UNIVERSITY OF SWAZILAND

MAIN EXAMINATION, FIRST SEMESTER DECEMBER 2012

FACULTY OF SCIENCE

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

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|---|---|
| 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) A satellite link operates at $15GHz$. The elevation angle of the earth receiver station antenna is $30^0$ and the latitude of the location is given as $30^0$. The rain rate exceeded for 0.01% of an average year is $50\frac{mm}{hr}$. Find the rain attenuation for 0.1% of an average year.

(10 marks)

(b) The transmitter power of a satellite is $100W$ at $10GHz$ with an antenna having a gain of $20dB$. A receiver station on earth receives this signal with an antenna having a gain of $40dB$. If the additional losses including rain is $5dB$, find the received signal strength at the receiver input. What is the $EIRP$ of the satellite transmitter?

(10 marks)

(c) If the efficiency of the receiver antenna is 0.65, find the diameter of the antenna and its beam width.

(5 marks)

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

(a) A satellite receiver has an antenna efficiency of 0.7. Evaluate the antenna noise temperature under a rain with $5dB$ attenuation. You may assume a cosmic noise of $40^0K$. The physical temperature of rain and earth are $290^0K$ and $300^0K$ respectively.

(7 marks)

(b) A receiver operating at $290^0K$ with a noise figure of $8dB$, receives a $2.048\frac{Mb}{s}$ QPSK modulated signal and the received signal level at the input of the receiver is $-150dBm$ with a signal to noise ratio of $27dB$. Find the $\frac{E_b}{N_o}$ ratio for this signal. Bandwidth expansion factor and the FEC code rate are 1.2 and $\frac{2}{3}$ respectively.

(6 marks)

(c) A satellite transmits $10GHz$ signal with $80W$ of power. The receiver system consists of a dish antenna, which connects to the receiver with a waveguide. Calculate the $\frac{C}{N}$ ratio at the output of the receiver. You may assume the following data.

| | |
|---|---|
| Transmitter antenna gain | = 20 $dB$ |
| Receiver antenna gain | = 40 $dB$ |
| Bandwidth | = $2MHz$ |
| Receiver antenna efficiency | = 0.7 |
| Transmitter antenna efficiency | = 1 |
| Physical temperature | = $300^0K$ |
| Brightness temperature | = $80^0K$ |
| Waveguide loss | = $1.5dB$ |
| Receiver noise temperature | = $500^0K$ |

(12 marks)

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

(a) A mobile network is based on 4 cells per cluster.

(i) Find the co-channel re-use ratio.

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

(iii) If $120^0$ sector antennas are used, what is the carrier to co-channel interference ratio.

(10 marks)

(b) A mobile service is given a $30MHz$ bandwidth for uplink. If a cluster size of 4 is used, find the grade of service of the network. Number of users in a cell are 1000. Assume a user makes two calls of 3min duration in one hour. The channel bandwidth is $200kHz$.

(10 marks)

(c) A mobile station is at a distance of $1.5\ km$ from the base station. The height of the base station tower is $20m$ and the height of the mobile station is $1m$. If the frequency band used is $900MHz$, calculate the propagation loss.

(5 marks)

**QUESTION FOUR (*25 marks*)**

(a) (i) Draw the block diagram of an optical digital link and state the factors related to the signal degradation in an optical fiber.

(ii) State the factors related to the use of multimode and single mode fibers.

(4 marks)

(b) The refractive index of the core and the cladding of an optical fiber are 1.556 and 1.526 respectively.

(i) Draw the cross section of an optical fiber.

(ii) Calculate the critical angle.

(iii) Calculate the acceptance angle.

(vi) Calculate the numerical aperture and relative refractive index difference.

(7 marks)

(c) An optical link operates between a distance of $200km$. Splicing is done in every $5\ km$. An optical amplifier having a gain of $18dB$is used in the link and the sensitivity of the optical receiver is $-30dBm$. The input sensitivity of the amplifier is $-25dBm$. Find the power of the optical transmitter required. What is the location at which the amplifier must be placed?

| | |
|---|---|
| Attenuation loss | $= 0.2 \frac{dB}{km}$ |
| Connector loss | = 0.3 dB per connector |
| Splicing loss | = 0.1 $dB$ per splice |
| Link margin | = $5dB$ |

(14 marks)

**QUESTION FIVE (25 *marks*)**

(a) Draw the block diagrams for the following cases.

(i) Time switch $(T)$ with sequential write and random read.

(ii) Space switch $(S)$.

(iii) Time-Space-Time switch with a $(m \times n)$ array.

(8 marks)

(b) A network is offered 1000 call attempts during the busy hour. The average call duration is 2 $min$ and the grade of service is 2 %. Find,

(i) the number of lost calls.

(ii) the offered traffic.

(iii) the carried traffic.

(iv) the lost traffic.

(4 marks)

(c) A group of 30 trunks is attempted 80 calls during a period of $15min$. If the grade of service of the network is 2%, find the call holding time and the amount of traffic carried.

(6 marks)

(d) A local switch is connected to 550 subscribers in an area. The switch is connected to 40 outgoing trunks. If the 70% of traffic is local calls, find the probability that a local subscriber will fail to originate a national call. Assume that the traffic generated by a single subscriber is $0.21E$.

(7 marks)

## SOME SELECTED USEFUL FORMULAE

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

$$a(h_m) = (1.1 \log F_c - 0.7)h_m - (1.56 \log F_c - 0.8)$$

| F (GHz) | a | b |
|---|---|---|
| 1 | $3.87 \times 10^{-5}$ | 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 | $\emptyset < -71^0$ |

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

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