Name of the problem:

If a total of 33 MHz of bandwidth 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. If 1 MHz of the allocated spectrum is dedicated to control channels, determine a equatable 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 × 2 = 50 KHz / duplex channel.

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 available channel per cell

= 660/7 = 94

(c) For $N = 12$

total number of available channel per cell

$= 660/12 = 55$ channels.

The number of available control channel $= 1000/50$
$= 20$

If 1 MHz Spectrum for control Channels implies that there are $1000/50 = 20$ control Channels out of the 660 channels available.

Now,

(a) For $N = 4$, we can have $(660-20)/4 = 165$ voice channels and $20/4 = 5$ control Channel/cell.

(b) For $N = 7$, We can have $(660-20)/7 = 91$ voice Channels and 3 control channels per cell.

(c) For $n = 12$, we can have $(660-20)/12 = 53$ voice Channels and 2 control channels.

Source Code:

```
clc;
clear all;
close all;
bW = 33000;
sim-ch-bW=25;
disp ('Channel Bandwidth..');
dup-ch-bw = 2* sim-ch-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)

for N = [4 7 12]
% n = size(N);
% for i=1:1:n
ch = (t-ch/N);
ch-per-cell = round (ch);
disp (N);
disp (ch-per-cell);
c = (t-cc/N);
cc = round(c);
```

CS CamScanner

```
vc = (ch-per-cell-cc);
disp ('cc & Ac are..');
% disp (N);
disp(cc);
disp (vc);
end.
```

Output:

```
channel Bandwidth..
50
total available channel
660
total Control channel
20
Channel per cell
4
165
cc and vc are..
5
160
Channel per cell
7
94
cc & vc are..
3
91
Channel per cell
12
55
cc & vc are..
2
53
```

Name of the problem:

If a signal to interference into 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) it $=4$, (b) it $=3$. 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.

Solution:

(a) $n=4$

first, let us consider a seven-cell reuse pattern. using equation $Q=\frac{D}{R}=\sqrt{3N}$, , frequency reuse factor, $Q=\frac{D}{R}=\sqrt{3N}=\sqrt{21}=4.583$.

The signal to noise interference ratio is given by $S/I=(1/6)\times(4.583)^4=75.3=18.66\,dB$

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

(b) $n=3$

first, let us consider a seven-cell reuse pattern. The signal to interference ratio is given by,

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

Since, this is less than the minimum required S/I, the need to use a large N. Using equation $N = i^2 + ij + j^2$ the next possible value of N is 12 $(i = j = 2)$. The corresponding co-channel ratio is given by $D/R = 6.0$.

Now, 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, $N = 12$ is used.

Source Code:

```
R_SI = 15;
io = 6;
for n = [4 3]
N = 7
Q = sqrt(3* N);
disp('n');
disp(n);
disp('Q');
disp(Q);
SI = 10* (log10((Q^n)/io));
disp('SI');
disp(SI);

if (SI < R_SI)
i = 2; j = 2;
N1 = (i*i) + (i*j) + (j* j);
Q = sqrt(3* N1);
disp('n');
disp(n);
disp('Q');
disp(Q);
SI1 = 10*(log10((Q^n)/io));
disp('SI1');
disp(SI1);
end
end
```

Output:

n

4

Q

4.5826

SE

18.6629

n

3

Q

4.5826

SE

12.0518

n

3

Q

6

SIL

15.5630.

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:

From the Erlang B chart, 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 bands that can be ~~ob~~ supported in the system.

(a) Given, $c = 1$, $A_u = 0.1$, $GOS = 0.005$

From Erlang B chart we obtain $A = 0.005$

Therefore, total number of users, $U = A/A_u$

$= .005/0.1$

$= 0.05$ 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 Erlangs B chart, we obtain $A = 1.13$.

Therefore, total number of users, $U = A/A_u$

$= 1.13/0.1$

$= 11$ users.

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

From Erlang B chart we obtain $A = 3.96$.

Therefore, total number of users, Users $= A/A_u$

$= 3.96/0.1$

$= 39$ users.

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

we obtain $A = 11.10$

Therefore, total number of users, $U = A/A_u = \frac{11.1}{0.1}$

≈ 110 users.

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

From Erlang B we obtain $A = 80.9$

Therefore, total number of users, $U = A/A_u$

$= 80.9/0.1$

$= 809$ users.

Source Code:

```
clc;
close all;
clear all;

GOS = 0.5 * 100;
Au = 0.1;
% A = [0.005   1.13   3.96   11.10   80.9];
A = [0.005   1.13   3.96   11.10   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);

% end
```

Output:

blocking probability

50

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

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 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:

System A

Given:

probability of blocking $= 2\% = 0.02$

Number of channel per cell used in this system

$C = 19$.

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

$= 0.1$ Erlang

For GOS $= 0.02$ and $C = 19$, from Erlang B chart

we obtain, $A = 12$.

∴ The number of User, $U = A/A_U = 12/0.1$
$= 120$

Since, there are 394 cells, total number of subscriber of A $= 120 \times 394 = 47280$

System B

Given:

number of channel $C = 57$

Traffic intensity, $A_U = \lambda H = 2 \times (3/60) = 0.1$ Erlang

For GOS $= 0.01$ and $C = 57$, we obtain

$A = 45$ Erlangs

∴ The number of user per cell $= A/A_U = 45/0.1$
$= 450$

∴ Total number of subscriber of system B $= 450 \times 98$
$= 44100$

System C

Given:

number of channels, $C = 100$

For GOS $= 0.02$ and $C = 100$, the traffic intensity $n = 88$

∴ The number of user per cell $= A/A_U = 88/0.1$
$= 880$

∴ Total number of subscriber for system e

is $880 \times 49 = 43,120$.

∴ Total number of subscribers of all the systems

$= 47280 + 44100 + 43120 = 134500$

Since, there are two million residents in the given area and System A has 47280 users.

∴ percentage market penetration of A $= 47280/2000000$

$= 2.36\%$

System B has 44100 users, thus the percentage market penetation of B $= 44100/2000000$

$= 2.205\%$

system c has 43120 users, thus the market penetation of system c $= 43120/2000000$

$= 2.156\%$

∴ The market penetration of the three systems Combined $= 134500/2000000$

$= 6.725\%$

CamScanner

Source code :

```
clc;
clear all;
blocking- probability = 2/100;
% Au = Traffic intensity per user
Au = (2/60) * 3;
disp ('for system A')
number_A- chanel- per-cell =19;
A =12;
U = A/Au ;
Aa = U * 394;
number-A- channel-per-cell =100;
A = 88;
U = A/Au;
c = U * 49;
T = A+B+c
disp (Au)
percentage-market-penetration-for-A = (An/2000000)
                                      *100

disp ('For system B')
disp ('Total number A subscriber of B =');
disp (B)
```

percentage-market-penetration-for-B = (B/2000000) * 100

disp('C for system C')

disp('Total number of subscriber of C =')

disp(C)

percentage-market-penetration-for-C = (C/2000000) *100

disp('Total number of subscriber supported by A, B, C')

disp(T)

market-penetration-for-three-system = (T/2000000) * 100

Sample output:

For system A

Total number of subscriber of A = 47280

percentage-market-penetration-for-A = 2.364

For system B

Total number of subscriber of B = 44100

percentage-market-penetration-for-B = 2.205

percentage -

For system C

Total number of subscriber of C = 43120

percentage - market - penetration for C = 2.156

Total number of subscriber supported by A, B, C
= 134500

Market - penetration - for - three - system = 6.725

Name of the problem:

A certain city has an area of 1300 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 40MHz of spectrum with a full duplex channel bandwidth of 60kHz. 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:

(a) Given:

Total city coverage area = 1300 sq miles.

Cell radius, R = 4 miles

each cell covers $= 2.5981 (4)^2$

$= 41.54$ miles

total number of cells are $N_c = \text{floor}(1300/41)$

$= 31$

(b) Total number of channels per cell = floor(40000/(60×7))

= 95

(c) Given:

c = 95 and GoS = 0.02

From Erlang B chart, A, traffic intensity = 84

(d) Maximum carried traffic = number of cells × traffic intensity

= 31 × 84

= 2604

(e) Given traffic per user = 0.03 Erlang

Total number of users = total traffic / traffic per user

= 2604/0.03

= 86800

(f) Number of mobiles per channel = 86800/666

= 130

(g) Theoritical maximum number of user that could be solved = 95 × 31

= 2945

CamScanner

Source code :

```
clc;
clear all;

total_city_coverage_area =1300;
radius = 4;
each cell_covers =floor (2.5981 * radius^2);
disp ('(a)')
number of cells =floor (total_coverage_area/
                              each_cell_covers)
disp ('(b)')

number_of_channel_per_cell = floor (40000/(60x7))

disp ('(c)')
traffic_intensity_per_cell =84
disp ('(d)')
maximum_carried_traffic = number_of_cells +
                      traffic_intensity per_cell

disp ('(e)')
total number_of_user = maximum_carried_traffic/
                                       0.03

disp ('(f)')
number_of_mobile_per channel = floor (total_number
         of_user/number_of_channel_per_cell*7
disp ('(g)')
```

theoritical_maximum_number_of_user_that could_be_served = number_of channel_per_cell * number_of_cells

Sample 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_max_number_of_user_that could_be_served = 2945.

Name of the problem:

A hexagonal cell within a 4-cell system has a radius of 1.367 Km. A total of 60 channels are used within the entire system. If the load per user is 0.029 Erlangs and $\lambda = 1$ 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; $R = 1.367$ km

Area covered per cell $= 2.598 \times (1.367)^2$

$= 539$ km

Num of cells per cluster $= 4$

Total number of channels $= 60$

Number of channel per cell $= 60/4 = 15$ channels.

(a) From Erlang C chart, for 5% probability of delay with $c = 15$, traffic intensity = 9 Erlang

∴ Number of Users = total traffic intensity / traffic per user

$= 9 / 0.029$

$= 310$ users / 5 sq km

$\simeq 62$ users / sq km.

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

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

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

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

$= \exp(-(15-9)\,10/104.4)$

$= 56.29\%$

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

probability that a call is delayed more than 10 seconds,

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

$= 0.05 \times 0.5629$

$= 2.81\%$

Source code :

```
clc;
clear all;
% R = cell radius, N = total no of channel, n = no of cells cluster
% A = area covered per cell.
R = 1.387; n = 4; N = 60;
A = 2.598 * R^2;
% C = no of channel per cell
C = N/4;
disp('(a)')
traffic intensity = 9;
number_of_user = floor(traffic_intensity/(0.029*A))
disp('(b)')
lemda = 1;
H = (0.029/ lemda) * 60* 60;
the_probability_to_wait = (exp(-(C-traffic_intensity)
                          * 10)/ H) * 100
disp('(c)')
the_probability_of_delay = 0.05* the_probability_to_wait
```

Sample Output :

(a) Number_of_User = 62

(b) the_probability_to_wait = 56.2867

(c) the_probability_of_delay = 2.8143

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 50Watts is applied to a unity gain antenna with a 900 MHz carrier frequency, find the received power in dBm of a free space distance of 100 m from the antenna, what is P(10 km)? Assume unity gain for the receiver antenna.

Solution:

Given,

Transmitter power, $P_t = 50W$

Carrier frequency, $f_c = 900MHz$

(a) Transmitter power,

$$P_t (dBm) = 10 \log [P_t (mW) / (1 mW)]$$
$$= 10\log [50 \times 10^{-3}]$$
$$= 47 \text{ dBm}$$

(b) Transmitter power,

$$P_t (dBW) = 10 \log [P_t (W) / (1 W)]$$
$$= 10 \log [50]$$
$$= 17 \text{ dBW}$$

The received power can be determined as,

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} = \frac{50(1)(1)(1/3)^2}{(4\pi)^2 (100)^2 \cdot 1} = 3.5\times10^{-3}\ mW$$

$$P_r(dBm) = 10\log P_r\ (mW) = 10\log(3.5\times10^{-3})$$
$$= -24.5\ dBm.$$

The received power at 10 km can be expressed in terms of dBm as –

$$P_r(10km) = P_r(100) + 20\log[100/1000]$$
$$= -24.5\ dBm - 40\ dBm$$
$$= -64.5\ dBm$$

Source Code:

```
clc;
clear all;
% Pt = transmitter power, fc = carrier frequency in MHz.

Pt =50;
fc = 900;
gt =1;
gr =1;
d = 100;
disp('(a)')
```

Transmitter_power_in_dBm = ceil (10 * log10 (50*1000));

disp ('(b)')

Transmitter_power_in_dBW = ceil (10 * log10 (50 * 1))

Pr_mW = ((Pt * gt * gr * (300/900)^2) / ((4 * 3.14)^2
* d^2 * 1) * 1000;

received_power_in_dBm = 10 * log10 (Pr_mW)

Pr_10km = received_power_in_dBm + (20 * log10
(100/1000))

Output:

a) Transmitter_power_in_dBm = 47

b) Transmitter_power_in_dBW = 17

received_power_in_dBm = -24.5369

Pr_10km = -64.53

Name of the problem:

A mobile is located 5 km away from a base station and uses a vertical 2.4 monopole antenna with a gain of 2.55 dB to receive cellular radio signals. The E-field at 1 km from the transmitter is measured to be 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 1.5 m above ground.

Solution:

Given:

T-R separation distance $= 5\ km$

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

frequency, $f = 900\ MHz$

$$\lambda = c/f = \frac{3\times10^8}{9\times10^8} = 0.333\ m$$

(a) Length of the antenna, $L = \lambda/4 = \frac{0.333}{4}$

$= 0.0833\ m$

$$gain = 10^{(2.55/10)} = 1.8$$

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

$$E_R(d) \approx \frac{\alpha E_0 d_0 2\pi h_t h_r}{d \cdot \lambda d}$$

$$= \frac{2\times10^{-3} \times 1\times10^{3} \times 2\pi \times 50 \times 1.5}{0.333 \times (5\times10^{3})^2}$$

$$= 113.1 \times 10^{-6} \text{ V/m}$$

The received power of distance d can be obtained

as,
$$P_r(d) = \frac{(113.1\times10^{-6})^2}{120\times\pi} \times \frac{1.8\times(0.333)^2}{4\pi}$$

$$= 5.4\times10^{-13} \text{ W}$$

$$\therefore P_r(d=5\text{Km}) = 10\log_{10}(5.4\times10^{-13})$$

$$= -122.65 \text{ dBW}$$

Source Code:

```
clc;
clear all;
T_R_field = 5;
E_field = 10-3;
f = 900;
```

```
Lemda = 300/900;
disp ('(a)')
Length_of_antenna = lemda/4
gain = ceil ( 10^(2.55/10))
disp ('(b)')
Er_d = (2* E-field * 1000 * 2 * 3.1416 * 50 * 1.5)/(lemda * d^2)
Ae = (gain * lemda^2)/(4 * 3.1416);
Pr_d = (Er_d^2 / (120 * 3.1416) * Ae
received_power_at_5km_distance = 10log10 (Pr_d)
```

Sample Output:

```
(a) Length_A_antenna = 0.0133
    gain = 1.8
(b) received_power_at_5km_distance = -122.68
```

Name of the problem:

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

Solution:

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

$$a(h_m) = 3.2 [\log (11.75 h_m)]^2 - 4.97$$

$$= 1.045 \text{ dB}$$

$$L_p = 69.55 + 26.16 \log f_c - 13.82 \log h_b - a(h_m) + [44.9 - 6.55 \log h_b] \log d$$

$$= 137.3 \text{ dB}$$

Source code:

```
clc;
clear all;
hm = 2; hb = 100;
fc = 900; d = 4;
ahm = (3.2 * (log10 (11.15 * hm)) ^2) - 4.97
Lp = 69.55 + 26.16 * log10 (fc) - 13.82 * log10 (hb) - ahm
     + (44.9 - 6.55 * log10(hb)) * log10 (d)
disp('loss path'); disp(Lp);
```

Sample Output:

a_hm = 1.0454

Loss-path = 137.2930

Name of the problem:

Determine the path loss between base station (BS) and mobile station (ms) of a 1.8 GHz 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 20 m.

Solution:

The distance of the mobile form the base station is $\sqrt{(20)^2+(30)^2} = 36.05\,m$. Using the appropriate equation, we can write the path loss as:

$$L_p = 135.41 + 12.49 \log f_c - 4.99 \log h_b + [46.84 - 2.34 \log h_b] \log d$$

$$= 68.89\,dB$$

Source Code:

```
clc;
clear all;
fc = 1.8 ;
hb = 20;
% d = distance of mobile form base station
d = ((20^2 + 30^2)^0.5)/1000;

path loss = 135.41 + (12.49 * log10(fc)) - (4.99 * log10
            (hb)) + ((46.82 - 2.34 * log10(hb)) * log10(d))
```

Sample Output:

```
path_loss = 68.9079
```