Radio Engineering Exam

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1. Consider the downlink of a mm-wave communication fixed wireless access system with the following characteristics

   - Carrier frequency: $f_c = 28$GHz
   - Bandwidth: 100MHz
   - Number of antennas at the BS: $N = 64$
   - Total TX power: 20 dBm
   - Antenna gain at BS: $10\log_{10}(N)$
   - Noise Figure at UE: 5dB
   - Antenna gain at UE: 5dB
   - Required SINR: 10dB

   (a) Compute the thermal noise and the receiver sensitivity. 1Pt

   (b) Assuming a Ricean fading channel with a Rice factor of 30dB, compute the fading margin that guarantees an outage probability of 1% (use the graph from the appendix). 1Pt

   (c) Compute the EIRP. 1Pt

   (d) Compute the maximum allowable path loss. 1Pt

   (e) Compute the maximum distance assuming a path loss model $PL(d) = 28 + 22log10(d) + 20log10(f_c)$ where d is the distance in m and f_c the carrier frequency in GHz. 1Pt

2. Assume that a system needs a $C/I = 10$dB to work at an acceptable quality. Further assume that the path loss decays with a path loss exponent $\eta = 4$ and the system requires a fading margin of $M = 10$dB.

   (a) Compute the relative reuse distance D/R and the minimum cluster size N. 1Pt

   (b) Assume an Erlang-B system with a blocking probability of 10%. Assume further that a total of 30 channels are available. What is the offered traffic in Erlang per cell (use the table in the appendix)? 1Pt

(c) The city of Nice has a population density of 5000 people per km^2. Assuming that every person generates a traffic of 2 milli-Erlang, what is the required cell radius (assume that each cell covers a surface of $A = r^2\pi$)? 2Pts

(d) How do you achieve a reuse factor of 1? Give an example parameter set that would achieve this result. 1Pt

3. What is the Kronecker channel model? Give the mathematical definition and explain/define all involved variables. What are the limitations of the model? If a channel has Kronecker structure, what are the implications on the double directional power spectrum? 2Pts

4. Wideband time-variant channels can be modeled as a time-variant linear system. What are the four system functions to describe such a system and how are they related? Write down the input-output relation for one of these system functions? 2Pts

5. What is the rms delay spread of a wideband channel and how can it be computed from the power delay profile? 2Pts

6. Free space propagation is described fy Friis' law

$$P_{RX}(d) = P_{TX} G_{TX} G_{RX} \left(\frac{\lambda}{4\pi d} \right)^2 .$$

This formula suggests that the received power decreases with increasing carrier frequency $f = \frac{c}{\lambda}$ (keeping all other parameters constant). What is the implicit assumption is this formula that allows this conclusion?

7. What are the requirements for a channel to be identifiable by means of channel sounding? 2Pts

Total: 20Pts

Good luck!

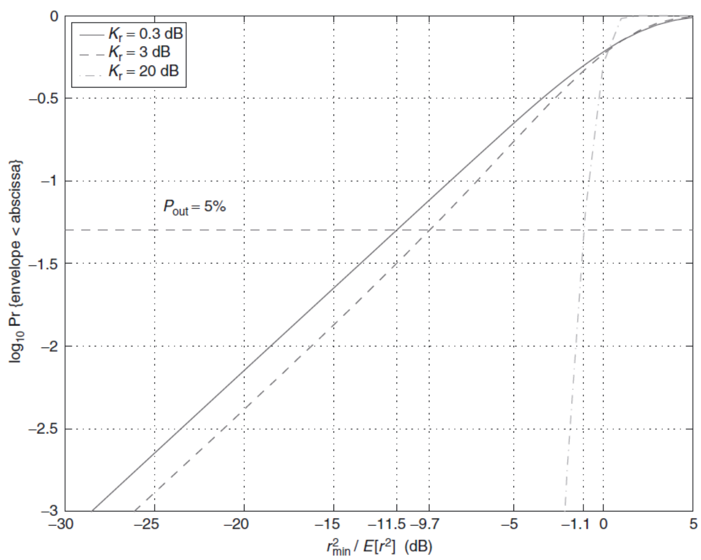

Figure 1: The Rice Power cdf with $\sigma = 1$.

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