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Sample midterm #2

Midterm Exam EE 276
Spring 1995

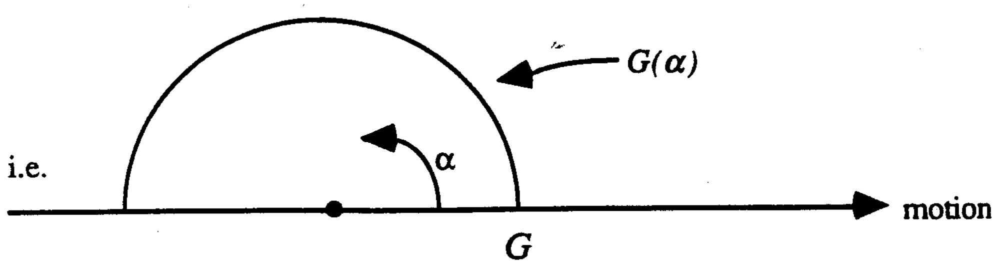
1. (10) Assume that a receiving antenna is moving at a uniform speed through a multipath propagation medium that has a very large number of waves arriving from angles uniformly distributed in azimuth in the horizontal plane. Assume that all arrival angles are confined to the horizontal plane and the amplitudes of the waves are random such that the received signal amplitude is Rayleigh distributed. Assume that the transmitted signal is a single frequency sinusoid at frequency f.

Assume that the receiving antenna has a horizontal beam pattern $G(\alpha)$ as a function of angle α. The angle α is the angle measured from the direction of motion.

Write the relationship for the Doppler Spectrum $S(f)$ of the received signal and sketch $S(f)$ for the $G(\alpha)$ specified in parts a) and b) below. (If you can write $S(f)$ by inspection from the derivation in the notes, you do not need to show your derivation, but explain in words how you arrived at your results.) Define your parameters.

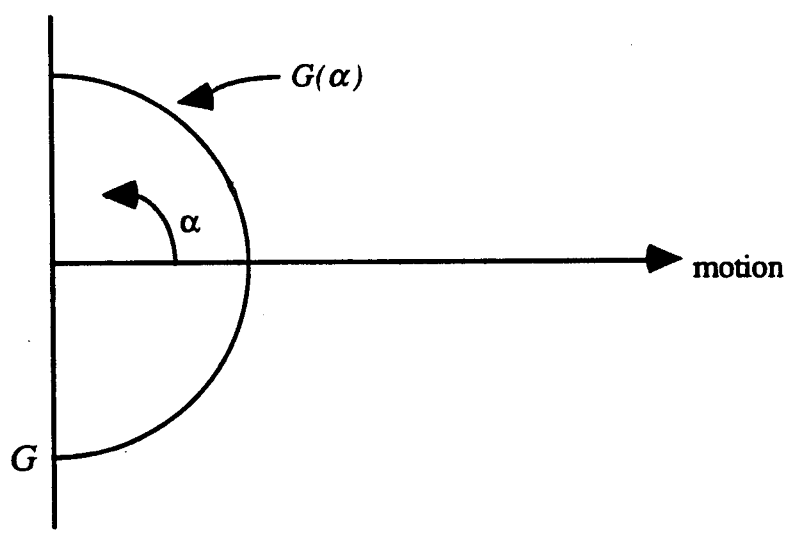
a) Assume that $G(\alpha)$ has a constant gain G for all positive angles, α, from 0 to 180° with respect to the direction of motion and a gain of 0 for all negative angles from 0 to -180°.

i.e.



b) Assume that $G(\alpha)$ has a constant gain G for angles α for $-90° \leq \alpha \leq +90°$ and $G(\alpha)$ is 0 for $90° < \alpha \leq 180°$ and for $-180° < \alpha < -90°$. Note that $G(\alpha)$ for part b) is similar to $G(\alpha)$ for part a) but rotated 90°.

i.e.



2) Consider a single isolated base station with N radio channels (servers) available.

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a) What is the maximum value of traffic carried in Erlangs for that base station using the definition of traffic ~~carried in~~ the notes?

b) Under what conditions can a base station that treats blocked calls in the way assumed for the Erlang B formula carry the maximum traffic that you stated in part a)? Discuss in one page or less.

c) For a small system with N=4 channels, what is the Erlang B probability of blocking for a traffic offered of 1.09 Erlangs? What are the state occupancy probabilities P_0, P_1, P_2, P_3 and P_4 for this set of conditions? What percentage of the time would you expect to find 2 or fewer of the 4 channels occupied?

3) Consider a wireless system as follows:

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1 ft = 0.3048 meters

- gain of transmitting antenna, $G_t = 10.8 dB$
- gain of receiving antenna, $G_r = 0\ dB$
- frequency f=1.964 GHz

You are told that your receiver has a minimum usable signal power of -100dBm in the residential environment in which it will be used. The minimum usable signal power is indicated as taking into account the multipath fading (i.e. the effects of the Rayleigh distributed multipath fading are included in the -100 dBm).

The propagation environment can be modeled as follows:

- large scale "shadow" variation is a log normal process with standard deviation s=10 dB where the large scale variation is the variation of the signal power used to define the minimum signal power.
- distance dependent trend of the mean (or median) of the log normal process is d^{-4}, where d is the distance between the base station and the user location
- at 1000 ft., the mean (or median) of the log normal process results in a received signal power that is 24 dB less than the signal power that would be received in free space using the same antennas, transmitters and receivers.

a) What is the required transmitter power in dBm if you want to serve 90% of the locations that are 1414 feet from the base station?

b) Using the transmitter power from a) above, what is the received signal power in dBm if the receiver is moved to a location that is 20 feet from the transmitter and within line of sight. Assume that at 20 feet the propagation is equivalent to free space.

Note: c=186,000 miles/sec 1 meter=0.3048 feet
1 mile=5280 feet

c) Now assume that the location is equal distance (1414 feet) from 3 base stations arranged at the corners of an equilateral triangle. Assume other propagation conditions and minimum signal power as specified earlier and the transmitter power determined for a). Assuming that the large scale log normally distributed signal variations are uncorrelated for the 3 base stations, what is the percentage of areas near the location that will have signal power above the minimum usable (-100dBm). (Another way to ask the question is, given an ensemble of different sets of 3 base stations and locations the maximum distance of 1414 feet from them, what is the probability of a particular location having a signal power greater than the usable signal level.)

d) Consider again a location equidistance from three base stations at the corners of an equilateral triangle as in part c). Again assume the large scale signal variations are uncorrelated from the three base stations. With this three branch macroscopic diversity arrangement, how far from the location can the base stations be moved to and still provide the minimum received power of -100 dBm for 90% of such locations in an ensemble of different sets of 3 base stations?

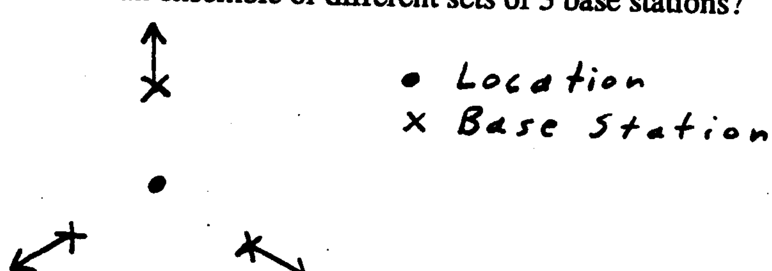

TABLE I

Area under the Normal Density Function

$$\text{A table of } \Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{1}{2}y^2}\, dy$$

x	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998
3.6	.9998	.9998	.9999	.9999	.9999	.9999	.9999	.9999	.9999	.9999