Sample midterm #5

EE 276 Final Exam, Spring 1997

(25pts)

(1) The average delay profile of a wireless channel is given by $P(\tau) = P_0 e^{-\lambda\tau}$ for $\tau > 0$ and 0 otherwise. λ is in units of 1/seconds. τ is in seconds.

a) Determine the mean excess delay and delay spread as a function of λ. If $\lambda = 10^6$, what is the delay spread?

b) If we want to transmit $10M$ bits/sec in this environment with multicarrier (multitone) transmission using 4 QAM signaling with raised cosine pulse ($\alpha = 0.75$) on each carrier, and the target average BER is 10^{-3} at high signal to noise ratio (S/N) for each frequency, what is the number of frequencies required for the channel specified in part a)?

Check → c) You are to choose the carriers to have the minimum possible separation that will not have any overlap of the frequency spectrum for adjacent modulated carriers. What is the total bandwidth required for the 10 Mbits/sec multicarrier transmission?

25 pts

(3) Consider a wireless system as follows:

- gain of transmitting antenna, $G_T = 4\,dB$
- gain of receiving antenna, $G_R = 0\,dB$
- transmitter power, $P_T = 100$ milliwatts
- wavelength, $\lambda = (\pi/3.96)$ ft
- minimum usable receiver power, i.e. median of Rayleigh process or the threshold level in Rayleigh distributed multipath fading, $P_{R_{thresh}} = -100\,dBm$
- antenna temperature = 290°K = T_o.

This system is to be operated in a cluttered wireless environment. You are given the attached figure that represents measurements taken in that environment using the same antennas at the same heights as those to be used in the system. You are told that the labeled solid line is the regression line representing the trend through a large number of scattered data points (scattered data are not shown). The scattered data points were medians of small scale Rayleigh distributed multipath fading for many different small areas throughout the region in which the system is to operate. You are also told that the remaining residual large scale variation of the data points after removing the regression line can be represented with a log normal distribution having a standard deviation, $\sigma = 8.6\,dB$.

a) At what distance from the transmitter can this wireless receiver operate in this environment if the receiver is to be above the minimum usable threshold in 99% of the small areas? (Another way to ask this question is, if the receiver is traveling in the cluttered environment in a circle at a constant distance from the transmitter, at what distance will the receiver be above threshold for 99% of the small areas along the circumference of the circle?)

b) The receiver threshold specified of $-100\,dBm$ for the Rayleigh median is for a 3 branch microscopic selection diversity receiver. The signals received on the 3 receiver branches fade independently. The $-100\,dBm$ threshold for the Rayleigh distributed multipath fading has the combined output of the 3 diversity branches above their thermal noise non-fading threshold for 99% of the time. The thermal noise non-fading threshold is the same for all 3 receiver branches. What is the thermal noise non-fading threshold in *dBm* for each of the receiver branches?

c) The thermal noise non-fading threshold for part b) is specified at a bit error ratio (BER) of $1x10^{-3}$. The receiver branches use synchronous detectors and matched filters to demodulate a 4-QAM digital received signal. Assume carrier and bit timing recovery are perfect and there is no ISI. The noise figures of all 3 receiver branches are the same and are $3.6\,dB$. What is the bit rate of the 4-QAM transmissions being received?

Finish

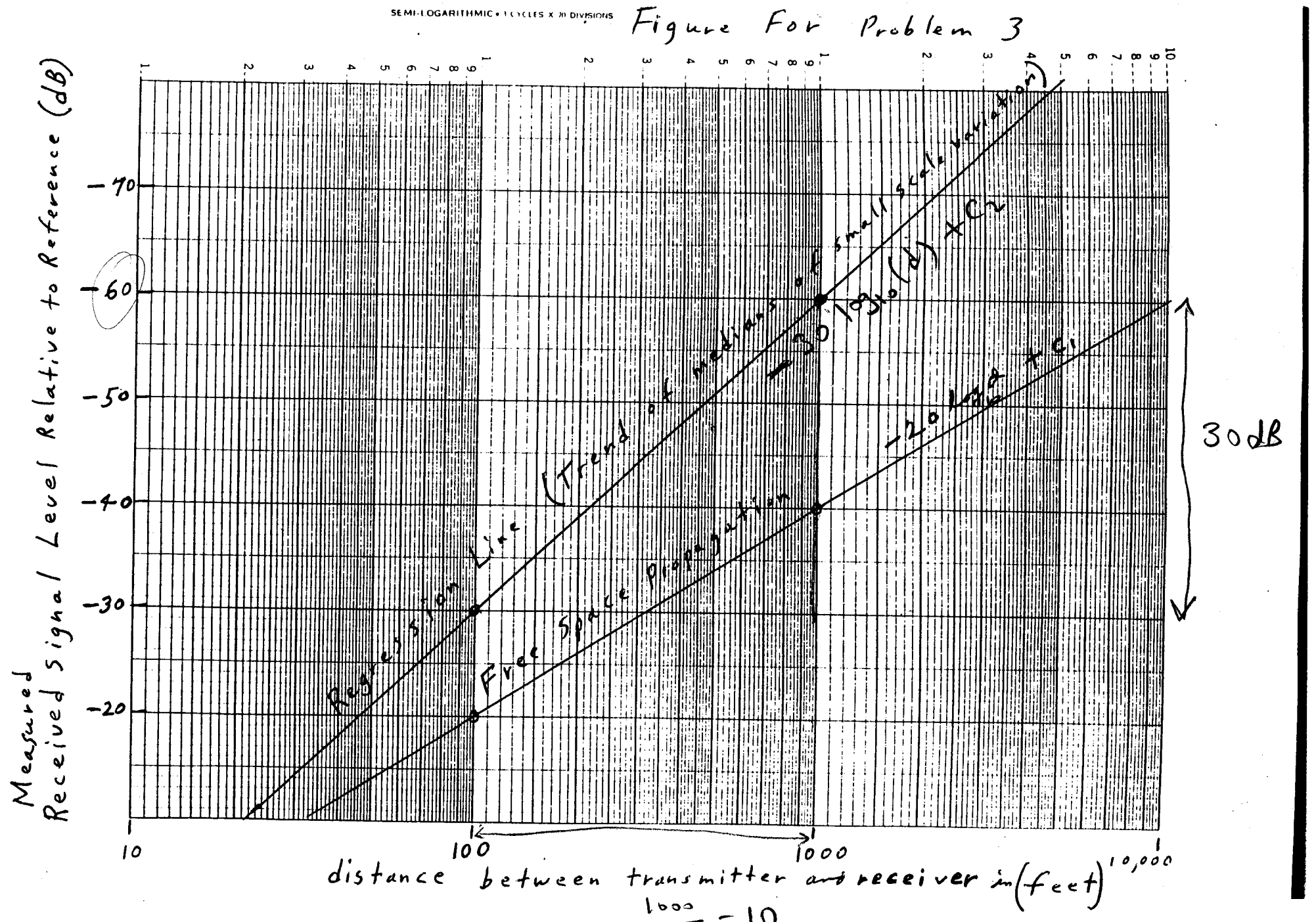
SEMI-LOGARITHMIC • 1 CYCLES X 10 DIVISIONS
Figure For Problem 3
Measured Received Signal / Level Relative to Reference (dB)
-70
-60
-50
-40
-30
-20
10
100
1000
10,000
distance between transmitter and receiver in (feet)
Regression Line
(Trend of medians of small scale variation)
Free Space propagation
30 log10(d) + C2
-20 log10 + C1
30 dB
1000/100 = 10

TABLE I

Area under the Normal Density Function

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