Pabna University of Science and Technology

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Lab Report

Faculty of Engineering and Technology

Department of Information and Communication Engineering

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INDEX

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

Name of the Experiment: 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 ineach cell for each of the three systems.

Theory:

Frequency-division duplexing (FDD) is a method for establishing a full-duplex communications link that uses two different radio frequencies for transmitter and receiver operation. FDD operation normally assigns the transmitter and receiver to different communication channels. One frequency is used to communicate in one direction, and the other frequency is required to communicate in the opposite direction. The transmit direction and receive direction frequencies are separated by a defined frequency offset.

Frequency Reuse:

Cellular radio systems rely on an intelligent allocation and reuse of channnels throughout a coverage region. Each cellular base station is allocated a group of radio channels to be used within a small geographic area called a cell. Base stations in adjacent cells are assigned channel groups which contain completely different channels than neighboring cells. The base station antennas are designed to achieve the desired coverage within the particular cell. By limiting the coverage area to within the boundaries of a cell, the same group of channels may be used to cover different cells that are separated from one another by distances large enough to keep interference levels within tolerable limits. The design process of selecting and allocating channel groups for all of the cellular base stations within a system is called frequency reuse orfrequency planning.

Given,
Total bandwidth =33 MHz
Channel bandwidth = 25 * 2 simplex channels = 50 kHz/duplex channelTotal available channels = 33,000000/50000 = 660 channels

(a) For N= 4,
Total number of channels available per cell = 660/4 = 165 channels.Allocated spectrum =1MHz=1000000Hz
Total control channel =Allocated channel/Channel bandwidth
=1000000/50000 = 20
Control channel =Total control channel/N
=20/4 = 5

Voice Channel = Total number of channels available per cell - Control channel = 165-5 = 160

(b)For N=7,
Total number of channels available per cell = 660/7 = 95 channels.Control channel =Total control channel/N
=20/7= 3
Voice Channel = Total number of channels available per cell - Control channel = 94-3 = 91

(c)For N = 12,
Total number of channels available per cell = 660/12 = 55 channels.Control channel =Total control channel/N
=20/12 = 2

of channels available per cell
- Control channel = 55-2 = 53

Source Code with python:

```
Bandwidth = 33000;
schannel_bandwidth = 25;
channel_bandwidth = 2*schannel_bandwidth;
print(f'Channel Bandwidth - {channel_bandwidth}')
TotalChannel = (Bandwidth/channel_bandwidth);
print(f'Total Channel - {TotalChannel}')
ControlChannelBandwidth = 1000;
Total_control_channel =
(ControlChannelBandwidth/channel_bandwidth)
print(f'Total Control Channel - {Total_control_channel}')
ReuseCellList = [4, 7, 12]
for i in ReuseCellList:
    channel = TotalChannel/i
    control_channel = round(Total_control_channel/i)
    voice_channel = round((TotalChannel-
Total_control_channel)/i)
    print(f'Reuse {i} and Channel Per Cell '
          f'{round(channel)}')
    print(f'Control Channel {control_channel} and voice
channel {voice_channel}')
```

Output:

Channel Bandwidth - 50

Total Channel - 660.0

Total Control Channel - 20.0

Reuse 4 and Channel Per Cell 165

Control Channel 5 and voice channel 160

Reuse 7 and Channel Per Cell 94

Control Channel 3 and voice channel 91

Reuse 12 and Channel Per Cell 55

Control Channel 2 and voice channel 53

Experiment no: 02

Name of the Experiment: 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:

Co-channel Interference and System Capacity:

Frequency reuse implies that in a given coverage area there are several cells that use the same set of frequencies. These cells are called co-channel cells, and the interference between signals from these cells is called co-channel interference. Unlike thermal noise which can be overcome by increasing the signal-to-noise ratio (SNR), co-channel interference cannot be combated by simply increasing the carrier power of a transmitter This is because an increase in carrier transmit power increases the interference to neighboring co-channel cells. To reduce co-channel interference, co-channel cells must be physically separated by a minimum distance toprovide sufficient isolation due to propagation.

(a) n = 4

First, let us consider a 7-cell reuse pattern.

Co-channel cell = 6

Frequency reuse factor, Q = $\sqrt{3N}$ = 4.583.

SNI = $10log\frac{Q^n}{6}$ = 75.3 = 18.66 dB>15 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.

SNI = $10log\frac{Q^n}{6}$ = 12.05 dB<15 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).

Frequency reuse factor, Q = $\sqrt{3N}$ = 4.583. here, N=12

SNI = $10log\frac{Q^n}{6}$ = 15.5 >15 dB

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

Source Code with python:

```
import math
n = [4, 3]
R_SI = 15  # R_IR = Ratio of Signal to Interference
io = 6  # io = co_channel
N = 0
for value in n:
    N += value
for i in n:
    Q = math.sqrt(3*N);
    print(f'n : {i}')
    print(f'Frequency Reuse Factor {Q}')
    SI = 10*(math.log(((1/io) * (Q**i)), 10))
    print(f'Signal to interference ratio : {round(SI, 2)} dB')
    if SI < R_SI:
        k = 2; j = 2;
        N = (k**2) + (k*j) + (j**2)
        Q = math.sqrt(3*N)
        print(f'n : {i}')
        print(f'Frequency Reuse Factor {Q} ')
        SI1 = 10*(math.log(((1/io) * (Q**i)), 10));
        print(f'Signal to interference ratio : {round(SI1, 2)} dB')
```

Output:

n : 4
Frequency Reuse Factor 4.58257569495584
Signal to interference ratio : 18.66 dB
n : 3
Frequency Reuse Factor 4.58257569495584
Signal to interference ratio : 12.05 dB
n : 3
Frequency Reuse Factor 6.0
Signal to interference ratio : 15.56 dB

SNI Ratio = 12.0518
Cluster size 7 can not be used.
The possible cluster size = 12
Frequency Reuse Factor = 6
SNI Ratio = 15.563

Experiment no: 03

Name of the Experiment: 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:

Cellular radio systems rely on trunking to accommodate a large number of users in a limited radio spectrum. The concept of trunking allows a large number of users to share the relatively small number of channels in a cell by providing access to each user, on demand, from a pool of available channels. In a trunked radio system, each user is allocated a channel on a per call basis, and upon termination of the call, the previously occupied channel is immediately returned to the pool of available channels.

The grade of service (GOS) is a measure of the ability of a user to access a trunked system during the busiest hour. The busy hour is based upon customer demand at the busiest hour during a week, month, or year. The busy hours for cellular radio systems typically occur during rush hours, between 4 p.m. and 6 p.m. on a Thursday or Friday evening. The grade of service is a benchmark used to define the desired performance of a particular trunked system by specifying a desired likelihood of a user obtaining channel access given a specific number of channels available in the system.

The traffic intensity offered by each user is equal to the call request rate multiplied by the holding time.
That is, each user generates a traffic intensity of A_u Erlangs given by

$A_u = \lambda H$ ------------ 1

where H is the average duration of a call and k is the average number of call requests per unittime.

For a system containing U users and an unspecified number of channels, the total offered trafficintensity A, is given as

A = U$A_{\bar{u}}$--------2

Source Code:

```
clc;
clear all;
close all;
GOS=0.5/100;
Au=0.1;
c=[1 5 10 20 100];
A=[0.005 1.13 3.96 11.1 80.9];

for i=1:5
    user=floor(A(i)/Au);
    if user<1
        user=ceil(A(i)/Au);
    end
    disp(['For channel ',num2str(c(i))]);
    disp(['User = ',num2str(user)]);
end
```

Output:

For channel 1
User = 1
For channel 5
User = 11
For channel 10
User = 39
For channel 20
User = 110
For channel 100
User = 809

Experiment no: 04

Name of the Experiment: 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, computethe percentage market penetration of each cellular provider.

Theory:

There are two types of trunked systems which are commonly used. The first type offers no queuing for call requests. That is, for every user who requests ser vice, it is assumed there is no setup time and the user is given immediate access to a channel if one is available. If no channels are available, the requesting user is blocked without access and is free to try again later. This type of trunking is called blocked calls cleared and assumes that calls arrive as determined by' a Poisson distribution. Furthermore, it is assumed that there are an infinite number of users as well as the following: (a) there are memoryless arrivals of requests, implying that all users, including blocked users, may request a channel at any time; (b) the probability of a user occupying a channel is exponentially distributed, so that longer calls are less likely to occur as described by an exponential distribution; and (c) there are a finite number of channels available in the trunking pool.

The second kind of trunked system is one in which a queue is provided to hold calls which are blocked. If a channel is not available immediately, the call request may be delayed until a channel becomes available. This type of trunking is called Blocked Calls Delayed, and its measure of GOS is defined as the probability that a call is blocked after waiting a specific length of time in the queue.

Source Code with python:

```
GOS = 0.02  # Probability of blocking
AU = 0.1  # Traffic intensity per user


def Calculation(A, cells):
    # U = Number of users that can be
    # supported per cell
    U = A / AU
    return U * cells

# System A
NumSubsSys_A = Calculation(45, 98)
print(f'The total number of subscriber that can be '
      f'supported by System A is equal to'
      f' {NumSubsSys_A}')
# System B
NumSubsSys_B = Calculation(88, 49)
print(f'The total number of subscriber that can be '
      f'supported by System B is equal to'
      f' {NumSubsSys_B}')
# System C
NumSubsSys_C = Calculation(12, 394)
print(f'The total number of subscriber that can be '
      f'supported by System C is equal to'
      f' {NumSubsSys_C}')

dict = {
    'A': NumSubsSys_A,
    'B': NumSubsSys_B,
    'C': NumSubsSys_C
}


for value in dict:
    print('Since there is two million in the given urban '
          'area and the total number of cellular subscriber'
          f'in system {value} is equal to {dict[value]},'
          f'the percentage market penetration is equal to '
          f'{round((dict[value]/2000000)*100, 2)}%')

print(f'The market penetration of the three system '
  f'combined is equal to
{round(((NumSubsSys_A+NumSubsSys_B+NumSubsSys_C)/2000000)*100,
2)}%')
```

Output:

The total number of subscriber that can be supported by System A is equal to 44100.0

The total number of subscriber that can be supported by System B is equal to 43120.0

The total number of subscriber that can be supported by System C is equal to 47280.0

Since there is two million in the given urban area and the total number of cellular subscriber in system A is equal to 44100.0,the percentage market penetration is equal to 2.21%

Since there is two million in the given urban area and the total number of cellular subscriber in system B is equal to 43120.0,the percentage market penetration is equal to 2.16%

Since there is two million in the given urban area and the total number of cellular subscriber in system C is equal to 47280.0,the percentage market penetration is equal to 2.36%

Experiment no: 05

Name of the Experiment: 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:

To find the GOS, it is first necessary to find the likelihood that a call is initially denied access to the system. The likelihood of a call not having immediate access to a channel is determined by the Erlang C formula derived in Appendix A

$$\text{Pr [delay >0]} = \frac{A^C}{A^C C + C!\left(1 - \frac{A}{C}\right)\sum_{k=0}^{C-1}\frac{A^K}{K!}} \text{ --------------------------------- } 1$$

• The Cellular Concept — System Design Fundamentals If no channels are immediately available the call is delayed, and the probability that the delayed call is forced to wait more than t seconds is given by the probability that a call is delayed, multiplied by the conditional probability that the delay is greater than t seconds. The GOS of a trunked system where blocked calls are delayed is hence given by

Pr[delay > t] = Pr [delay> OlPr [delay> tldelay >0]

= Pr[delay>0] exp(—(C—A)t/H) -- 2

The average delay D for all calls in a queued system is given by

D = Pr[delay>0]j'A --- 3

where the average delay for those calls which are queued is given by Hi(C—A).

Source Code with python:

```
import math
AU = 0.02 # GOS
area = 1300 # coverage area | sq miles
N = 7
radius = 4 # miles
allocated_spectrum = 40000 # MHz
BW = 60 # MHz
A = 0.03 # offered traffic intensity | Earling


print('Answer of question A')
CellArea = 2.5981*(radius)**2
Number_Cell = math.floor(1300/CellArea)
print(f'The area of cell can be shown {CellArea}')
print(f'Total number of cells are {Number_Cell}')
print('\n')
print('Answer of question B')
Number_channel_per_cell =
math.floor(allocated_spectrum/(BW*N))
print(f'The total Number of channel per cell
{Number_channel_per_cell}')
print('\n')
print('Answer of question C')
intensity_per_cell = 84
print(f'According to the table of erling B chart'
      f' trucked '
      f'channel {Number_channel_per_cell} and '
      f'GOS is {AU} '
      f'traffic {intensity_per_cell}')

print('\n')
print('Answer of question D')
maximum_carried_traffic = Number_Cell *
intensity_per_cell
print(f'Maximum carried traffic
{maximum_carried_traffic} Erlangs')

print('\n')
print('Answer of question E')
Total_number_user = maximum_carried_traffic/A
print(f'Total Number of user
{round(Total_number_user)} users')
print('\n')
print('Answer of question F')
print(f'Number of per channel
```

```
{math.floor(Total_number_user/Number_channel_per_cell
*N)} '
      f'mobiles/channel')
print('\n')
print('Answer of question g')
print(f'The theoretical maximum number of served
mobiles'
      f' is the number of available channels in the
system'
      f' {Number_Cell*Number_channel_per_cell}')
```

Output:

Answer of question A
The area of cell can be shown 41.5696
Total number of cells are 31

Answer of question B
The total Number of channel per cell 95

Answer of question C
According to the table of erling B chart trucked channel 95 and GOS is 0.02 traffic 84

Answer of question D
Maximum carried traffic 2604 Erlangs

Answer of question E
Total Number of user 86800 users

Answer of question F
Number of per channel 6395 mobiles/channel

Answer of question g
The theoretical maximum number of served mobiles is the number of available channels in the system 2945

Experiment no: 06

Name of the Experiment: 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:
The free space propagation model is used to predict received signal strength when the transmitter and receiver have a clear, unobstructed line-of-sight path between them. Satellite communication systems and microwave line-of-sight radio links typically undergo free space propagation. In satellite link there is no obstruction between the transmitter and the receiver. As there is no obstruction, we are able to calculate the signal strength of the received signal. The free space power received by a receiver antenna which is separated from a radiating transmitter antenna by a distance d, is given by the Friis free space equation,

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \quad \text{--} \quad (1)$$

Where,
Pr = Receiver Power
Pt = Transmitter Power
G_t is the transmitter antenna gain
G_r is the receiver antenna gain
d is the T-R separation distance in meters
λ is the wavelength in meters
L is the system loss factor not related to propagation (L$\geq$ 1)
The miscellaneous losses L (L$\geq$ 1) are usually due to transmission line attenuation, filter losses, and antenna losses in the communication system. A value of L = I indicates no loss in the system hardware.

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

$$G = \frac{4\pi Ae}{\lambda^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where A_e is effective aperture and λ is related to the carrier frequency by

$$\lambda = \frac{c}{f} = \frac{2\pi c}{W_c} \text{ ……………………………..(3)}$$

Where f is the carrier frequency in Hertz

W_c is the carrier frequency in radius per second c is the speed of light given in meter/second

An isotropic radiator is an ideal antenna which radiates power with unit gain uniformly in all directions, and is often used to reference antenna gains in wireless systems. The Effective Isotropic Radiated Power (EIRP) is defined as,

$$EIRP = P_t G_t \qquad \text{………………………..(4)}$$

The path loss, which represents signal attenuation as a positive quantity measured in DB, as defined as the difference between the effective transmitted power and the received power, and may or may not include the effect of the antenna gains. The path loss for the free space model when antenna gains are included is given by

$$\text{PL}(dB) = 10log\frac{P_t}{P_r} = -10log\left[\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2}\right] \text{........................ (5)}$$

When antenna gains are excluded, the antennas are assumed to have unity gain, and path loss is given by

$$\text{PL}(dB) = 10logPt/Pr = -10log[\ \lambda^2/(4\pi)^2 d^2\ ]$$

The far-field, or Fraunhofer region, of a transmitting antenna is defined as the region beyond the far field distance d_f, which is related to the largest linear dimension of the transmitter antenna aperture and the carrier wavelength. The Fraunhofer distance is given by

$$d_f = \frac{2D^2}{\lambda} \quad \text{..............................(7)}$$

where D is the largest physical linear dimension of the antenna. Additionally, to be in the far-field region, d_f must satisfy

$$d_f \gg D \text{..(7.1)}$$

And

$$d_f \gg \lambda \text{...(7.2)}$$

For path loss models, d can't be 0. For this reason, large-scale propagation models use a close- in distance d_0, known received power reference point. The received power, $P_r(d)$, at any distance $d > d_0$. The reference distance must be chosen such that it lies in the far-field region, that is $d_0 \geq d_f$ and d_0 is chosen to be smaller than any practical distance used in the mobile communication system. Thus using equation 1), the received power in free space at any distance greater than d_0 is given by,

$$P_r\,(d) = P_r(d_0)\left(\frac{d_0}{d}\right)^2 \; d \geq d_0 \geq d_f \qquad (7)$$

Equation 8 may be expressed in units of dBm or dBW by simply taking the logarithm of both

sides and multiplying by 10. For example, if is in units of dBm, the received power is given

$$P_r(d)dBm = 10 \log\frac{P_r(d_0)}{0.001W} + 20 \log\frac{d_0}{d} \quad d \geq d_0 \geq d_f \qquad 8$$

Source Code:

```
import math


def math_calculation():
    PT = 50  # Transmitter power | W
    fc = 900  # Carrier Frequency | MHz
    lamda = 1 / 3
    d = 100
    L = 1
    GT = 1  # Gain of transmitter
    GR = 1  # Gain of receiver
    print('Answer of section A of the question')
    PT_dBm = round(10 * math.log((50 * 10 ** 3), 10))
    print(f'Transmitter power in dBm {PT_dBm} dBm')
    print('\n')
    print('Answer of section B of the question')
    PT_dBW = round(10 * math.log(50, 10))
    print(f'Transmitter power in dBm {PT_dBW} dBW')
    FirstValue = (PT * GT * GR * (lamda ** 2))
    secondVale = ((4 * math.pi) ** 2) * (d ** 2) * L
    PR = (FirstValue / secondVale) * 1000  # Received Power |W
    PR_dBm = round(10 * math.log(PR, 10), 2)
    print(f'Received Power {PR_dBm} dB')
    PR_10 = PR_dBm + 20 * math.log((100 / 10000), 10)
    print(f'When  receiver  power  in  10km  distance,  received
power at 10 km distance {round(PR_10, 2)} dB')


math_calculation()
```

Output:

Answer of section A of the question

Transmitter power in dBm 47 dBm

Answer of section B of the question

Transmitter power in dBm 17 dBW

Received Power -24.54 dB

When receiver power in 10km distance, received power at 10 km distance -64.54 dB

Experiment no: 07

Name of the Experiment: 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:

The Hata model 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

$L50(\mathrm{Urban}) = 69.55 + 26.16 * \log10(fc) - 13.82 * \log10(hte) - a(hre) + (44.9 - 6.55 * \log10(hte)) * \log10(d)$ ------------------ (1)

where is the frequency (in MHz) from 150 MHz to 1500 MHz,
hte is the effective transmitter (base station) antenna height (in meters) ranging from 30 m to200 m,

hre 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(hre) is the correction factor for effective mobile antenna height which is a function of the sizeof the coverage area.

For a small to medium sized city, the mobile antenna correction factor is given by

$a(hre) = 1.1(\log f - 0.7)hre - (1.56\log fc - 0.8)dB$------------- (2)

For a large city, it is given by
a(hre) = 8.29(log1.54hre)^2 -1.1dB for fc<=300MHz --------------- (3)
a(hre) = 3.2(log11.75hre)^2 -4.97dB for fc>=300MHz ---------------(4)

To obtain the path loss in suburban area the standard Hata formula is modified as
L50(dB) = L50(urban)-2[log(fc/28)]^2-5.4------------- (5)

for path loss in open rural areas, the formula is modified as

L50(dB) = L50(urban)-4.78log(fc)^2-18.33logfc-40.98------------- (5)

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:

```
Loss path
  137.2930
```

Experiment no: 08

Name of the Experiment: 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:

The Okumura model is a radio propagation model that was built using the data collected in the city of Tokyo, Japan. The model is ideal for using in cities with many urban structures but not many tall blocking structures. The model served as a base for the Hata model.

Okumura model was built into three modes. The ones for urban, suburban and open areas. The model for urban areas was built first and used as the base for others.

The Okumura model is formally expressed as:

$$L = L_{FSL} + A_{MU} - H_{MG} - H_{BG} - \sum K_{correction}$$

where,

L = The median path loss. Unit: Decibel (dB)

L_{FSL} = The free space loss. Unit: decibel (dB)

A_{MU} = Median attenuation. Unit: decibel (dB)

H_{MG} = Mobile station antenna height gain factor.

H_{BG} = Base station antenna height gain factor.

$K_{correction}$ = Correction factor gain (such as type of environment, water surfaces, isolated obstacle etc.)

Source Code:

```
clc;
clear all;
close all;
fc=1.8;
hb=20;
d=sqrt((20)^2+(30)^2)/1000;
disp(d);
PathLoss=135.41+(12.49*log10(fc))-(4.99*log10(hb))+((46.82-
2.34*log10(hb))*log10(d));
disp(['PathLoss ',num2str(PathLoss)]);
```

Output:

0.0361

PathLoss 68.9368

Experiment no: 09

Name of the Experiment: 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 thissystem 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:

In a mobile radio channel, a single direct path between the base station and a mobile is seldom the only physical means for propagation, and hence the free space propagation model most cases inaccurate when used alone. The 2-ray ground reflection model shown in Figure 01 is a useful propagation model that is based n geometric optics, and considers both the direct path and a ground reflected propagation path between transmitter and receiver. This node] has been found to be reasonably accurate for predicting the large-scale signal strength over distances of several kilometers for mobile radio systems that use tall towers (heights which exceed 50 m), as well as for line-of-sight microcell channels in urban environments.

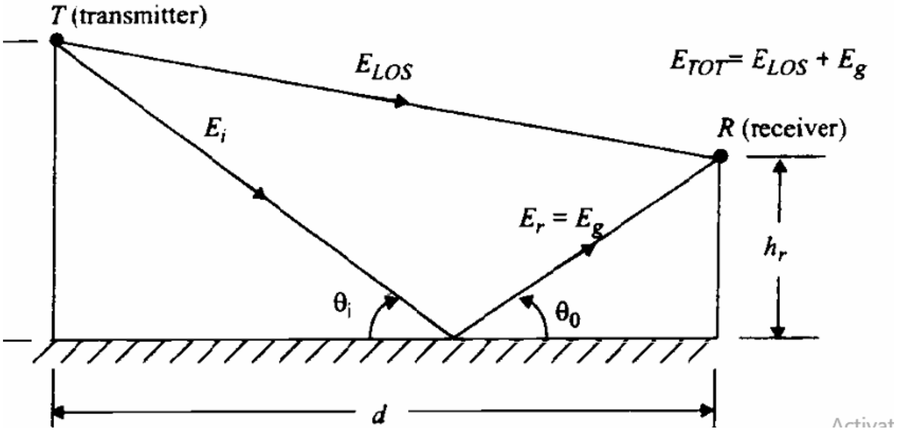

Fig - 01

Source Code:

```
clc;
clear all;
close all;
T_R_distance = 5;
E_field = 10^(-3);
f = 900;
do=1000;
lamda=(3*10^8)/(900*10^6);

ht=50;
hr=1.5;
d=5*10^3;

%a

length_of_antenna = lamda/4;
gain = (10^(2.55/10));
effective_aperture=(gain*(lamda)^2)/(4*3.1416);
disp([Gain is ',num2str(gain)]);

%b
Er_d = (2*E_field*do*2*3.1416*ht*hr)/(lamda*d^2);
disp(['Electric Field ',num2str(Er_d)]);

pr_d=((Er_d^2)/(120*3.1416))*effective_aperture;
received_power_at_5km_distance = 10*log10(pr_d);
disp(['Received power at distance in dBW
',num2str(received_power_at_5km_distance)]);

received_power2=10*log10(pr_d*1000);
disp(['Received power at distance in dBm
',num2str(received_power2)]);
```

Output:

Gain is 1.7988
Electric Field 0.0001131
Received power at distance in dBW -122.6788
Received power at distance in dBm -92.67

Experiment no :10

Name of the Experiment: 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:

A **cellular network** or **mobile network** is a telecommunications network where the link to and from end nodes is wireless and the network is distributed over land areas called **cells**, each served by at least one fixed-location transceiver (typically three cell sites or base transceiver stations). These base stations provide the cell with the network coverage which can be used for transmission of voice, data, and other types of content. A cell typically uses a different set of frequencies from neighboring cells, to avoid interference and provide guaranteed service quality within each cell.

To study of how a large population could be accommodated by a limited number of servers, this is actually based of GOS. In sort way, grade is service (GOS) is a measure of the ability of a user to access a trunked system during busiest hour.

Source Code:

```
clc;
clear all;
close all;
radius = 1.387;
cluster = 4;
total_channel = 60;
channel_per_cell = total_channel/cluster
each_cell_covers = 2.5981*radius^2
traffic_per_user = 0.029;
t = 10;
blocking_probability = 5/100;


disp('(a)')
traffic_intensity = 9;
no_of_user =
```

```
floor(traffic_intensity/(traffic_per_user*each_cell_covers))

disp('(b)')
lembda=1; %Au = lembda/H_holding time
holding_time = (traffic_per_user/lembda)*60*60
probability_to_wait = exp(-(channel_per_cell -
traffic_intensity)*t/holding_time)*100

disp('(c)')
probability_of_delay = blocking_probability *
probability_to_wait
```

Output:

channel_per_cell = 15
each_cell_covers =4.9981

(a)

no_of_user = 62

(b)holding_time =104.4000
probability_to_wait = 56.2867

(c)probability_of_delay = 2.8143