Pabna University Of Science And Technology

Lab Report

Faculty of Engineering and Technology

Department Of Information And Communication Engineering

Course Title:Cellular and Mobile Communication Sessional

Course Code : ICE-4104

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Signature

INDEX

Serial No.	Experiment Name
01	If a total of 33 MHz of bandwidth is allocated to a particular FDD cellular telephone system which uses two 25 kHz simplex channels to provide full duplex voice and control channels, compute the number of channels available per cell if a system uses (a) 4-cell reuse, (b) 7-cell reuse (c) 12-cell reuse. If 1 MHz of the allocated spectrum is dedicated to control channels, determine an equitable distribution of control channels and voice channels in each cell for each of the three systems.
02	If a signal to interference ratio of 15 dB is required for satisfactory forward channel performance of a cellular system, what is the frequency reuse factor and cluster size that should be used for maximum capacity if the path loss exponent is (a) n= 4 , (b) n = 3? Assume that there are 6 co-channels cells in the first tier and all of them are at the same distance from the mobile. Use suitable approximations.
03	How many users can be supported for 0.5% blocking probability for the following number of trunked channels in a blocked calls cleared system? (a) 1, (b) 5, (c) 10, (d) 20, (e) 100. Assume each user generates 0.1 Erlangs of traffic.
04	An urban area has a population of 2 million residents. Three competing trunked mobile networks (systems A, B, and C) provide cellular service in this area. System A has 394 cells with 19 channels each, system B has 98 cells with 57 channels each, and system C has 49 cells, each with 100 channels. Find the number of users that can be supported at 2% blocking if each user averages 2 calls per hour at an average call duration of 3 minutes. Assuming that all three trunked systems are operated at maximum capacity, compute the percentage market penetration of each cellular provider.
05	A certain city has an area of 1,300 square miles and is covered by a cellular system using a 7-cell reuse pattern. Each cell has a radius of 4 miles and the city is allocated 40 MHz of spectrum with a full duplex channel bandwidth of 60 kHz. Assume a GOS of 2% for an Erlang B system is specified. If the offered traffic per user is 0.03 Erlangs, compute (a) the number of cells in the service area, (b) the number of channels per cell, (c) traffic intensity of each cell, (d) the maximum carried traffic; (e) the total number of users that can be served for 2% GOS, (f') the number of mobiles per channel, and (g) the theoretical maximum number of users that could be served at one time by the system.
06	If a transmitter produces 50 watts of power, express the transmit power in units of (a) dBm, and (b) dBW. If 50 watts is applied to a unity gain antenna

	with a 900 MHz carrier frequency, find the received power in dBm at a free space distance of 100 m from the antenna, what is P (10 km)? Assume unity gain for the receiver antenna.
07	Determine the path loss of a 900MHz cellular system in a large city from a base station with the height of 100m and mobile station installed in a vehicle with antenna height of 2m. The distance between mobile and base station is 4Km.
08	Determine the path loss between base station (BS) and mobile station (MS) of a 1.8GHz PCS system operating in a high-rise urban area. The MS is located in a perpendicular street to the location of the BS. The distances of the BS and MS to the corner of the street are 20 and 30 meters, respectively. The base station height is 20m.
09	A mobile is located 5 km away from a base station and uses a vertical λ /4 monopole antenna with a gain of 2.55 dB to receive cellular 3 radio signals. The E-field at 1 km from the transmitter is measured to be V/rn. The carrier frequency used for this system is 900 MHz. (a) Find the length and the gain of the receiving antenna. (b) Find the received power at the mobile using the 2-ray ground reflection model assuming the height of the transmitting antenna is 50 m and the receiving antenna is 1.5m above ground.
10	A hexagonal cell within a 4-cell system has a radius of 1.387 km. A total of 60 channels are used within the entire system. If the load per user is 0.029 Erlangs, and λ= call/hour, compute the following for an Erlang C system that has a 5% probability of a delayed call: (a) How many users per square kilometer will this system support? (b) What is the probability that a delayed call will have to wait for more than 10s? (c) What is the probability that a call will be delayed for more than 10 seconds?

Experiment No : 01

Experiment Name: If a total of 33 MHz of bandwidth is allocated to a particular FDD cellular telephone system which uses two 25 kHz simplex channels to provide full duplex voice and control channels, compute the number of channels available per cell if a system uses (a) 4-cell reuse, (b) 7-cell reuse (c) 12-cell reuse. If 1 MHz of the allocated spectrum is dedicated to control channels, determine an equitable distribution of control channels and voice channels in each cell for each of the three systems.

Theory:

Given:

Total bandwidth =33 MHz
Channel bandwidth = 25kHz x 2simplex channels = 50 kHz/duplex channels
Total available channels = 33000/50 = 660 channels

(a) For N= 4, total number of channels available per cell = 660/4 = 165 channels.

(b)For N=7, total number of channels available per cell = 660/7 =94.28 channels.

(c) For N = 12, total number of channels available per cell = 660/12 = 55 channels.

If 1 MHz spectrum for control channels implies that there are 1000/50 = 20 control channels out of the 660 channels available. To evenly distribute the control and voice channels, simply allocate the same number of channels in each cell wherever possible.

(a)For N = 4, we can have 20/4=5 control channels and (660-20)/4=160 voice channels per cell.

(b) For N = 7, we can have 20/7= 2.85 control channels and (660-20)/7=91.41 voice channels per cell.

(c) For N = 12, we can have 20/12=1.67 control channels and (660-20)/12=53.33 voice channels per cell.

Source Code:

```
clc;
clear all;
close all;
bw=33000;
schannel_bw=25;
disp('Channel Bandwidth..');
dup_ch_bw=2*schannel_bw;
t_ch=(bw/dup_ch_bw);
disp(dup_ch_bw);
disp('Total available channel');
disp(t_ch);
cc_bw=1000;
t_cc=cc_bw/dup_ch_bw;
disp('Total control channel');
```

```
disp(t_cc);
N=[4 7 12];
for i=1:3
    ch=t_ch/N(i);
    ch_per_cell=round(ch);
    disp('Channel per cell')
    disp(N(i));
    disp(ch_per_cell);
    c=(t_cc/N(i));
    cc=round(c);
    v=(t_ch-t_cc)/N(i);
    vc=round(v);
    disp('Control channel and voice channel are..');
    disp(cc);
    disp(vc);
end
```

Output:

Channel Bandwidth = 50

Total available channel = 660

Total control channel = 20

Channel per cell = 4

Total number of channels available per cell = 165

Control channel and voice channel are = 5 and 160

Channel per cell =7

Total number of channels available per cell = 94

Control channel and voice channel are = 3 and 91

Channel per cell = 12

Total number of channels available per cell = 55

Control channel and voice channel are = 2 and 53

Experiment No: 02

Experiment Name: If a signal to interference ratio of 15 dB is required for satisfactory forward channel performance of a cellular system, what is the frequency reuse factor and cluster size that should be used for maximum capacity if the path loss exponent is (a) n= 4 , (b) n = 3? Assume that there are 6 co-channels cells in the first tier and all of them are at the same distance from the mobile. Use suitable approximations.

Theory:

(a)n = 4 First, let us consider a 7-cell reuse pattern.

The co-channel reuse ratio $D/_R = \sqrt{3N} = \sqrt{3*7} = \sqrt{21}$ =4.583.

The signal-to-noise interference ratio is given by,

$S/_I = \left\{\frac{1}{6} * (4.583)^4\right\}$=73.67= $10\log(73.67) = 18.67\ dB$

Since this is greater than the minimum required S/I, N = 7 can be used.

b) n = 3 First, let us consider a 7-cell reuse pattern.

the signal-to-interference ratio is given by,

$$S/_I = \left\{\frac{1}{6} * (4.583)^3\right\} = 16.07 = 10\log(16.07) = 12.06\ dB$$

Since this is less than the minimum required S/I, we need to use a larger N.

The next possible value of N is 12, (i = j = 2). The corresponding co-channel ratio is given by $D/_R$= 6.0

The signal-to-interference ratio is given by,

$$S/_I = \left\{\frac{1}{6} * (6)^3\right\} = 36 = 10\log(36) = 15.56\ dB$$

. Since this is greater than the minimum required S/I, N = 12 can be used

Source Code:

```
clc;
clear all;
close all;
R_SI=15;
io=6;
n=[4 3];
for a=1:2
    N=7;
    Q=sqrt(3*N);
    disp('n: ')
    n(a)
    disp('Frequency reuse factor: ')
    Q
    SI=10*(log10((1/io)*(Q^n(a))));
    disp('Signal to interference ratio: ')
```

```
    SI
    if(SI<R_SI)
        i=2; j=2;
        N= (i^2)+(i*j)+(j^2);
        Q=sqrt(3*N);
        disp('n: ')
        n(a)
        disp('Frequency reuse factor: ')
        Q
        SI1=10*(log10((1/io)*(Q^n(a))));
        disp('Signal to interference ratio: ')
        SI1
    end
end
```

Output:

n=4

Frequency reuse factor,Q=4.5826

Signal to interference ratio,SI=18.66.29

n=3

Frequency reuse factor, Q=4.5826

Signal to interference ratio,SI= 12.05

n=3

Frequency reuse factor,Q=6

Signal to interference ratio,SI1=15.5630

Experiment No: 03

Experiment Name: How many users can be supported for 0.5% blocking probability for the following number of trunked channels in a blocked calls cleared system? (a) 1, (b) 5, (c) 10, (d) 20, (e) 100. Assume each user generates 0.1 Erlangs of traffic.

Theory:

Number of Channels C	Capacity (Erlangs) for GOS = 0.01	= 0.005	= 0.002	= 0.001
2	0.153	0.105	0.065	0.046
4	0.869	0.701	0.535	0.439
5	1.36	1.13	0.900	0.762
10	4.46	3.96	3.43	3.09
20	12.0	11.1	10.1	9.41
24	15.3	14.2	13.0	12.2
40	29.0	27.3	25.7	24.5
70	56.1	53.7	51.0	49.2
100	84.1	80.9	77.4	75.2

From Table we can find the total capacity in Erlangs for the 0.5% GOS for different numbers of channels. By using the relation $A = UA_u$we can obtain the total number of users that can be supported in the system.

(a) Given C = 1 A_u= 0.1, GOS = 0.005. From table we obtain A = 0005. Therefore, total number of users, $U = A/_{A_u}$= 0.005/0.1 = 0.05 users. But, actually one user could be supported on one channel. So, U = 1.

(b) Given C = 5, A_u = 0.1, GOS = 0.005 .From table, we obtain A = 1.13. Therefore, total number of users, $U = A/_{A_u}$= 1.13/0.1= 11.3 users.

(c) Given C = 10, A_u= 0.1 , GOS = 0.005 .From table, we obtain A = 3.96. Therefore, total number of users, $U = A/_{A_u}$= 3.96/0.1=39.1 users.

(d) Given C = 20, A_u = 0.1 , GOS = 0.005. From table, we obtain A = 11.10. Therefore, total number of users, $U = A/_{A_u}$= 11.1/0.1 = 111 users.

(e)Given C = 100, A_u= 0.1 , GOS =0.005. From table ,we obtain A = 80.9. Therefore, total number of users, $U = A/_{A_u}$= 80.9/0.1 = 809 users.

Source Code:

```
clc;
clear all;
close all;
Gos=0.5/100;
Au=0.1;
A=[0.005 1.13 3.96 11.1 80.9];
c=[1 5 10 20 100];
disp('Blocking probability');
disp(Gos);
disp('Traffic intensity per user ');
disp(Au);
disp('Traffic intensity');
disp(A);
disp('Channel');
disp(c);
U=(A/Au);
u=round(U);
disp('Number of users');
disp(u);
```

Output:

Blocking probability = 0.0050

Traffic intensity per user =.1000

Traffic intensity= 0.0050 1.1300 3.9600 11.1000 80.9000

Channel = 1 5 10 20 100

Number of users=0 11 40 111 809

Experiment No: 04

Experiment Name: An urban area has a population of 2 million residents. Three competing trunked mobile networks (systems A, B, and C) provide cellular service in this area. System A has 394 cells with 19 channels each, system B has 98 cells with 57 channels each, and system C has 49 cells, each with 100 channels. Find the number of users that can be supported at 2% blocking if each user averages 2 calls per hour at an average call duration of 3 minutes. Assuming that all three trunked systems are operated at maximum capacity, compute the percentage market penetration of each cellular provider.

Theory:

Erlang B Chart:

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
44	24.33	26.53	27.64	30.80	32.54	34.68	38.56	43.09	47.09	51.09	59.92	71.01
45	25.08	27.32	28.45	31.66	33.43	35.61	39.55	44.17	48.25	52.32	61.35	72.67
46	25.83	28.11	29.26	32.52	34.32	36.53	40.55	45.24	49.40	53.56	62.77	74.33
47	26.59	28.90	30.07	33.38	35.22	37.46	41.54	46.32	50.56	54.80	64.19	76.00
48	27.34	29.70	30.88	34.25	36.11	38.39	42.54	47.40	51.71	56.03	65.61	77.66
49	28.10	30.49	31.69	35.11	37.00	39.32	43.53	48.48	52.87	57.27	67.04	79.32
50	28.87	31.29	32.51	35.98	37.90	40.26	44.53	49.56	54.03	58.51	68.46	80.99
51	29.63	32.09	33.33	36.85	38.80	41.19	45.53	50.64	55.19	59.75	69.88	82.65
52	30.40	32.90	34.15	37.72	39.70	42.12	46.53	51.73	56.35	60.99	71.31	84.32
53	31.17	33.70	34.98	38.60	40.60	43.06	47.53	52.81	57.50	62.22	72.73	85.98
54	31.94	34.51	35.80	39.47	41.51	44.00	48.54	53.89	58.66	63.46	74.15	87.65
55	32.72	35.32	36.63	40.35	42.41	44.94	49.54	54.98	59.82	64.70	75.58	89.31
56	33.49	36.13	37.46	41.23	43.32	45.88	50.54	56.06	60.98	65.94	77.00	90.97
57	34.27	36.95	38.29	42.11	44.22	46.82	51.55	57.14	62.14	67.18	78.43	92.64
58	35.05	37.76	39.12	42.99	45.13	47.76	52.55	58.23	63.31	68.42	79.85	94.30
59	35.84	38.58	39.96	43.87	46.04	48.70	53.56	59.32	64.47	69.66	81.27	95.97
60	36.62	39.40	40.80	44.76	46.95	49.64	54.57	60.40	65.63	70.90	82.70	97.63
61	37.41	40.22	41.63	45.64	47.86	50.59	55.57	61.49	66.79	72.14	84.12	99.30
62	38.20	41.05	42.47	46.53	48.77	51.53	56.58	62.58	67.95	73.38	85.55	101.0
63	38.99	41.87	43.31	47.42	49.69	52.48	57.59	63.66	69.11	74.63	86.97	102.6
64	39.78	42.70	44.16	48.31	50.60	53.43	58.60	64.75	70.28	75.87	88.40	104.3
65	40.58	43.52	45.00	49.20	51.52	54.38	59.61	65.84	71.44	77.11	89.82	106.0
66	41.38	44.35	45.85	50.09	52.44	55.33	60.62	66.93	72.60	78.35	91.25	107.6
67	42.17	45.18	46.69	50.98	53.35	56.28	61.63	68.02	73.77	79.59	92.67	109.3
68	42.97	46.02	47.54	51.87	54.27	57.23	62.64	69.11	74.93	80.83	94.10	111.0
69	43.77	46.85	48.39	52.77	55.19	58.18	63.65	70.20	76.09	82.08	95.52	112.6
70	44.58	47.68	49.24	53.66	56.11	59.13	64.67	71.29	77.26	83.32	96.95	114.3
71	45.38	48.52	50.09	54.56	57.03	60.08	65.68	72.38	78.42	84.56	98.37	116.0
72	46.19	49.36	50.94	55.46	57.96	61.04	66.69	73.47	79.59	85.80	99.80	117.6
73	47.00	50.20	51.80	56.35	58.88	61.99	67.71	74.56	80.75	87.05	101.2	119.3
74	47.81	51.04	52.65	57.25	59.80	62.95	68.72	75.65	81.92	88.29	102.7	120.9
75	48.62	51.88	53.51	58.15	60.73	63.90	69.74	76.74	83.08	89.53	104.1	122.6
76	49.43	52.72	54.37	59.05	61.65	64.86	70.75	77.83	84.25	90.78	105.5	124.3
77	50.24	53.56	55.23	59.96	62.58	65.81	71.77	78.93	85.41	92.02	106.9	125.9
78	51.05	54.41	56.09	60.86	63.51	66.77	72.79	80.02	86.58	93.26	108.4	127.6
79	51.87	55.25	56.95	61.76	64.43	67.73	73.80	81.11	87.74	94.51	109.8	129.3
80	52.69	56.10	57.81	62.67	65.36	68.69	74.82	82.20	88.91	95.75	111.2	130.9
81	53.51	56.95	58.67	63.57	66.29	69.65	75.84	83.30	90.08	96.99	112.6	132.6
82	54.33	57.80	59.54	64.48	67.22	70.61	76.86	84.39	91.24	98.24	114.1	134.3
83	55.15	58.65	60.40	65.39	68.15	71.57	77.87	85.48	92.41	99.48	115.5	135.9
84	55.97	59.50	61.27	66.29	69.08	72.53	78.89	86.58	93.58	100.7	116.9	137.6
85	56.79	60.35	62.14	67.20	70.02	73.49	79.91	87.67	94.74	102.0	118.3	139.3
86	57.62	61.21	63.00	68.11	70.95	74.45	80.93	88.77	95.91	103.2	119.8	140.9
87	58.44	62.06	63.87	69.02	71.88	75.42	81.95	89.86	97.08	104.5	121.2	142.6
88	59.27	62.92	64.74	69.93	72.82	76.38	82.97	90.96	98.25	105.7	122.6	144.3
89	60.10	63.77	65.61	70.84	73.75	77.34	83.99	92.05	99.41	107.0	124.0	145.9
90	60.92	64.63	66.48	71.76	74.68	78.31	85.01	93.15	100.6	108.2	125.5	147.6
91	61.75	65.49	67.36	72.67	75.62	79.27	86.04	94.24	101.8	109.4	126.9	149.3
92	62.58	66.35	68.23	73.58	76.56	80.24	87.06	95.34	102.9	110.7	128.3	150.9
93	63.42	67.21	69.10	74.50	77.49	81.20	88.08	96.43	104.1	111.9	129.8	152.6
94	64.25	68.07	69.98	75.41	78.43	82.17	89.10	97.53	105.3	113.2	131.2	154.3
95	65.08	68.93	70.85	76.33	79.37	83.13	90.12	98.63	106.4	114.4	132.6	155.9
96	65.92	69.79	71.73	77.24	80.31	84.10	91.15	99.72	107.6	115.7	134.0	157.6
97	66.75	70.65	72.61	78.16	81.25	85.07	92.17	100.8	108.8	116.9	135.5	159.3
98	67.59	71.52	73.48	79.07	82.18	86.04	93.19	101.9	109.9	118.2	136.9	160.9
99	68.43	72.38	74.36	79.99	83.12	87.00	94.22	103.0	111.1	119.4	138.3	162.6
100	69.27	73.25	7–.25	80.91	84.06	87.97	95.24	104.1	112.3	120.6	139.7	164.3

N is the number of servers. The numerical column headings indicate blocking probability B in %. Table generated by Dan Dexter

System A
Given:

Probability of blocking = 2% = 0.02

Number of channels per cell used in the system, C = 19

Traffic intensity per user, $A_u = \lambda H = 2 * \left(\frac{3}{60}\right) = 0.1$ Erlangs

For GOS = 0.02 and C = 19, from the Erlang B chart, the total carried traffic, A is obtained as 12.33 Erlangs.

Therefore, the number of users that can be supported per cell is $U = {}^{A}/_{A_u}$ = 12/0.1 = 120.

Since there are 394 cells, the total number of' subscribers that can be supported by System $A = 120 * 394 = 47280$

System B
Given:

Probability of blocking = 2% = 0.02

Number of channels per cell used in the system, C = 57

Traffic intensity per user, $A_u = \lambda H = 2 * \left(\frac{3}{60}\right) = 0.1$ Erlangs

For GOS = 0.02 and C = 57, from the Erlang B chart, the total carried traffic, A is obtained as 45 Erlangs.

Therefore, the number of users that can be supported per cell is $U = {}^{A}/_{A_u}$ = 45/0.1 = 450.

Since there are 98 cells, the total number of subscribers that can be supported by System $B = 98 * 450 = 44100$

System C
Given:

Probability of blocking = = 0.02

Number of channels per cell used in the system, C = 100

Traffic intensity per user, , $A_u = \lambda H = 2 * \left(\frac{3}{60}\right) = 0.1$ Erlangs

For GOS = 0.02 and C = 100, from the Erlang B chart, the total carried traffic, A is obtained as 88 Erlangs.

Therefore, the number of users that can be supported per cell is $U = {}^{A}/_{A_u}$ = 88/0.1= 880.

Since there are 49 cells, the total number of subscribers that can be supported by System $C = 49 * 880 = 43120$

Therefore, total number of cellular subscribers that can be supported by these three systems are 47280 + 44100 + 43120 = 134500 users.

Since there are 2 million residents in the given urban area and the total number of cellular subscribers in System A is equal to 47280, the percentage market penetration is equal to 47280/2000000 = 2.36%

Similarly, market penetration of System B is equal to 44100/2000000 = 2.205% and the market penetration of System C is equal to 43120/2000000 = 2.156%. The market penetration of the three systems combined is equal to 134500/2000000 = 6.725%.

Source Code:

```
clc;
clear all;
close all;
blocking_p= 2/100;
lamda=2;
H=3/60;
Au=lamda*H;
disp('For system A')
channel_a=19;
cell_A=394;
A=12;
disp('Number of users in System A');
Ua=A/Au
disp('Total number of subscriber in system A');
subscriber_A=Ua*cell_A;
disp(subscriber_A);
percentage_market_penetration_for_A=(subscriber_A/2000000)*100

disp('For system B')
channel_b=57;
cell_B=98;
Ab=45;
disp('Number of users in System B');
Ub=Ab/Au
disp('Total number of subscriber in system B');
subscriber_B=Ub*cell_B;
disp(subscriber_B);
percentage_market_penetration_for_B=(subscriber_B/2000000)*100

disp('For system C')
channel_c=100;
cell_C=49;
Ac=88;
disp('Number of users in System C');
Uc=Ac/Au
disp('Total number of subscriber in system C');
subscriber_C=Uc*cell_C;
disp(subscriber_C);
percentage_market_penetration_for_C=(subscriber_C/2000000)*100
Total_number_of_subscriber= subscriber_A+subscriber_B+subscriber_C
Market_penetration_for_three_system= (Total_number_of_subscriber/2000000)*100
```

Output:

For system A
Number of users in System A ,U_A =120
Total number of subscriber in system A =47280
percentage_market_penetration_for_A =2.3640

For system B
Number of users in System B, U_B=450
Total number of subscriber in system B=44100
percentage_market_penetration_for_B =2.2050

For system C
Number of users in System C ,$U_C = 880$
Total number of subscriber in system C=43120
percentage_market_penetration_for_C =2.1560

Total_number_of_subscriber = 134500
Market_penetration_for_three_system = 6.7250

Experiment No: 05

Experiment Name: A certain city has an area of 1,300 square miles and is covered by a cellular system using a 7-cell reuse pattern. Each cell has a radius of 4 miles and the city is allocated 40 MHz of spectrum with a full duplex channel bandwidth of 60 kHz. Assume a GOS of 2% for an Erlang B system is specified. If the offered traffic per user is 0.03 Erlangs, compute (a) the number of cells in the service area, (b) the number of channels per cell, (c) traffic intensity of each cell, (d) the maximum carried traffic; (e) the total number of users that can be served for 2% GOS, (f') the number of mobiles per channel, and (g) the theoretical maximum number of users that could be served at one time by the system.

Theory:

(a)Given:

Total coverage area = 1300 miles

Cell radius = 4 miles

The area of a cell (hexagon) can be shown to be $2.5981R^2$, thus each cell covers $2.5981 * 4^2$=41.5696 sqmi. =41.57 sqmi

Hence, the total number of cells are = 1300/41.57 = 31 cells.

(b) The total number of channels per cell (C) = allocated spectrum /(channel bandwidth * frequency reuse factor) = 40, 000,000/ (60,000 * 7) = 95 channels/cell

(c) Given: C = 95, and GOS = 0.02 From the Erlang B chart, we have traffic intensity per cell A = 84 Erlangs/cell

(d) Maximum carried traffic = number of cells * traffic intensity per cell = 31 * 84 = 2604 Erlangs.

(e) Given traffic per user = 0.03,
Erlangs total number of users = Total traffic / traffic per user = 2604 / 0.03 = 86,800 users.

(f) Number of mobiles per channel = number of users/number of channels = 86,800 / 666 = 130 mobiles/ehannel.

(g) The theoretical maximum number of served mobiles is the number of available channels in the system (all channels occupied) = $C * N_c \ = 95 * 31$= 2945 users, which is 3.4% of the customer base.

Source Code:

```
clc;
clear all;
close all;
area=1300;
radius=4;
each_cell_covers=floor(2.5981*radius^2);
disp('(a)');
number_of_cells=floor(area/each_cell_covers)
%b
allocated_spectrum=40000;
channel_width=60;
frequency_reuse_factor=7;
disp('(b)');
number_of_channel_per_cell=floor(allocated_spectrum/(channel_width*frequency_
reuse_factor))
%c
disp('(c)');
traffic_intensity_per_cell=84
%d
disp('(d)');
maximum_carried_traffic=number_of_cells*traffic_intensity_per_cell
%e
traffic_per_user=0.03;
disp('(e)');
total_number_of_user = maximum_carried_traffic/traffic_per_user
%f
number_of_channels=number_of_channel_per_cell*frequency_reuse_factor;
disp('(f)');
number_of_mobile_per_channel=floor( total_number_of_user/number_of_channels)
%g
disp('(g)');
theoritical_maximum_number_of_user_that_could_be_served=
number_of_cells*number_of_channel_per_cell
```

Output:

(a)number_of_cells = 31

(b)number_of_channel_per_cell = 95

(c)traffic_intensity_per_cell = 84

(d)maximum_carried_traffic =2604

(e)total_number_of_user =86800

(f)number_of_mobile_per_channel = 130

(g)theoritical_maximum_number_of_user_that_could_be_served =2945

Experiment No: 06

Experiment Name: If a transmitter produces 50 watts of power, express the transmit power in units of (a) dBm, and (b) dBW. If 50 watts is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dBm at a free space distance of 100 m from the antenna, what is P (10 km)? Assume unity gain for the receiver antenna.

Theory:

Given:

Transmitter power, = 50 W

Carrier frequency, = 900 MHz =$900 * 10^6 = 9^8 Hz$

(a) Transmitter power, $P_t(dBm)$= $10 \log \left[P_t(mW) / (1mW) \right]$= $10 \log[50 * 10^3] = 47\ dBm$

(b) Transmitter power, $P_t(dBW)$= $10 \log \left[P_t(W) / (1W) \right]$= 10log(50) =17.0 dBW.

The received power can be determined ,

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 l} = \frac{50*1*1*(1/3)^2}{(4\pi)^2 (100)^2 (1)} = 3.5 * 10^{-6} W = 3.5 * 10^{-3} mW$$

$$P_r(dBm) = 10 \log \left[P_r(mW) / (1mW) \right] = 10 \log[3.5 * 10^{-3} mW] = -24.5 dBm$$

The received power at 10 km can be expressed in terms of dBm where d_0= 100 m and d = 10km

$$P_r(10km) = P_r(100) + 20 \log \left[\frac{100}{10000} \right] = -24.5dBm - 40dBm = -64.5dBm$$

Source Code:

```
clc;
clear all;
close all;
%pt=Transmitted power, fc=carrier frequency in MHz
pt=50;
fc=900;
gt=1;
gr=1;
d=100;
do=10*10^3;
disp('(a)')
Transmitted_power_in_dBm= ceil(10*log10(50*10^3))
disp('(b)')
Transmitted_power_in_dbW= ceil(10*log10(50))
lamda=(3*10^8)/(900*10^6);
pr_mw=((pt*gt*gr*(lamda^2))/(((4*3.1416)^2)*(d^2)*1))*1000;
received_power_in_dbm = 10*log10(pr_mw)
pr_10km = received_power_in_dbm+(20*log10(d/do))
```

Output:

(a)Transmitted_power_in_dBm = 47

(b)Transmitted_power_in_dbW = 17

received_power_in_dbm = -24.5369

pr_10km =-64.5369

Experiment No: 07

Experiment Name: Determine the path loss of a 900MHz cellular system in a large city from a base station with the height of 100m and mobile station installed in a vehicle with antenna height of 2m. The distance between mobile and base station is 4Km.

Theory:

Given:

Mobile station antenna height, $h_{re} = 2m$
Base Station antenna height, $h_{te} = 100m$
Distance between mobile and base station , $d = 4km$
Frequency , $f_c = 900MHz$

We calculate the terms in the Okumura-Hata model as,

$$a(h_{re}) = 3.2[\log(11.75h_{re})]^2 - 4.97\ dB \qquad \text{for } f_c \geq 300\ MHz$$
$$= 3.2[\log(11.75 * 2)]^2 - 4.97\ dB$$
$$= 1.045\ dB$$

And,

$$L_p = 69.55 + 26.16 \log f_c - 13.82 \log h_{te} - a(h_{re}) + [44.9 - 6.55 \log h_{te}] \log d$$
$$= 69.55 + 26.16 \log(900) - 13.82 \log(100) - 1.045 + [44.9 - 6.55 \log(100)] * \log(4)$$
$$= 137.3\ dB$$

Source Code:

```
clc;
clear all;
close all;
hre=2;
hte=100;
fc=900;
d=4;
a_hre=3.2*(log10(11.75*hre))^2-4.97
Lp=69.55+26.16*log10(fc)-13.82*log10(hte)-a_hre+(44.9-
6.55*log10(hte))*log10(d);
disp('Loss path');
disp(Lp);
```

Output:

a_hre =1.0454

Loss path = 137.2930

Experiment No: 08

Experiment Name: Determine the path loss between base station (BS) and mobile station (MS) of a 1.8GHz PCS system operating in a high-rise urban area. The MS is located in a perpendicular street to the location of the BS. The distances of the BS and MS to the corner of the street are 20 and 30 meters, respectively. The base station height is 20m.

Theory:

Given:

Base Station antenna height, $h_{te} = 20m$

Frequency , $f_c = 1.8GHz$

Distance between mobile and base station , $d = \frac{\sqrt{20^2+30^2}}{1000} = 0.036m$

Path loss ,

$$L_p = 135.41 + 12.49 \log f_c - 4.99 \log h_{te} + [46.82 - 2.34 \log h_{te}] \log d$$
$$= 135.41 + 12.49 \log(1.8) - 4.99 \log(20) + [46.82 - 2.34 \log(20)] * \log(0.036)$$
$$= 68.86\ dB$$

Source Code:

```
clc;
clear all;
close all;
hte=20;
fc=1.8;
d=((20^2+30^2)^0.5)/1000;
Lp=135.41+12.49*log10(fc)-4.99*log10(hte)+(46.82-2.34*log10(hte))*log10(d);
disp('Loss path');
disp(Lp);
```

Output:

Loss path = 68.9368

Experiment No: 09

Experiment Name: A mobile is located 5 km away from a base station and uses a vertical λ /4 monopole antenna with a gain of 2.55 dB to receive cellular 3 radio signals. The E-field at 1 km from the transmitter is measured to be V/rn. The carrier frequency used for this system is 900 MHz.
(a) Find the length and the gain of the receiving antenna.
(b) Find the received power at the mobile using the 2-ray ground reflection model assuming the height of the transmitting antenna is 50 m and the receiving antenna is 1.5m above ground.

Theory:

Given:

T-R separation distance ,d = 5 km
E-field at a distance of 1 km = $10^{-3} V/m$
Frequency of operation, $f = 900MHz$
Transmitting antenna height,$h_t = 50m$
Receiveing antenna height,$h_r = 1.5m$

$$\lambda = \frac{c}{f} = \frac{3*10^8}{900*10^6} = 0.333m$$

Length of the antenna, $L = \lambda/_4 = 0.333/_4 = 0.08325m = 8.325cm = 8.33cm$

(a)Gain of antenna =1.8 = 2.55 dB.

(b) Since $d \gg \sqrt{h_t h_r}$,the electric field is given by ,

$$E_R(d) \cong \frac{2E_0 d_0}{d} \frac{2\pi h_t h_r}{\lambda d} \cong \frac{k}{d^2} V/_m$$

$$= \frac{2*10^{-3}*1*10^3}{5*10^3}\left[\frac{2\pi(50)*(1.5)}{0.333(5*10^3)}\right]$$

$$=113.1 * 10^{-6}\, V/_m$$

The received power at a distanced can be obtained by,

$$P_r(d) = \frac{(113.1*10^{-6})^2}{377}\left[\frac{1.8*(0.333)^2}{4\pi}\right] = 5.4 * 10^{-13}W$$

$$P_r(d) = 10\log(5.4 * 10^{-13}) = -122.65\ dBW$$

Source Code:

```
clc;
clear all;
close all;
T_R_field = 5;
E_field = 10^(-3);
f = 900;
do=1000;
lamda=(3*10^8)/(900*10^6);
disp('(a)')
length_of_antenna = lamda/4
gain = (10^(2.55/10))
```

```
disp('(b)')
ht=50;
hr=1.5;
d=5*10^3;
Er_d = (2*E_field*do*2*3.1416*ht*hr)/(lamda*d^2)
Ae=(gain*lamda^2)/(4*3.1416);
pr_d=((Er_d^2)/(120*3.1416))*Ae
received_power_at_5km_distance = 10*log10(pr_d)
```

Output:

(a)length_of_antenna =0.0833
gain =1.7989

(b)Er_d = 1.1310e-04
pr_d = 5.3966e-13
received_power_at_5km_distance =-122.6788

Experiment No: 10

Experiment Name: A hexagonal cell within a 4-cell system has a radius of 1.387 km. A total of 60 channels are used within the entire system. If the load per user is 0.029 Erlangs, and λ= call/hour, compute the following for an Erlang C system that has a 5% probability of a delayed call:

(a) How many users per square kilometer will this system support?

(b) What is the probability that a delayed call will have to wait for more than 10s?

(c) What is the probability that a call will be delayed for more than 10 seconds?

Theory:

Erlang C 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	.0100	.0200	.0500	.1000	.1500	.2000	.3000	.4000
2	.0142	.0319	.0452	.1025	.1465	.2103	.3422	.5000	.6278	.7403	.9390	1.117
3	.0860	.1490	.1894	.3339	.4291	.5545	.7876	1.040	1.231	1.393	1.667	1.903
4	.2310	.3533	.4257	.6641	.8100	.9939	1.319	1.653	1.899	2.102	2.440	2.725
5	.4428	.6289	.7342	1.065	1.259	1.497	1.905	2.313	2.607	2.847	3.241	3.569
6	.7110	.9616	1.099	1.519	1.758	2.047	2.532	3.007	3.344	3.617	4.062	4.428
7	1.026	1.341	1.510	2.014	2.297	2.633	3.188	3.725	4.103	4.406	4.897	5.298
8	1.382	1.758	1.958	2.543	2.866	3.246	3.869	4.463	4.878	5.210	5.744	6.178
9	1.771	2.208	2.436	3.100	3.460	3.883	4.569	5.218	5.668	6.027	6.600	7.065
10	2.189	2.685	2.942	3.679	4.077	4.540	5.285	5.986	6.469	6.853	7.465	7.959
11	2.634	3.186	3.470	4.279	4.712	5.213	6.015	6.765	7.280	7.688	8.336	8.857
12	3.100	3.708	4.018	4.896	5.363	5.901	6.758	7.554	8.099	8.530	9.212	9.761
13	3.587	4.248	4.584	5.529	6.028	6.602	7.511	8.352	8.926	9.379	10.09	10.67
14	4.092	4.805	5.166	6.175	6.705	7.313	8.273	9.158	9.760	10.23	10.98	11.58
15	4.614	5.377	5.762	6.833	7.394	8.035	9.044	9.970	10.60	11.09	11.87	12.49
16	5.150	5.962	6.371	7.502	8.093	8.766	9.822	10.79	11.44	11.96	12.77	13.41
17	5.699	6.560	6.991	8.182	8.801	9.505	10.61	11.61	12.29	12.83	13.66	14.33
18	6.261	7.169	7.622	8.871	9.518	10.25	11.40	12.44	13.15	13.70	14.56	15.25
19	6.835	7.788	8.263	9.568	10.24	11.01	12.20	13.28	14.01	14.58	15.47	16.18
20	7.419	8.417	8.914	10.27	10.97	11.77	13.00	14.12	14.87	15.45	16.37	17.10
21	8.013	9.055	9.572	10.99	11.71	12.53	13.81	14.96	15.73	16.34	17.28	18.03
22	8.616	9.702	10.24	11.70	12.46	13.30	14.62	15.81	16.60	17.22	18.19	18.96
23	9.228	10.36	10.91	12.43	13.21	14.08	15.43	16.65	17.47	18.11	19.10	19.89
24	9.848	11.02	11.59	13.16	13.96	14.86	16.25	17.51	18.35	19.00	20.02	20.82
25	10.48	11.69	12.28	13.90	14.72	15.65	17.08	18.36	19.22	19.89	20.93	21.76
26	11.11	12.36	12.97	14.64	15.49	16.44	17.91	19.22	20.10	20.79	21.85	22.69
27	11.75	13.04	13.67	15.38	16.26	17.23	18.74	20.08	20.98	21.68	22.77	23.63
28	12.40	13.73	14.38	16.14	17.03	18.03	19.57	20.95	21.87	22.58	23.69	24.57
29	13.05	14.42	15.09	16.89	17.81	18.83	20.41	21.82	22.75	23.48	24.61	25.50
30	13.71	15.12	15.80	17.65	18.59	19.64	21.25	22.68	23.64	24.38	25.54	26.44

Given,

Cell radius, R = 1.387 km

Area covered per cell is $2.598 * (1.387)^2 = 4.99 = 5\ sq\ km$

Number of cells per cluster = 4

Total number of channels = 60

Traffic per user , $A_u = 0.029\ Erlangs$

Therefore, number of channels per cell = 60 / 4 = 15 channels.

(a)From Erlang C chart, for 5% probability of delay with C = 15, traffic intensity ,A = 9.0 Erlangs.

Therefore, number of users = total traffic intensity / traffic per user

=9.0/0.029 = 310 users

= 310 users/5 sq km = 62 users/sq km

(b) Given ,λ= 1 , holding time, $H = {}^{A_u}/_{\lambda} = {}^{0.029}/_{1} = .029 hour = 104.4\ seconds$

The probability that a delayed call will have to wait for more than 10 s is ,

$$Pr[delay > t|delay] = exp(-(C - A)t/H)$$

$$= \exp\left(-\frac{(15-9.0)10}{104.4}\right) = 56.29\%$$

(c) Given , $Pr[delay > 0] = 5\% = 0.05$

Probability that a call is delayed more than 10 seconds,

$$Pr[delay > 10] = Pr[delay > 0]\ \ Pr[delay > t|delay]$$

$$= 0.05 * 0.5629$$

$$= 0.0281 = 2.81\%$$

Source Code:

```
clc;
clear all;
close all;
%R=cell radius, N=total no of channel, n=number of cell per cluster
R=1.387;
n=4;
N=60;
%A=Area covered per cell
A=2.598*R^2;
%c=number of channel per cell
c=N/4;
disp('(a)');
traffic_intensity=9;
load_per_user=0.029;
number_of_users = floor((traffic_intensity/load_per_user)/A)
%b
disp('(b)');
lamda=1;
t=10;
H=(load_per_user/lamda)*3600;
the_probability_to_wait=exp(-(c-traffic_intensity)*t/H)*100
```

```
%c
disp('(c)');
p=5/100;
probability_of_delay_more_than_10sec = p*the_probability_to_wait
```

Output:

(a)number_of_users =62

(b)the_probability_to_wait =56.2867

(c)probability_of_delay_more_than_10sec =2.8143