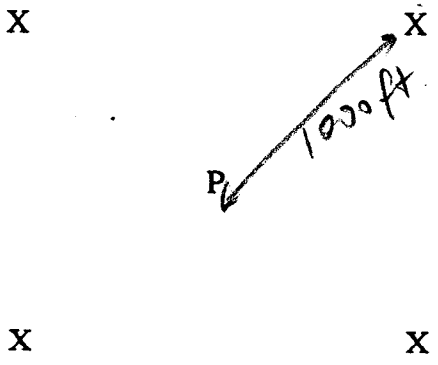
2. A wireless system used in an environment with many houses and small buildings consists of base stations arranged in a square grid. Portable receivers exercise macroscopic diversity when initially accessing channels at the base stations. For this simplified problem, only signal power will be considered, i.e. do not consider co-channel interference. The following system and propagation conditions apply: (24 pts)

- distance dependent trend of the mean (or median) of the log normal process is $1/d^3$ where d is the distance between a base station and a user.
- standard deviation of log normal large scale "shadow" variation is σ=11.4 dB.
- frequency f=982 MHz
- gain of transmitting antenna = 10 dB = G_T
- gain of receiving antenna = 0 dB = G_R
- minimum usable signal power at receivers is -100 dBm in the environment being considered. This minimum usable signal power (threshold) includes effects of Rayleigh distributed multipath fading, i.e. the -100 dBm is the Rayleigh median required.
- at distance d = 2000 feet the mean (or median) of the log normal process results in a received signal power that is 36 dB less than the signal power that would be received in free space using the same transmitter, receiver and antennas, i.e. the average "excess attenuation" at 2000 feet is 36 dB greater than free space.
- consider users located at the point maximum distance from the 4 base stations as indicated by P below. X indicates base stations.



- the point P is 1000 feet from each of the 4 base stations.
- the large scale log normally distributed signal variation from each of the base stations is independent at point P.

a) For an ensemble of different sets of 4 base stations and locations P at 1000 ft distance from them, calculate the transmitter power P_T required so that 98.8% of the locations will have the received power at the threshold level of -100 dBm. Include the benefit of the 4 branch macroscopic diversity.

b) What would be the percentage of locations P that would have received power at the threshold level if only one base station were present, i.e. without the macroscopic diversity? Use transmitter power calculated in a).

c) What distance between transmitter and receiver in free space would yield a received signal power of -100 dBm using the same antenna gains specified above and the transmitter power calculated in part a)?

d) The receiver threshold specified for this problem of -100 dBm for the Rayleigh median is for a two branch microscopic selection diversity receiver. The signals received on the two receiver branches fade independently. The two diversity receiver branches are above their thermal noise non-fading threshold for 98% of the time to yield the -100 dBm threshold in Rayleigh distributed multipath fading. What is the thermal noise non-fading threshold for the diversity receiver branches? The threshold is the same for both receiver branches.

e) The thermal noise non-fading threshold for part d) is specified at a bit error ratio, BER, of 1.1×10^{-4}. The receiver front ends are matched to their antennas. Assume an antenna temperature of $T_0 = 290°$ K. The receiver branches use synchronous detectors and matched filters to demodulate a 4-QAM digital received signal having a bit rate, r_b, of 200 kilobits/sec. Assume carrier and bit timing recovery are perfect. Assume no ISI, i.e. flat fading. What is the noise figure of the receiver branches? Assume the noise figures for the two branches are the same.

ASK

after diversity combining

3. You have a base station in a wireless system that has 30 duplex radio channels. Over a time period of interest, you measure the following parameters at the base station:

(10 pts)

- Traffic carried by the 30 channels is 23.56 Erlangs $T.C = 23.56$
- The traffic presented to the 30 channels by the fixed network (i.e. the base station originated traffic) is Poisson distributed with an arrival rate of 3.60 attempts/minute and an average call duration of 3 minutes. $\lambda = 3.60$ /min, $\frac{1}{\mu} = 3$ min
- Note the attached traffic table.

Assume that blocked calls are cleared and do not retry. Assume that the total traffic offered to the 30 channels is the sum of the traffic offered by the fixed network plus the traffic offered by mobile users.

a) What is the percentage of total call attempts on the 30 channels that are blocked?

b) What is the total traffic offered to the 30 channels in Erlangs?

c) What is the traffic offered to the 30 channels by the mobile users in Erlangs?

FOR QUESTION 3

30 $a = \lambda/\mu = 10.8$

Erlang B Traffic Table

$100 \times B(N, a) = \%$ Block

T_o = Traffic offered in Erlangs

N = Number of Channels

N	1% Block T_o		2% Block T_o		5% Block T_o
1	0.01	0.7	0.02	1.8	0.05
2	0.15	7.9	0.22	14	0.38
3	0.46	22	0.60	32	0.90
4	0.87	39	1.09	55	1.52
5	1.36	60	1.66	80	2.22
6	1.91	82	2.28	107	2.96
7	2.50	106	2.94	135	3.74
8	3.13	131	3.63	163	4.54
9	3.78	158	4.34	193	5.37
10	4.46	183	5.08	224	6.22
11	5.16	210	5.84	256	7.08
12	5.88	238	6.62	286	7.95
13	6.61	267	7.41	318	8.83
14	7.35	295	8.20	350	9.73
15	8.11	324	9.01	383	10.63
16	8.87	354	9.83	415	11.54
17	9.65	384	10.66	449	12.46
18	10.44	414	11.49	482	13.38
19	11.23	444	12.33	515	14.31
20	12.03	474	13.18	549	15.25
21	12.84	505	14.04	583	16.19
22	13.65	536	14.90	617	17.13
23	14.47	567	15.76	651	18.08
24	15.29	599	16.63	685	19.03
25	16.12	630	17.50	720	19.99
26	16.96	662	18.38	754	20.94
27	17.80	693	19.26	788	21.90
28	18.64	725	20.15	823	22.87
29	19.49	757	21.04	858	23.83
30	20.34	789	21.93	893	24.80
31	21.19	822	22.83	928	25.77
32	22.05	854	23.73	963	26.75
33	22.91	887	24.63	998	27.72
34	23.77	919	25.53	1033	28.70
35	24.64	951	26.43	1068	29.68
36	25.51	984	27.34	1104	30.66
37	26.38	1017	28.25	1139	31.64
38	27.25	1050	29.17	1175	32.63
39	28.13	1083	30.08	1210	33.61
40	29.01	1116	31.00	1246	34.60
41	29.89	1149	31.92	1281	35.59