

## **ETM3086 Mobile and Satellite Communications**

### **Assignment (20%)**

Due date: **31 MAY 2021 (MONDAY)** by turn in the report through ETM3086 Google Classroom. [Late submission will not be entertained].

### **Objectives:**

- 1) To further investigate the concept of cellular network and the free-space propagation path loss of the radio wave.
- 2) To allow the students to explore numerical analysis software on the investigation of a cellular network.

### **Learning Outcome:**

CLO3: Choose appropriate solutions for complex engineering problems through investigation and research

### **Tasks**

Students are required to answer all questions. For the final deliverable, you are required to submit a softcopy of detailed report. The project is an individual project.

### **Report Guidelines**

All reports should be typewritten except for simulation codes and graphs with a cover page showing your name and student ID (the cover page is as attached).

### **Notes**

- 1) All graphs must be plotted using a numerical analysis software such as MATLAB, SciLab, Octave etc.
- 2) Plagiarism is strictly prohibited. Students with suspicious reports will be asked to do oral exam and presentation to prove their authenticity of their work.

## Modelling of Cellular Networks Using MATLAB

You are the engineer assigned to model a cellular network which operates at the frequency of 900 MHz. The noise power is assumed to be  $-90$  dBm. The path loss exponent is assumed to be 2 in this environment.

### Part A: Cellular System with Single Cell

- 1) The sample code given in Table 1 is to generate a hexagonal cell with the radius of 1 km. Using the sample code, generate a hexagonal cell with the radius of  $R$  km. Print your figure in your report. **(3 marks)**  
*[ $R$  is half of the average of all digits of your student ID.  
Example: Student ID is 1991114538.  $R = [(1+9+9+1+1+1+4+5+3+8)/10]/2 = 2.1$  km]*
- 2) Create and place a base station at the center of the cell. Show the lines of code that generate the base station and print the figure in your report. **(3 marks)**  
*[Hint: Plot a point at the center of the cell using the correct coordinates where the point represents the base station. Alternatively, refer to the code in Table 2 and combine it with the code in Table 1.]*
- 3) The base station in this cellular system is required to provide coverage up to  $R$  km. Calculate the required transmit power level (in dBm) of the base station if signal-to-noise ratio (SNR) for a subscriber in the cell must be at least 15 dB. Assume that there is no interference in the system Besides, transmitting and receiving antenna gains are assumed to be unity and no system loss occurs in this network. Show your calculations in the report. **(5 marks)**
- 4) Do the following to simulate a subscriber in the cell.
  - a) Create and place one subscriber at the cell edge that is located  $R$  km from the base station. Show the lines of code that generate the subscriber and print the figure in your report. **(3 marks)**
  - b) Compute the received power level at the subscriber with the base station is transmitting the power level as determined in Step 3. Show the lines of code that compute the received power and print the result from the command window in your report. **(3 marks)**
  - c) Compute the SNR of the subscriber. Show the lines of code that compute the SNR and print the result from the command window in your report. Verify the result with the answer obtained in Step 3. **(3 marks)**
- 5) Do the following to simulate multiple subscribers in the cell.
  - a) Generate 5 subscribers that are randomly distributed within the cell. Show the lines of code that generate these subscribers and print the figure in your report. **(3 marks)**
  - b) Calculate the distances of the subscriber from the base station. Show the lines of code that compute the distances and print the results from command window. **(4 marks)**
  - c) Verify your answer (distance obtained from simulation) mathematically. **(3 marks)**

*[Hint: Plot a point by generating random coordinates within the cell where the point represents the subscriber. Alternatively, refer to the code in Table 2 and combine it with the code in Table 1.]*

- 6) Based on the answer from Step 5, compute the SNR for the 5 subscribers. Show the lines of code that compute the SNR and print the results from the command window in your report. **(5 marks)**
- 7) Verify your answer (SNR obtained from the simulation) mathematically. Show your calculations in the reports. **(5 marks)**

### **Part B: Cellular System with Multiple Cells without Frequency Reuse**

- 1) Do the following generate a cluster of hexagonal cells (without frequency reuse).
  - a) Modify the code in Table 1 to generate a cluster of cells (each cell having a radius of  $R$  km) in the cellular system which can provide a coverage to an area of  $5 \text{ km} \times 7 \text{ km}$ . Print the figure in the report. **(5 marks)**
  - b) How many cells are required to provide this coverage? **(2 marks)**
  - c) Compute the actual total area covered by all the cells. **(3 marks)**
- 2) Generate one base station for every cell generated in Step 1. Print the figure in the report. **(5 marks)**
- 3) Generate 10 subscribers for each cell, who are randomly distributed. Print the figure in the report. **(5 marks)**
- 4) Choose one cell from the systems above and show the SNRs for the 10 subscribers from that cell if the base station transmits power with 50 dBm to all subscribers. **(5 marks)**
- 5) In this cellular system, there are 200 channels available for the whole system. Assume that there is no frequency reuse implementation. Calculate the number of users that can be supported by each cell and by the whole system at 1% of call blocking if each user has average 2.5 calls per hour and average call duration is 3.5 minutes. **(8 marks)**

### Part C: Cellular System with Multiple Cells with Frequency Reuse

- 1) If the cellular system reuses the frequency with a factor of 0.25, repeat Step 1 in Part B and label all co-channel cells on the figure. **(7 marks)**
- 2) Determine the co-channel interference.
  - a) Calculate the frequency reuse distance. **(2 marks)**
  - b) Compute the SNR for every cell if co-channel interference is much higher than the noise. Consider only the co-channel interference from the first tier. **(6 marks)**
- 3) Similarly, there are 200 channels available for the whole system with frequency reuse. Calculate the number of users that can be supported for each cell and the whole system at 1% blocking if each user has average 2.5 calls per hour and average call duration is 3.5 minutes. **(8 marks)**
- 4) Compare the capacity obtained in Step 3 (Part C) with the capacity obtained in Step 5 (Part B). Please give your comments in terms of the capacity improvement and SNR degradation. **(4 marks)**

Total Marks: 100

----- This space is intentionally left blank -----

## Appendix

Table 1: Sample code for generating one cell

```
clear all
%the code below creates multiple hexagonal cell with the radius of R=1
(assuming to be 1km)
N=0;
M=0;
R=1;
NoUser=5;
x_hexagon=R*[-1 -0.5 0.5 1 0.5 -0.5 -1];
y_hexagon=R*[0 -sqrt(3)/2 -sqrt(3)/2 0 sqrt(3)/2 sqrt(3)/2 0];
figure(1)
hold on
for nn=0:N
    for mm=0:M
        plot(x_hexagon+3*R*nn,y_hexagon+sqrt(3)*R*mm)
    end
end
for nn=0:N-1
    for mm=0:M-1
        plot(x_hexagon+1.5*R+3*R*nn,y_hexagon+R*sqrt(3)/2+sqrt(3)*R*mm)
    end
end
hold off
axis equal
```

Table 2: Sample code for generating subscribers and base stations

```
%generate randomly and uniformly distributed points
c_x = R-rand(1,3*NoUser)*2*R+3*R*nn;
c_y = R-rand(1,3*NoUser)*2*R+sqrt(3)*R*mm;
%get the points within the polygon
IN = inpolygon(c_x, c_y, x_hexagon+3*R*nn, y_hexagon+sqrt(3)*R*mm);
%drop nodes outside the hexagon
c_x = c_x(IN);
c_y = c_y(IN);
%choose only N points
idx = randperm(length(c_x));
c_x = c_x(idx(1:NoUser));
c_y = c_y(idx(1:NoUser));
%generate and plot N subscribers
plot(c_x, c_y, 'k*')
hold on
%generate and plot 1 base station at the center of the cell
plot(3*R*nn,sqrt(3)*R*mm,'r^')
hold on
```

Table 3: Sample code for calculating the SNR of users

```
d=1000*sqrt(((0-c_x).^2)+((0-c_y).^2)) %calculate the distance
from subscribers to the base station
Pt=22.4228; %transmit power
lambda=0.3333; %wavelength
N=-80; %noise power in dBm
for i=1:length(d)
    Pr(i)=(Pt*(lambda)^2)/(4*pi*d(i))^2
    PrdBm(i)=10*log10(Pr(i)/0.001)
    SNR(i)=PrdBm(i)-N
end
```



Faculty of Engineering and Technology

**ETM3086**

**Mobile and Satellite Communications**

**Trimester 3 (2020/2021)**

# **Assignment Report**

No.	Name	Student ID