UNIVERSITY OF SWAZILAND

MAIN EXAMINATION, FIRST SEMESTER DECEMBER 2016

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.
3. Some useful information is given at the end of the paper.

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THIS PAPER CONTAINS EIGHT (9) PAGES INCLUDING THIS PAGE

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

(a) (i) An antenna of a satellite receiver is immersed in rain. If the attenuation due to rain is A in dB, show that the background noise temperature seen by the antenna is given by $T_B = T_W\left(1 - 10^{-\frac{A}{10}}\right) + T_c 10^{-\frac{A}{10}}$ where T_W and T_c are the physical temperature of the rain and the cosmic noise temperature in ${}^0K$.

(6 marks)

(ii) An antenna operating at $25GHz$ having a gain of $50dB$ with a diameter of $1.4m$, experiences a rain attenuation of $10dB$. Find the noise temperature of the antenna. You may assume that the cosmic noise temperature, physical temperature of the rain and the temperature of the earth are 50 °K, 260 °K and 300 °K respectively.

(9 marks)

(b) A satellite earth station operating at $20GHz$ with an antenna elevation angle of 50^0 is at a location having an latitude of -30^0. The rain rate at this location exceeds 65 $\frac{mm}{hr}$ for a 0.01% of an average year. Calculate the non diversity fade margin required to have the link outage not more than 0.005% of a year. Assume that there may be additional system losses of $5dB$.

(10 marks)

QUESTION TWO ***(25 marks)***

(a) A geostationary satellite operating at $12GHz$ has a transmitter power of $165W$. The gains of the satellite transmitter antenna and the earth station receiver antenna are $30dB$ and $45dB$. If the system fade margin is $12dB$, find the minimum sensitivity of the earth station receiver. Also calculate the beam width of the earth station antenna if its diameter is $1.5m$.

(9 marks)

(b) A satellite link connects two locations on the earth through a transparent 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)

(c) A satellite signal is $8PSK$ modulated and the BER required at the output of the receiver is 10^{-6}. The signal has a data rate of $12\frac{Mb}{s}$ and the noise power seen at the receiver input is $2 \times 10^{-10} mW$. Calculate the signal power required at the input of the receiver. You may assume the following data.

Receiver noise figure $= 8dB$ Bandwidth expansion factor = 1.2

FEC code rate $= \frac{5}{6}$

(10 marks)

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

(a) A mobile service is having a cluster size of 4 and a cell radius of $500m$.

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

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

(iii) What is the carrier to co-channel interference ratio if 60^0 sectoring is used? (3 marks)

(b) (i) A $60MHz$ of total bandwidth is allocated to a mobile service for forward and reverse channels. The cluster size is 7 and the GSM channel bandwidth is assumed with blocked calls cleared. If the grade of service required is 1% , find the number of customers that can be served in a cell. You may assume that an average user makes a one call in a hour and the average call holding time is $3min$. (10 marks)

(ii) The number of users per cell in (i) above is to be increased by using 120^0 sectoring. Show how this can be implemented effectively and calculate the resulting estimate of the number of users per cell. What is the percentage of increase of the users? (8 marks)

QUESTION FOUR (*25 marks*)

(a) (i) In a mobile network, the cell radius is $1km$. The received mean signal power at a $20m$ distance from the base station is $0.1mW$ and at the cell radius it is $3.3 \times 10^{-9}mW$. Find the path loss exponent for this propagation environment and show an expression for the mean received power in dB.

(6 marks)

(ii) Indicate using an expression, the received signal power in dB including the shadowing effect for the case (a) above identifying the terms.

It is found that the received signal power level in this case varies at the cell radius with a standard deviation of $8.8dB$. Find the probability that the received signal level at the cell radius be greater than $-87dBm$.

(7 marks)

(iii) Determine the percentage area of the cell which receives signal level above $-87dBm$. You may use data in (i) and (ii) above

(5 marks)

(b) A PABX in a small organization serves 100 internal extension lines. It is connected to the PSTN with 5 external lines. The busy hour average calling rate of a user is 3 calls and the call holding time is three minutes. If the external traffic is 20% of the total, find the probability that a user finds the lines busy for an external call.

(7 marks)

QUESTION FIVE (25 *marks*)

(a) The refractive indices of the core and cladding of an optical fiber are 1.455 and 1.423 respectively.

(i) Calculate the critical angle and the acceptance angle.

(3 marks)

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

(3 marks)

(iii) What is the coupling efficiency if the source-fiber interface is filled with a filler of refractive index 1.15?

(2 marks)

(b) (i) A multimode optical fiber cable of $10km$ length has a model dispersion of $0.65\frac{ns}{km}$. Calculate the maximum bit rate if NRZ fóormat is employed for the transmission.

(5 marks)

(ii) An optical link is to be designed for a distance of $100km$. The splicing is done in every10 km. The power of the optical transmitter and the sensitivity of the end point optical receiver are $1.2mW$ and $-18dBm$ respectively. Complete the design of the link indicating the important specifications of any additional component/s. You may assume that an access to the link exists at the mid-point.

Attenuation loss	$= 0.25\frac{dB}{km}$
Connector loss	= 0.2 dB per connector
Splicing loss	= 0.1 dB per splice
Link margin	= $5dB$

(12 marks)

SOME SELECTED USEFUL FORMULAE

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

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

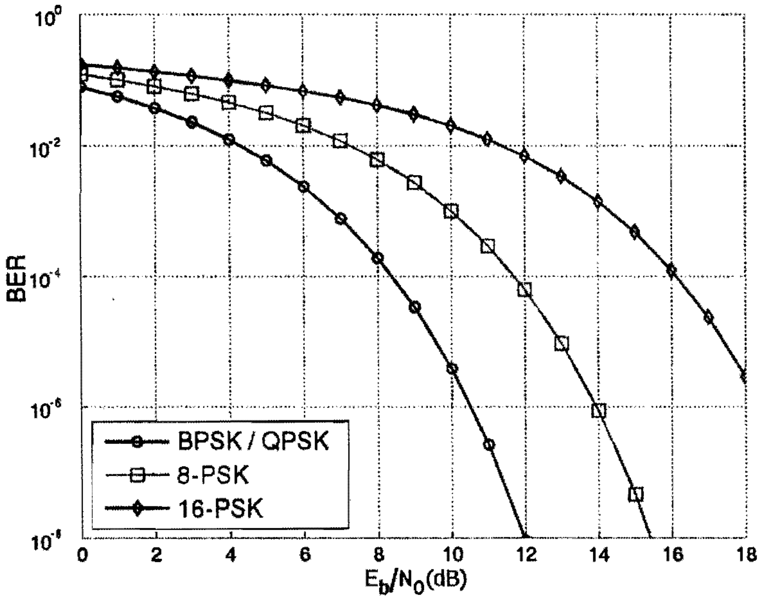
F (GHz)	a	b
1	3.87×10^{-5}	0.912
10	0.0101	1.276
20	0.0751	1.099
30	0.187	1.021
40	0.35	0.939

h_R(km):

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

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

$L_P = L_{0.01} \times 0.12\, P^{-(0.546 + 0.043 \log P)}$ 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

z	$erf(z)$	z	$erf(z)$
0.1	0.11246	1.6	0.97635
0.2	0.22270	1.7	0.98379
0.3	0.32863	1.8	0.98909
0.4	0.42839	1.9	0.99279
0.5	0.52049	2.0	0.99532
0.6	0.60385	2.1	0.99702
0.7	0.67780	2.2	0.99814
0.8	0.74210	2.3	0.99885
0.9	0.79691	2.4	0.99931
1.0	0.84270	2.5	0.99959
1.1	0.88021	2.6	0.99976
1.2	0.91031	2.7	0.99987
1.3	0.93401	2.8	0.99993
1.4	0.95228	2.9	0.99996
1.5	0.96611	3.0	0.99998