	1.525	2.045	2.501	2.945	3.891	5.021
5	.4520	.6486	.7621	1.132	1.361	1.657	2.219	2.881	3.454	4.010	5.189	6.596
6	.7282	.9957	1.146	1.622	1.909	2.276	2.960	3.758	4.445	5.109	6.514	8.191
7	1.054	1.392	1.579	2.158	2.501	2.935	3.738	4.666	5.461	6.230	7.856	9.800
8	1.422	1.830	2.051	2.730	3.128	3.627	4.543	5.597	6.498	7.369	9.213	11.42
9	1.826	2.302	2.558	3.333	3.783	4.345	5.370	6.546	7.551	8.522	10.58	13.05
10	2.260	2.803	3.092	3.961	4.461	5.084	6.216	7.511	8.616	9.685	11.95	14.68
11	2.722	3.329	3.651	4.610	5.160	5.842	7.076	8.487	9.691	10.86	13.33	16.31
12	3.207	3.878	4.231	5.279	5.876	6.615	7.950	9.474	10.78	12.04	14.72	17.95
13	3.713	4.447	4.831	5.964	6.607	7.402	8.835	10.47	11.87	13.22	16.11	19.60
14	4.239	5.032	5.446	6.663	7.352	8.200	9.730	11.47	12.97	14.41	17.50	21.24
15	4.781	5.634	6.077	7.376	8.108	9.010	10.63	12.48	14.07	15.61	18.90	22.89
16	5.339	6.250	6.722	8.100	8.875	9.828	11.54	13.50	15.18	16.81	20.30	24.54
17	5.911	6.878	7.378	8.834	9.652	10.66	12.46	14.52	16.29	18.01	21.70	26.19
18	6.496	7.519	8.046	9.578	10.44	11.49	13.39	15.55	17.41	19.22	23.10	27.84
19	7.093	8.170	8.724	10.33	11.23	12.33	14.32	16.58	18.53	20.42	24.51	29.50
20	7.701	8.831	9.412	11.09	12.03	13.18	15.25	17.61	19.65	21.64	25.92	31.15
21	8.319	9.501	10.11	11.86	12.84	14.04	16.19	18.65	20.77	22.85	27.33	32.81
22	8.946	10.18	10.81	12.64	13.65	14.90	17.13	19.69	21.90	24.06	28.74	34.46
23	9.583	10.87	11.52	13.42	14.47	15.76	18.08	20.74	23.03	25.28	30.15	36.12
24	10.23	11.56	12.24	14.20	15.30	16.63	19.03	21.78	24.16	26.50	31.56	37.78
25	10.88	12.26	12.97	15.00	16.13	17.51	19.99	22.83	25.30	27.72	32.97	39.44
26	11.54	12.97	13.70	15.80	16.96	18.38	20.94	23.89	26.43	28.94	34.39	41.10
27	12.21	13.69	14.44	16.60	17.80	19.27	21.90	24.94	27.57	30.16	35.80	42.76
28	12.88	14.41	15.18	17.41	18.64	20.15	22.87	26.00	28.71	31.39	37.21	44.41
29	13.56	15.13	15.93	18.22	19.49	21.04	23.83	27.05	29.85	32.61	38.63	46.07
30	14.25	15.86	16.68	19.03	20.34	21.93	24.80	28.11	31.00	33.84	40.05	47.74
31	14.94	16.60	17.44	19.85	21.19	22.83	25.77	29.17	32.14	35.07	41.46	49.40
32	15.63	17.34	18.21	20.68	22.05	23.73	26.75	30.24	33.28	36.30	42.88	51.06
33	16.34	18.09	18.97	21.51	22.91	24.63	27.72	31.30	34.43	37.52	44.30	52.72
34	17.04	18.84	19.74	22.34	23.77	25.53	28.70	32.37	35.58	38.75	45.72	54.38
35	17.75	19.59	20.52	23.17	24.64	26.44	29.68	33.43	36.72	39.99	47.14	56.04
36	18.47	20.35	21.30	24.01	25.51	27.34	30.66	34.50	37.87	41.22	48.56	57.70
37	19.19	21.11	22.08	24.85	26.38	28.25	31.64	35.57	39.02	42.45	49.98	59.37
38	19.91	21.87	22.86	25.69	27.25	29.17	32.62	36.64	40.17	43.68	51.40	61.03
39	20.64	22.64	23.65	26.53	28.13	30.08	33.61	37.72	41.32	44.91	52.82	62.69
40	21.37	23.41	24.44	27.38	29.01	31.00	34.60	38.79	42.48	46.15	54.24	64.35
41	22.11	24.19	25.24	28.23	29.89	31.92	35.58	39.86	43.63	47.38	55.66	66.02
42	22.85	24.97	26.04	29.09	30.77	32.84	36.57	40.94	44.78	48.62	57.08	67.68
43	23.59	25.75	26.84	29.94	31.66	33.76	37.57	42.01	45.94	49.85	58.50	69.34