

Pabna University of Science & Technology



Department of Information and Communication Engineering Faculty of Engineering and Technology Lab Report

Course Title: Cellular and Mobile Communication Sessional

Course Code: ICE-4104

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Problem No: 01

Name of the Problem: 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.

Solution:

Given:

Total bandwidth = 33 MHz Channel bandwidth = $25 \text{ kHz} \times 2 \text{ simplex channels} = 50 \text{ kHz/duplex channel}$

Total available channels = $33,000/50 = 660$ channels

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

(b) For $N=7$, total number of channels available per cell = $660/7 \approx 95$ channels.

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

A 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. Here, the 660 channels must be evenly distributed to each cell within the cluster. In practice, only the 640 voice channels would be allocated, since the control channels are allocated separately as 1 per cell.

(a) For $N=4$, we can have 5 control channels and 160 voice channels per cell. In practice, however, each cell only needs a single control channel (the control channels have a greater reuse distance than the voice channels). Thus, one control channel and 160 voice channels would be assigned to each cell.

(b) For $N=7$, 4 cells with 3 control channels and 92 voice channels, 2 cells with 3 control channels and 90 voice channels, and 1 cell with 2 control channels and 92 voice channels could be allocated. In practice, however, each cell would have one control channel, four cells would have 91 voice channels, and three cells would have 92 voice channels.

(c) For $N=12$, we can have 8 cells with 2 control channels and 53 voice channels, and 4 cells with 1 control channel and 54 voice channels each. In an actual system, each cell would have 1 control channel, 8 cells would have 53 voice channels, and 4 cells would have 54 voice channels.

Procedure(s):

- a. Open Matlab and create a new Matlab file
- b. Write basic Matlab commands
- c. Define variables to solution of the given problem
- d. Use appropriate formula for calculating the given problem
- e. Print the answer of the given problem.

Matlab 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

165

Control channel and voice channel are...

5

160

Channel per cell

7

94

Control channel and voice channel are..

3

91

Channel per cell

12

55

Control channel and voice channel are..

2

53

Problem No: 02

Name of the Problem: 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:

The co-channel reuse ratio is,

$$Q = \frac{D}{R} = \sqrt{3N} \text{-----} (1)$$

The signal-to-interference ratio is given by,

$$\frac{S}{I} = \frac{\left(\frac{D}{R}\right)^n}{i_0} = \frac{(\sqrt{3N})^n}{i_0} \text{-----} (2)$$

Cluster size is given by,

$$N = i^2 + ij + j^2 \text{-----} (3)$$

Table -1: Co-channel Reuse Ratio for Some Values of N

Value of i and j	Cluster Size(N)	Co-Channel Reuse Ratio(Q)
i= 1, j = 1	3	3
i= 1, j = 2	7	4.58
i= 2, j = 2	12	6
i= 1, j = 3	13	6.24

Solution:

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

Using equation (1), the co-channel reuse ratio $D/R = 4.583$.

Using equation (2), the signal-to-noise interference ratio is given by,

$$S/I = (1/6) \times (4.583)^4 = 75.3 = 18.66 \text{ dB.}$$

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.

Using equation (2), the signal-to-interference ratio is given by,

$$S/I = (1/6) \times (4.583)^3 = 16.04 = 12.05 \text{ dB.}$$

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

Using equation (3), the next possible value of N is 12, ($i = j = 2$).

The corresponding co-channel ratio is given by equation (1) as
 $D/R = 6.0$.

Using equation (3) the signal-to-interference ratio is given by,

$$S/I = (1/6) \times 6^3 = 36 = 15.56 \text{ dB.}$$

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

Procedure(s):

- Open Matlab and create a new Matlab file
- Write basic Matlab commands
- Define variables to solution of the given problem
- Use appropriate formula for calculating the given problem
- Print the answer of the given problem.

Matlab 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:
ans =
    4
Frequency reuse factor:
Q =
    4.5826
Signal to interference ratio:
SI =
    18.6629
```

```
n:
ans =
    3
Frequency reuse factor:
Q =
    4.5826
Signal to interference ratio:
SI =
    12.0518
```

```
n:
ans =
    3
Frequency reuse factor:
Q =
    6
Signal to interference ratio:
SI1 =
    15.5630
```

Problem No: 03

Name of the Problem: 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.

Solution:**Table-1: Capacity of an Erlang B System**

Number of Channel 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-1 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-1, we obtain $A = 0.005$.

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-1, we obtain $A = 1.13$.

Therefore, total number of users, $U = A/A_u = 1.13/0.1 \approx 11$ users.

(c) Given $C = 10$, $A_u = 0.1$, GOS = 0.005

From Table-1, we obtain $A = 3.96$.

Therefore, total number of users, $U = A/A_u = 3.96/0.1 \approx 39$ users.

(d) Given $C = 20$, $A_u = 0.1$, GOS = 0.005

From Table-1, we obtain $A = 11.1$.

Therefore, total number of users, $U = A/A_u = 11.1/0.1 \approx 110$ users.

(e) Given $C = 100$, $A_u = 0.1$, GOS = 0.005,

From Table-1, we obtain $A = 80.9$.

Therefore, total number of users, $U = A/A_u = 80.9/0.1 = 809$ users.

Procedure(s):

- Open Matlab and create a new Matlab file
- Write basic Matlab commands
- Define variables to solution of the given problem
- Use appropriate formula for calculating the given problem
- Print the answer of the given problem.

Matlab 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  
0.1000  
  
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
```

Problem No: 04

Name of the Problem: 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.

Solution:

Table-1: Capacity of an Erlang B System

Number of Channel 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

System A

Given: Probability of blocking = 2% = 0.02

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

Traffic intensity per user, $A_u = \lambda H = 2 \times (3/60) = 0.1$ Erlangs

For GOS = 0.02 and $C = 19$, from the Erlang B chart, the total carried traffic, A , is obtained as 12 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 is equal to $120 \times 394 = 47,280$.

System B

Given: Probability of blocking = 2% = 0.02

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

Traffic intensity per user, $A_u = \lambda H = 2 \times (3/60) = 0.1$ 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 is equal to $450 \times 98 = 44,100$.

System C

Given: Probability of blocking = 2% = 0.02

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

Traffic intensity per user, $A_u = \lambda H = 2 \times (3/60) = 0.1$ 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 is equal to $880 \times 49 = 43,120$.

Therefore, total number of cellular subscribers that can be supported by these three systems are $47,280 + 44,100 + 43,120 = 134,500$ 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 47,280, the percentage market penetration is equal to $47,280/2,000,000 = 2.36\%$

Similarly, market penetration of System B is equal to $44,100/2,000,000 = 2.205\%$ and

the market penetration of System C is equal to $43,120/2,000,000 = 2.156\%$

The market penetration of the three systems combined is equal to $134,500/2,000,000 = 6.725\%$

Procedure(s):

- Open Matlab and create a new Matlab file
- Write basic Matlab commands
- Define variables to solution of the given problem
- Use appropriate formula for calculating the given problem
- Print the answer of the given problem.

Matlab 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
Ua =

    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
Ub =

    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
Uc =

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

Problem No: 05

Name of the Problem: 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.

Solution:

Table-1: Capacity of an Erlang B System

Number of Channel 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

(a) Given:

Total coverage area = 1300 miles, and Cell radius = 4 miles

The area of a cell (hexagon) can be shown to be $2.5981R^2$, thus each cell covers $2.5981 \times (4)^2 = 41.57$ sq. mi.

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

(b) The total number of channels per cell (C),

= allocated spectrum / (channel width \times frequency reuse factor)

= $40,000,000 / (60,000 \times 7) = 95$ 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 \times traffic intensity per cell

= $31 \times 84 = 2604$ 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/channel.

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

Procedure(s):

- Open Matlab and create a new Matlab file
- Write basic Matlab commands
- Define variables to solution of the given problem
- Use appropriate formula for calculating the given problem
- Print the answer of the given problem.

Matlab 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');  
theoretical_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)  
theoretical_maximum_number_of_user_that_could_be_served =  
    2945
```

Problem No: 06

Name of the Problem: 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 $P_r(10 \text{ km})$? Assume unity gain for the receiver antenna.

Theory:

If P_r is in units of dBm, the received power is given by,

$$P_r(d) \text{ dBm} = 10 \log \left[\frac{P_t(d_0)}{0.001 \text{ W}} \right] + 20 \log \left(\frac{d_0}{d} \right) \quad d \geq d_0 \geq d_f \text{ ----- (1)}$$

The Friis free space equation is given by,

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \text{ ----- (2)}$$

Solution:

Given:

Transmitter power, $P_t = 50 \text{ W}$

Carrier frequency, $f_c = 900 \text{ MHz}$

Using equation (1),

$$\begin{aligned} \text{(a) Transmitter power, } P_t(\text{dBm}) &= 10 \log[P_t(\text{mW})/(1\text{mW})] \\ &= 10 \log[50 \times 10^3] \\ &= 47.0 \text{ dBm.} \end{aligned}$$

$$\begin{aligned} \text{(b) Transmitter power, } P_t(\text{dBW}) &= 10 \log[P_t(\text{W})/(1\text{W})] \\ &= 10 \log[50] \\ &= 17.0 \text{ dBW.} \end{aligned}$$

The received power can be determined using equation (2),

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

$$P_r(\text{dBm}) = 10 \log P_r(\text{mW}) = 10 \log(3.5 \times 10^{-3}) = -24.5 \text{ dBm}$$

The received power at 10 km can be expressed in terms of dBm using equation (1), where $d_0 = 100 \text{ m}$ and $d = 10 \text{ km}$.

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

Procedure(s):

- Open Matlab and create a new Matlab file
- Write basic Matlab commands

- c. Define variables to solution of the given problem
- d. Use appropriate formula for calculating the given problem
- e. Print the answer of the given problem.

Matlab 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

```

Problem No: 07

Name of the Problem: Determine the path loss of a 900 MHz 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: The Hata model [Hat90] is an empirical formulation of the graphical path loss data provided by Okumura, and is valid from 150 MHz to 1500 MHz. Hata presented the urban area propagation loss as a standard formula and supplied correction equations for application to other situations. The standard formula for median path loss in urban areas is given by,

$$L_{50}(\text{urban})\text{dB} = 69.55 + 26.16\log f_c - 13.82\log h_{te} - a(h_{re}) + [44.9 - 6.55\log h_{te}]\log d$$

where f_c is the frequency (in MHz) from 150 MHz to 1500 MHz, h_{te} is the effective transmitter (base station) antenna height (in meters) ranging from 30 m to 200 m, h_{re} is the effective receiver (mobile) antenna height (in meters) ranging from 1 m to 10 m, d is the T-R separation distance (in km), and $a(h_{re})$ is the correction factor for effective mobile antenna height which is a function of the size of the coverage area.

The mobile antenna correction factor (for a large city) is given by,

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

Solution:

Given,

$$h_{re} = 2\text{m}$$

$$h_{te} = 100\text{m}$$

$$f_c = 900 \text{ MHz}$$

$$d = 4 \text{ km}$$

We calculate the terms in the Okumara-Hata modes as,

$$\begin{aligned} a(h_{re}) &= 3.2[\log(11.75h_{re})]^2 - 4.97 \\ &= 1.045 \text{ dB} \end{aligned}$$

$$\begin{aligned} L_p &= 69.55 + 26.16\log f_c - 13.82\log h_{te} - a(h_{re}) + [44.9 - 6.55\log h_{te}]\log d \\ &= 137.3 \text{ dB} \end{aligned}$$

Procedure(s):

- Open Matlab and create a new Matlab file
- Write basic Matlab commands
- Define variables to solution of the given problem
- Use appropriate formula for calculating the given problem

e. Print the answer of the given problem.

Matlab 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
```

Problem No: 08

Name of the Problem: 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.

Solution:

Given,

$$f_c = 1.8 \text{ GHz}$$

$$h_b = 20\text{m}$$

The distance of the mobile from the base station is, $d = \sqrt{20^2 + 30^2} = 36.05\text{m}$.

Using the appropriate equation, we can write the path loss as:

$$\begin{aligned} L_p &= 135.41 + 12.49\log f_c - 4.99\log h_b + [46.84 - 2.34\log h_b]\log d \\ &= 68.89 \text{ dB} \end{aligned}$$

Procedure(s):

- Open Matlab and create a new Matlab file
- Write basic Matlab commands
- Define variables to solution of the given problem
- Use appropriate formula for calculating the given problem
- Print the answer of the given problem.

Matlab Code:

```
clc;
clear all;
close all;
fc = 1.8;
hb = 20;
%d = distance of mobile from the base station
d = ((20^2+30^2)^0.5)/1000;
path_loss = 135.41+(12.49*log10(fc))-(4.99*log10(hb))+((46.84-2.34*log10(hb))*log10(d))
```

Output:

path_loss =

68.9079

Problem No: 09

Name of the Problem: A mobile is located 5 km away from a base station and uses a vertical $\lambda/4$ 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 10^{-3} V/m. 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.

Solution:

The gain of an antenna is related to its effective aperture, A_e by,

$$G = \frac{4\pi A_e}{\lambda^2} \text{----- (1)}$$

The power received at distance d , $P_r(d)$, is given by the power flux density times the effective aperture of the receiver antenna and can be related to electric field is,

$$P_r(d) = P_d A_e = \frac{|E|^2}{120\pi} A_e = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2} = \frac{|E|^2 G_r \lambda^2}{480\pi} W \text{----- (2)}$$

Given:

T-R separation distance = 5 km

E-field at a distance of 1 km = 10^{-3} V/m

Frequency of operation, $f = 900$ MHz

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

(a) Length of the antenna, $L = \lambda/4 = 0.333/4 = 0.0833 \text{ m} = 8.33 \text{ cm}$.

Gain of $\lambda/4$ monopole antenna can be obtained using equation (1).

Gain of antenna = 1.8 = 2.55 dB.

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

$$\begin{aligned} E_R(d) &= \frac{2E_0 d_0}{d} \frac{2\pi h_t h_r}{\lambda d} = \frac{k}{d^2} \text{ V/m} \\ &= \frac{2 \times 10^{-3} \times 1 \times 10^3}{5 \times 10^3} \left[\frac{2\pi(50)(1.5)}{0.333(5 \times 10^3)} \right] \\ &= 113.1 \times 10^{-6} \text{ V/m} \end{aligned}$$

The received power at a distance d can be obtained using equation (2),

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

$$P_r(d = 5 \text{ km}) = 5.4 \times 10^{-13} \text{ W}$$

$$= -122.68 \text{ dBW or } -92.68 \text{ dBm.}$$

Procedure(s):

- Open Matlab and create a new Matlab file
- Write basic Matlab commands
- Define variables to solution of the given problem
- Use appropriate formula for calculating the given problem
- Print the answer of the given problem.

Matlab 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
```

Problem No: 10

Name of the Problem: 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?

Solution:

Given,

Cell radius, $R = 1.387$ km

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

Number of cells per cluster = 4

Total number of channels = 60

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 = 9.0 Erlangs. Therefore, number of users = total traffic intensity / traffic per user

$$= 9.0 / 0.029 = 310 \text{ users}$$

$$= 310 \text{ users} / 5 \text{ sq. km} = 62 \text{ users/sq. km}$$

(b) Given $\lambda = 1$, holding time

$$H = A_u / \lambda = 0.029 \text{ hour} = 104.4 \text{ seconds.}$$

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

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

$$= \exp(-(15-9.0)10/104.4) = 56.29 \%$$

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

Probability that a call is delayed more than 10 seconds,

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

$$= 0.05 \times 0.5629 = 2.81 \%$$

Procedure(s):

- Open Matlab and create a new Matlab file
- Write basic Matlab commands
- Define variables to solution of the given problem
- Use appropriate formula for calculating the given problem
- Print the answer of the given problem.

Matlab 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
```