AMPS Cell Planning Lab

Student_____ **Date**_____

1. Objectives

The following Lab is on the Advanced Mobile Phone Service (AMPS) standard and it aims to:

- reinforce the concepts of cellular systems design such as frequency re-use, sectorization, frequency channel assignment, etc..
- investigate the effects of demographic, traffic, terrain and land-use data on cell –planning.
- expose students to a software tool used for cell planning.

2. What is AMPS?

In 1981, the Federal Communications Commission (FCC) determined that it would award cellular service licenses to two companies in each of 306 Metropolitan Statistical Areas (MSAs) and 428 Rural Statistical Areas (RSAs). According to the FCC rules, the wireline market (B block) was awarded to the existing wireline operator (i.e., local phone company), while the 'A Block' was to be issued to an unaffiliated wireless operator.

The first two cellular phone service network began operations in Chicago and Baltimore in 1983. (Ameritech offered the first cellular system introduced in Chicago, followed by a second system in the Baltimore-Washington area.) Because the cell size was not fixed, most service areas initially used cells eight miles in radius in more populous areas and 25 miles in radius in rural areas. As demand increased, the cell could be split into three to six smaller cells, but beyond this point the cost and complexity of further subdivision became prohibitive. Each time a new cell was added to a network, the frequency use plan for the entire network had to be redesigned to satisfy co-channel and adjacent channel interference requirements

The AMPS system uses Frequency Division Multiple Access (FDMA), to support multiple users in a cell or cell sector. The allocation of frequencies based on AMPS was designed around 416 duplex channels per operator. The frequency ranges were allocated in the 825-845 MHz and 870-890 MHz frequency bands. In each band, the channels have a 30 kHz bandwidth, and 21 channels are allocated for control channels leaving 395 traffic channels. In the AMPS FDMA scheme each user is assigned a unique 30 kHz bandwidth channel for a single cellular phone call.

Areas of coverage are divided into honeycomb-type cells and the cells overlap each other at the outer boundary. Frequencies are divided into cells or sectors to prevent co-channel and adjacent channel interference. The more users who subscribe to a network, the closer the transmitters are placed to each other. In rural areas, the cells are much further apart. For normal operation, cell sites may be separated by 1-25 miles, but as users complain of poor service due to congestion, cell splitting occurs. A cell can be subdivided into smaller cells, reallocating frequencies for continued use. The smaller the cell, the more equipment and other components are necessary. This places an added financial burden on the carriers as they attempt to match customer needs with returns on investments.

The mode of operation of a cell is determined by the type of antenna used to support the air interface between the cell site and the mobile phone. When an omnidirectional antenna is used, the site serves a single 360-degree area around itself. When interference reaches unacceptable levels, the site is usually sectorized to reduce co-channel interference. Sectorized sites use reflectors positioned behind the antenna to focus the coverage area into a portion of a cell. At least one transmit antenna is used in each sector and two receive antennas provide space diversity for each sector.

2. Coverage Area

Eugene is Oregon's second largest city and it covers approximately 36 square miles. Eugene is the home to more than 160,000 people. Eugene is positioned at latitude 44° 7' N, longitude 123° 13'W.

We want to deploy AMPS cellular system, which will cover a square degree area centered near Eugene, Oregon, USA.
- 43-45 degree North latitude
- 122-124 degree West longitude

3. Cell Planning Software

(1) EDX is the software package to provide cellular / PCS cell planning.
- EDX Signalpro V3.1 evaluation software is available at the following PCs in the Tele lab (Room 831):
  - **Parot**
  - **Alpes**
  - **Everest**

- A user name and password will be emailed to you by a class GSA.

- You can start EDX software by use of following menu path:

  ```
  Start->Programs->EDX engineering->SignalPro™ V3.1 Evaluation
  ```

- Then you will see "EDX Signal Pro" window.
- All files you need are in the following directory:

```
C:\Program Files\edx\edx software evaluation
```

(2) View the demo map
- Click on the **File** menu item, then **Open**
- Select the `cellular_system_demo.map` file. (`C:/Program Files/edx/edx software evaluation/cellular_system_demo.map`)
- Then, you will see the six cell sites within the cell service boundary. (Junction City, Coburg, West 11th, Downtown, Springfield, and Goshen)
- You can adjust map size by use of **zoom in /out** buttons.

[Initial Demo Map]
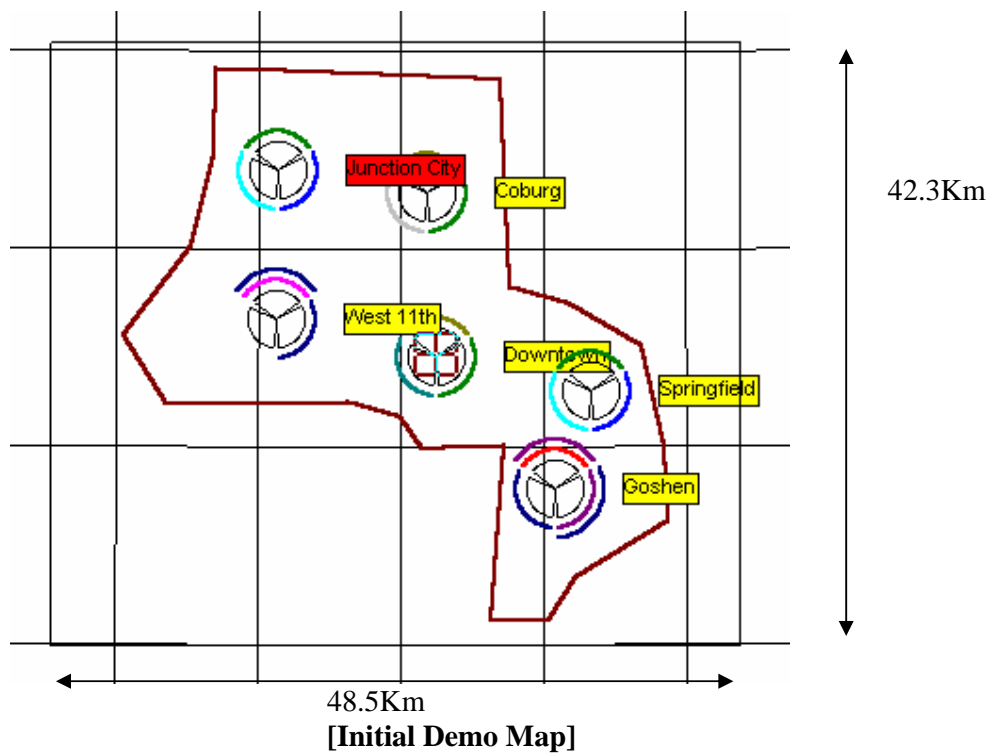
- We will use this demo map file for AMPS Cell Design. Please do not destroy this original file but copy and rename for your own use. For example to rename it `AMPS_Lab.map`
  - Click on **Open** from the **File** menu.
  - Click on **Save as** and type the name `AMPS_Lab.map`

[Job 1] Cell Site Information

- Right-click on the center of the cell site "Junction City."
- Then you can will a dialog box "Transmitter/Base/Hub detail"
- You can find all information about that cell site:
  - Name: Junction City
  - Site Elevation: 105.0 m
  - Number of sectors: 3 (AAAA0001, AAAA0002, AAAA0003)
  - Longitude and Latitude location
- Click on the "Transmit Parameter" button, then you will see
  - Antenna parameter: DA (Directional Antenna)
  - Antenna height: 30m
  - Max transmit power per channel: 10 dBW
- Click on the "Channel" button, then you will see
  - Number of channel: 19
  - SAT (Supervisory Audio Tone): 5970 Hz
  - Assigned Channel Group: 5A (5, 26, 47, 68, …, red colored channel number)
- Click on the "Receive Parameter" button, then you will find
  - Required service C/(I+N) ratio
- Do the same thing for all six cell-sites and fill in the following table.

| Cell Site Name	Location	Elevation	MaxTransmit Power	Channel Assignment (sector)		
Junction City	Latitude: 44° 10' N	105.0m	10 dBW / channel	5A	5B	5C
	Longitude:123° 13'W					
Coburg	Latitude:					
	Longitude:					
West 11th	Latitude:					
	Longitude:					
Downtown	Latitude:					
	Longitude:					
Springfield	Latitude:					
	Longitude:					
Goshen	Latitude:					
	Longitude:					

- This system uses the 25 MHz band from 869 MHz to 894 MHz and each channel has 30 kHz bandwidth. The AMPS system has 396 voice channels and 21 control channels and in this demo cell design each cell has 3 sectors. If you use a frequency reuse cluster size 7, some of cells have 56 channels and some others have 57 channels. Therefore, some sectors have 19 channels and others have 18 channels.
- How many channels does each sector have? Fill in the following blanks.

Cell Site	Junction City	Coburg	West 11th	Downtown	Springfield	Goshen
Sector1	19					

|						
Sector2	19					
Sector3	19					
Total	57					

[Job 2] Review Background Data

- Demographic, Traffic, Terrain and Land-Use data analyses are critical to determine cell cites
- Click on the "Map" menu and click again on the traffic data submenu in the drop down list.
- Make a check mark on the "Show Traffic Data?"
- Click on the button of "Set color level" and check out the color levels. Yellow color is 100 mErlang area. Red color is 90~100 mErlang, … …
- Then click on the O.K. button in the traffic data window.
- You will see the yellow colored area on the city of Eugene.
- Check demographic, terrain and land-use data as you did for traffic data.
- After checking out the data, click on the "Map Layers" button (12th button from the leftmost) and using the "Move Down" button put traffic data layer under the signal level layer.
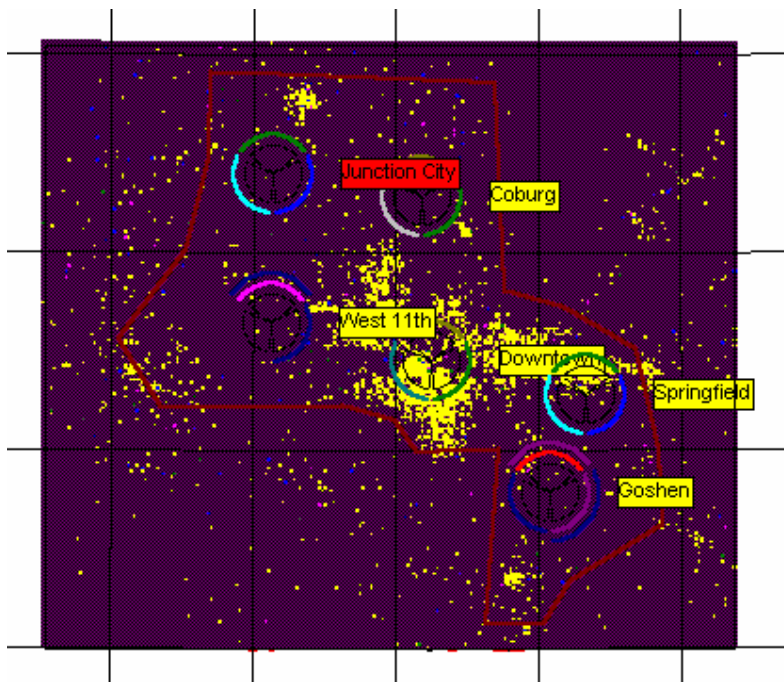- You should see the following graph.
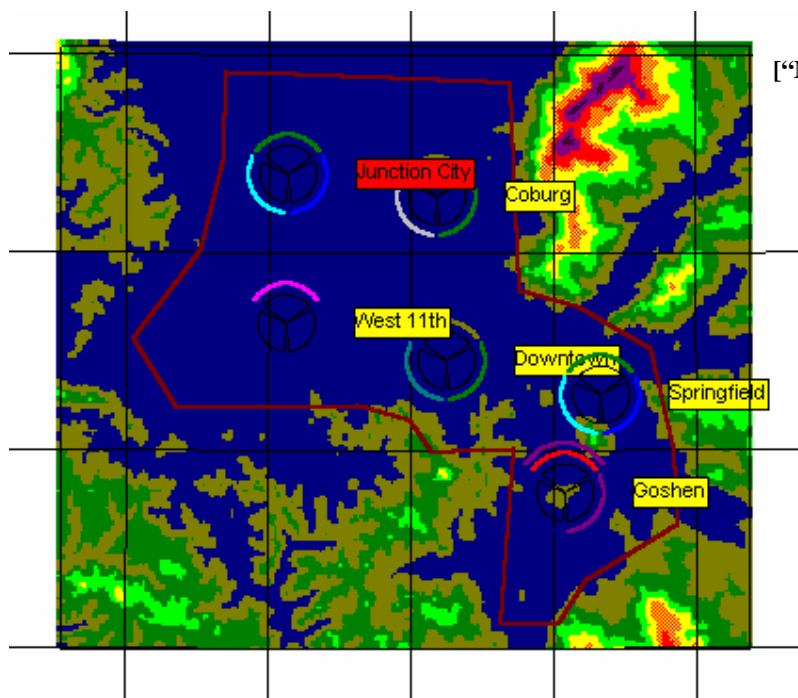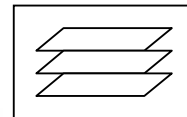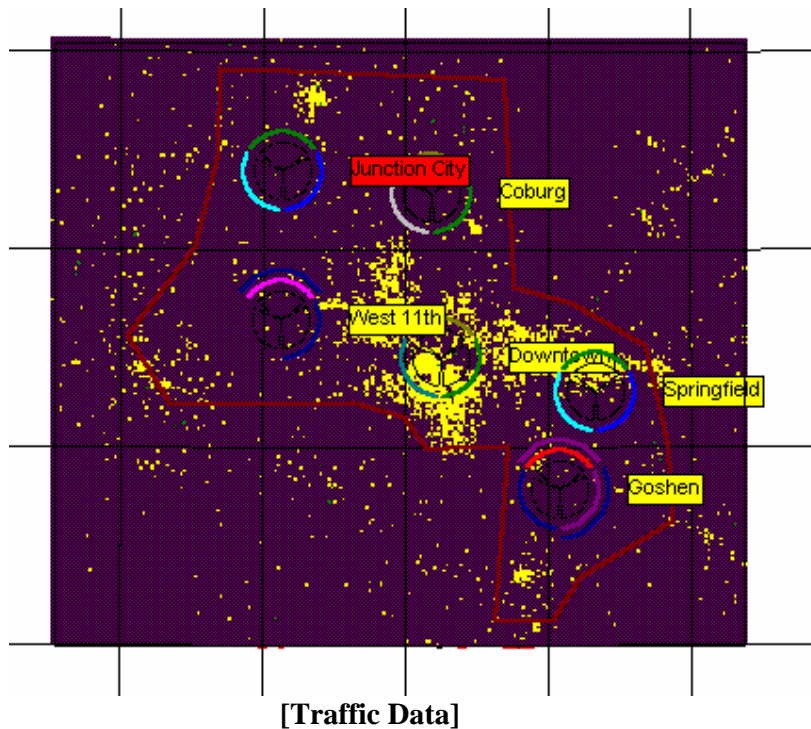

["Map Layer" Button]

[Terrain Data]
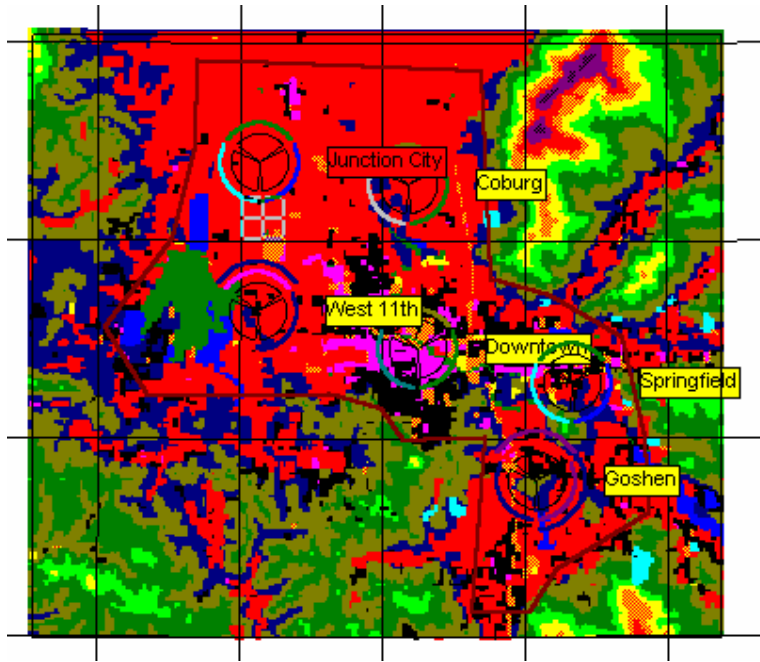
[Land-Use Data]

[Demographic Data]

[Traffic Data]

- What relationship do you see among the four graphs above?.
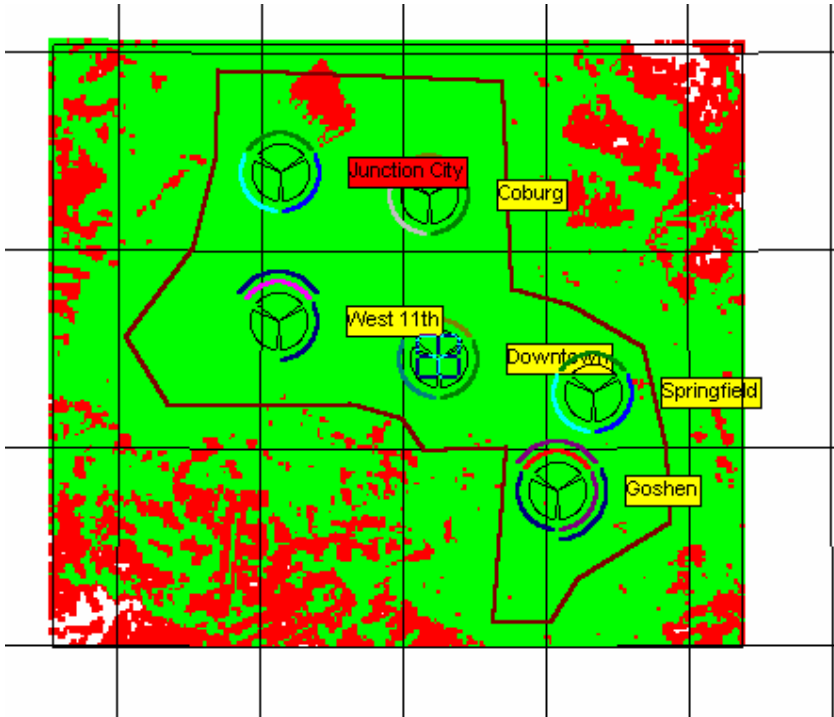

[Job 3] Signal Strength Study

- Click on the **Map Layer** button again.
- Click on the traffic layer and then click on the "Hide Layer" button.
- Then you will see the first original cellular map without any background data layer.
- Click on the "Studies" Menu and then click again on the "area studies" submenu.
- You can see "C/(I+N) using cellular / PCS Plan" in the area study type item.
- Click on the button "set signal color levels"
- Then you will see the signal "18 dB" to divide signal levels into two categories. For an AMPS system, your C/(I+N) ratio objective throughout the system will be 18 dB. Red color will indicate the area where signal strength is lower than 18 dB.
- Click "OK" button
- Finally click the 16th button ("Area Study") from the leftmost.
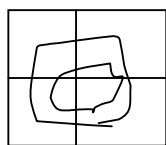
["Area Study" Button]

- About 10 minutes later, this shows you the area where the signal strength level is over 18 dB or under 18 dB.
- Did you see the red colored area where the signal level is lower than 18 dB? Southwestern area and northeastern area have large red colored areas.
- Click on the "Map Layers" button (12th button from the leftmost)
- By use of "Move down" button, move down the signal level layer under the "reference grid" layer. Click on the O.K. button, and then you will see the signal level and other cell sites information on the same screen.


[Signal Strength Study]

[Job 4] Modification I

The original cell design was based upon the assumption of uniform traffic distribution. But in reality, more traffic is in the downtown area and less traffic is in the suburban area. Therefore, we'd like to create one more cell site in the downtown area.

First, move the current downtown cell site (N 44° 3' 23.93") to the new site (N 44° 4' 23.93") and change the cite name into "Downtown1". And also change the max transmit power per channel into 5 dBW.

Second, make a new cell site and call it "Downtown2". Click on the "New Site" button. (7th button from the rightmost) Its location information are (N 44° 1' 12.25") and (123° 5' 58.05"). Assign channels (7A, 7B, and 7C) into each sector of this new site.
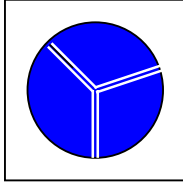
[New Site Button]

[Job 5] Modification II

We want to make new two sites: one in the northeastern corner and the other in the southwestern corner to cover the entire 4 square degree area.

When you move your mouse on the screen, left-click the mouse, and you will find the information about the 1st and 2nd signal strengths, elevation, and latitude and longitude.

Following is the requirement for new sites:

- Name: NorthEast and SouthWest
- Compare signal strengths from neighbor sites
- Find the highest point for new sites
- Use omnidirectional antenna (360°)
- Adjust Max transmit power per channel for larger coverage
- Assign a new group of channel to each sites
- And then click on the "Study Area" button and verify your new cell planning is good enough.
- If there is still a large red colored area, please do the above procedure again.
- Fill in the following table according to your new site planning

Cell Site Name	Location	Elevation	MaxTransmit Power	Channel Assignment (sector)		
Downtown1	Latitude: 44° 4' 23.95"N Longitude:123 ^{o} 5'37.76"W	183m	5dBW/ channel	4A	4B	4C
Downtown2	Latitude: Longitude:		5dBW/ channel	7A	7B	7C
NorthEast	Latitude: Longitude:		25dBW/ channel	6A, 6B, 6C		
SouthWest	Latitude: Longitude:	306.5m	25dBW/ channel	6A, 6B, 6C		

- Does your new cell design cover all the area? Print out your new cell design.

- If you have any question, please click on the "help" button, then you can look at the appropriate part of the manual.
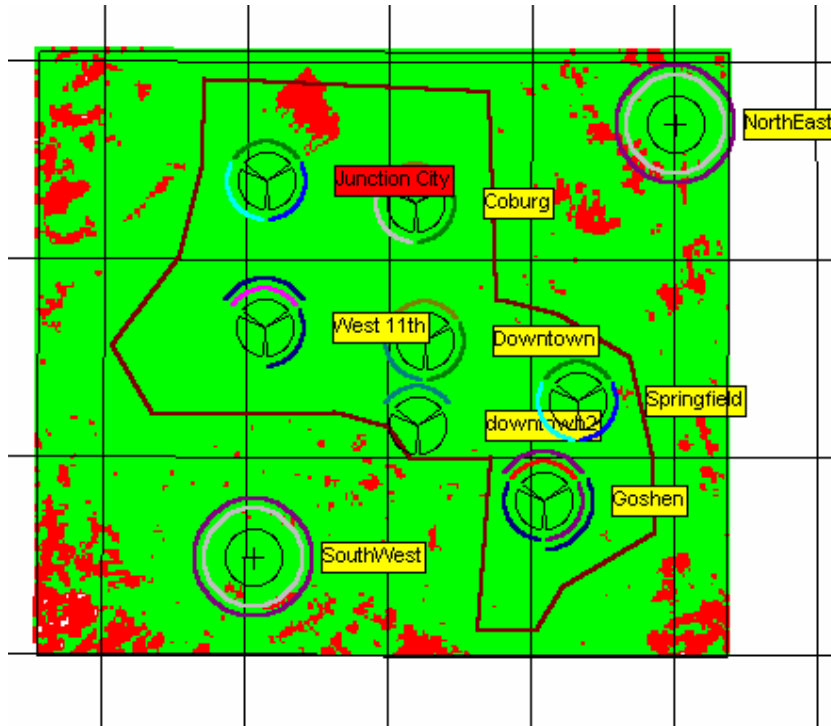
[Job 6] Comparison with manual calculation

- From the cell site information, you can find the value (dBW) of ERP (Effective Radiated Power = transmit power + antenna gain – loss factor). By use of the Okumura-Hata model and -122.2 dBmW receiver power requirement (this information comes from clicking the receiver parameter button), calculate the maximum cell size of each cell.

- Okumura-Hata model
  $PL = 69.55 + 26.16 \log(f) – 13.82\log(h) +[44.9 – 6.55 \log(h)]* \log(d) + C$
  $C = -2$ (dense urban), -5(urban), -10(suburban), -26 (rural)
- $Pr = Pt +Gt +Gr – PL$
- Example of Junction City
  -122.2 dBmW < 10*log(20/0.001) dBmW + 10 dB + 3 dB – (121.034 + 35.22486 * log(d))
  d= 41.97 = 42 Km

Site Name	frequency	Antenna Height	C	Pt (dBW)	Gt (dB)	Gr (dB)	Max distance
Junction City	870MHz	30	-5	20	10	3	42 Km
Coburg	870MHz	30	-5		10	3	
West 11th	870MHz	30	-5		10	3	
Downtown1	870MHz	30	-2		10	3	
Downtown2	870MHz	30	-2		10	3	
Springfield	870MHz	30	-5		10	3	
Goshen	870MHz	30	-5		10	3	
NorthWest	870MHz	30	-10		10	3	
SouthEast	870MHz	30	-10		10	3	

- Do you think these maximum distances are well fitted in the map of cellular design? If you think the max distance is too large, adjust transmit power (Pt) and comment.

- What is the reason for sectorization of each cell?

- Under the assumption that call arrival rate is poisson process with a mean rate of 2 calls/hour and call length is exponentially distributed with an average length of 3 minutes a call, we could roughly calculate the maximum users that can be supported by this system with 1% call blocking rate. How many users can the new AMPS system support?

## [Job 7] Erase all the sites in AMPS_project.map and do a new cell design.

(1) Click on "RF Systems" on the main menu and click on "Transmitter/Base/Hub Site" submenu on the drop-down list. Then, you can see the "master group" item selected.
(2) Click on the "Edit Group" button
(3) Click on the hub site name in the site/hub section, and then all of the sectors under this site name could be selected.
(4) Click on the "Delete Site" button.
(5) Repeat (3) and (4) until all of the sites are removed. For example, select "Coburg" and delete it, select "Downtown" and delete it, … …
(6) Click the "OK" button.

(7) Now you should not see any site in your map.

(8) Save this map as "clean.map" for your future use.
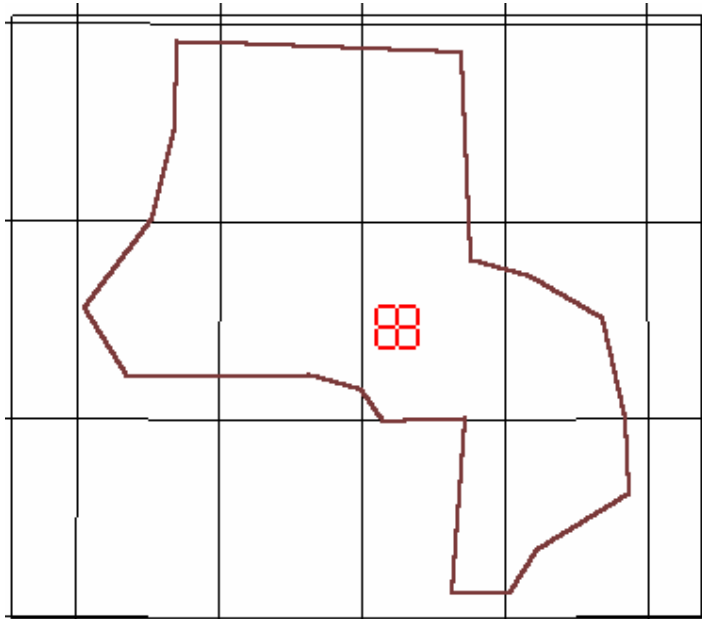
[Clean.map]

- From now on, we'd like to conduct initial cell design by use of "Network Design" Module.
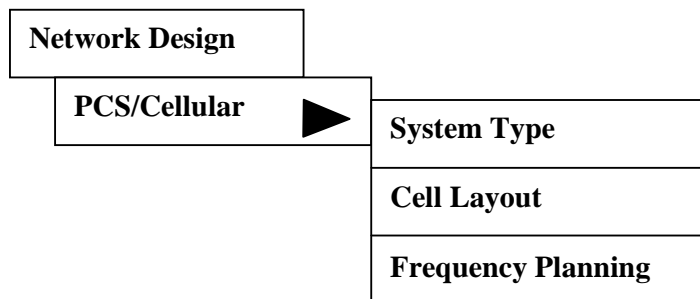
- Select "Network Design / PCS/Cellular / System Type" menu.
- Type the following data and click 'OK' button.
  - System Type: AMPS
  - Forward link lower band edge: 869 MHz
  - Forward link upper band edge: 894 MHz
  - System carrier spacing: 30 kHz
  - Voice channels per RF channel: 1
- Select "Network Design / PCS/Cellular / Cell Layout" menu.
- Type the following data and click 'Start Layout' button.
  - Nominal Cell Radius: 10 Km

- Service area boundary file: "C(E):\edx\edx software evaluation\cell_service.bna"
- Template: 3 sector cell
- Check mark on the show hexagon grid

• Then, you should see the following new cell design map when you click on "Create Cell/PCS sites".

- Now, you have 9 cell sites (AAAA ~ AAAI) to cover the whole area. Based upon this initial cell design, you can redesign a system as the number of users increase.
- What should you consider when you redesign?