Planning Terrestrial Radio Networks

Lab 2 Exercise Manual

Lab Information

The aim of this lab is to help students to develop basic skills in designing radio links. The simulation software used in this lab is *Radio Mobile*. All the files you need for this lab, including the simulation software, are available at Social. Begin by downloading the ZIP file from this address and extract it onto the desktop. You can start the lab application by clicking on rmweng.exe.

1 Introduction to Radio Mobile software

Radio Mobile is a software tool used to predict the performance of a radio network. It uses terrain elevation data for automatic extraction of path profile between a transmitter and a receiver. This data, along with environmental and statistical parameters are used as input to Irregular Terrain Model propagation model. (You can find more information on ITM propagation model in the documentation in the lab folder.) Elevation data is also used to produce virtual maps as background pictures when plotting simulation results. For most of the world the elevation data is readily available. The software can also produce 3D views, stereoscopic views, and animations. Background pictures can be merged with scanned maps, satellite photos, military maps, etc.
You can find more information, some examples and documentation on Radio Mobile at the following locations:

- online help included in Radio Mobile (press F1 to access)
- Radio Mobile homepage: http://www.cplus.org/rmw/rme.html
- user guide: http://www3.telus.net/hendersb/documents/Radio%20Mobile.pdf
- documentation website: http://radiomobile.pe1mew.nl

In the beginning of the lab exercise, you will go through a small tutorial presented in this chapter below to get yourself acquainted with the user interface of Radio Mobile. Allocate this part 10-20 minutes before you start with the exercises. Note that you will not include your answers to this tutorial part in your lab report.
Now, start the lab application. When you start Radio Mobile, the default radio network file will be loaded. In the case that the network is not displayed automatically, follow these steps:

1. Load the map data by selecting File → Open Map → Select default.map. You will get a message which tells you that elevation data was successfully loaded. It is normal that you do not see any map at the end of this operation because this operation only loads the elevation data to the program's memory. You will display the map in step 3.

2. Load the network: File → Open Networks → Select default.net This operation only loads the units' locations, their equipment properties, etc. to the program's memory. You will display the network members (units) in step 4.

3. Display the map picture: File → Open Picture → Select default.bmp

4. Show the network: View → Show Networks → All

You will see a number of transmitters and receivers (cars, boats) spread on the map over Stockholm area. After loading this map, click on the menu Tools→Radio Link . For the link from *TX1* to *Boat-1*, try to explain all the information you see. In Radio Link window (i.e. terrain profile window) look at the results given under View→Details, Range, Distribution and try to explain the information you see. For help, refer to the course book and also the help in the locations listed above if necessary. Is this a working link? What about the link from *TX2* to *Car 2* ?

Organization of network data in Radio Mobile

In Radio Mobile, information related to a simulation study is grouped in three layers: *network, map* and *picture*. These layers can be configured from the File menu. A *network* in Radio Mobile can be simply defined as a collection of units that communicate with each other on a certain frequency. A unit represents a transmitter or receiver that communicates with other units in the same network. You can define many networks in one simulation but keep in mind that the units that are supposed to communicate with each other must be members of the same network. Each unit has a system associated with it, which describes the physical/electrical properties of the communication equipment used by that unit. Different units in the same network may be equipped with different systems. For example, a transmitter unit and a receiver unit in the same network may be equipped with a transmitter system and a receiver system respectively. These concepts are further explained below:

Network The program reads the information of the simulated system from a network file. This file contains information which defines the systems that are used by the units, the positions of units, and their relations with respect to each other (i.e. whether they are in same or different networks, whether they are transmitters or receivers, etc.) This network related parameters can be controlled from File→Networks properties window. Read through the parameters listed in this window. Also get help from the sources listed above if you need. Note that, when you create a new network or networks, you only create placeholders for the units in these networks. You will not observe any change on the program window until you create actual units in these networks and then display them by View → Show networks → all .

Elevation data The elevation data is used to obtain the terrain profile between units in order to calculate the pathloss between them. The terrain data for the simulated area can be loaded from File→Open map dialog. Note that, when you load map data in this way, you will only get a message which tells you that elevation data was successfully loaded. You will not observe any change on the program window until you create a new picture using the map data that you have just loaded to the program's memory.

Picture Radio Mobile can produce a number of different representations of the working map to display simulation results. A new representation (i.e. a picture) can be generated using File → New picture dialog. A *rainbow* map is useful to visualize elevation information, whereas a *grayscale* map is more suited for presenting simulation results. City and road data can be added to the map picture by selecting Edit → Merge pictures.

Parameters controlling the simulated environment, transmitter and receiver properties are handled in the following way.

Network Parameters Under Networks properties → Parameters tab, the parameters related to all members of a network are listed such as carrier frequency, refractivity, permittivity, etc.

Units Units are the members of the networks defined in the simulated environment. Units can assume a number of different functions in a network, like transmitter, receiver, repeater, etc. The positions of units can be assigned from *File → Unit properties* window. Which unit is part of which network and which unit is equipped with which system can be specified under Networks properties → Membership tab. Note that each unit in the same network may be using a different system, for example receiver and transmitter units of a communication network are typically different.

Systems Under Networks properties → Systems tab the system properties such as transmit power, antenna gains, line losses, receiver thresholds, etc. can be specified. Although it is possible to define all these properties regardless of the unit's role in the network, Radio Mobile uses only the relevant parameters for each unit. For example when simulating half-duplex communication, transmit power defined for receiver unit will be ignored.

During the lab exercises, if you need further information to create networks, units and systems, you can refer to the appendix.

Now try to identify how many networks there are in the example. Which units are parts of which networks? How many different systems are used in total and by which units?

(Tip: Tools → Network Manager may be useful for this purpose)

2 Lab Exercises

Please read through the instructions carefully. At the end of this lab you will submit a report in which you will explain your results. For each of the exercises;

- answer the specific questions at the end of each exercise
- take necessary screenshots of your simulation results[1]
- write a short paragraph which explains the results you obtained.

Email your report to the lab assistant with Lab1 as the subject. Make sure that you have included the names of the authors of the report in the email, filename and on the report itself.

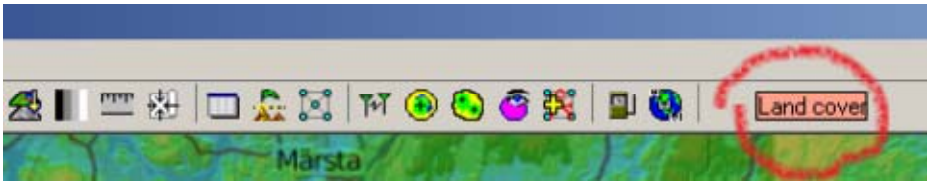
2.1 Service Area for Sveriges Radio P4

In this exercise you will estimate the service area of the Nacka broadcasting site for the radio program SR P4 on 103 MHz in FM broadcast band. Please read the exercise instructions fully before starting your simulations.
Also, refer to the appendix at the end of this manual to find out how some particular operations are performed in Radio Mobile.
Start with a new simulation environment (File → New Networks) open the Stockholm map and create a greyscale picture.
Then generate two systems; one for the transmitter and one for the receiver. Then configure the systems according to the approximate values below.

- Transmitter antenna height is 250m.
- EIRP is 50kW. Note that the transmit power and antenna gain are not specified explicitly. It is up to you to determine the transmit power and the transmit antenna gain parameters such that EIRP is 50kW. Think about the definition of EIRP; refer to your lecture notes if necessary.
- Required receiver threshold for good reception is 200µV. Receivers are placed at a height of 1m above ground and they have 2 dBi antenna gain.
- The transmitter and receivers have no line loss.

Use the following parameters for the simulation environment:

- Surface refractivity: 301
- Ground conductivity: 0.02
- Relative permittivity: 25
- Polarization: vertical
- Mode of variability: broadcast (90,90,90), as required for mobile reception.
- Additional loss: Forest 30%. If this field is not visible, go to the main window and click on the Land cover button to switch it off as in the following figure and try again.



- Since we are simulating the reception of an FM radio system, the operating frequency of your simulation system is the frequency of the radio station that you are trying to listen to. Enter the same value as the minimum and maximum frequency in the Networks Properties window.

[1]*You can obtain a screenshot of the active window by pressing Alt+Print Screen and then you can directly paste it in a Word document.*

Then create the Nacka transmitter at coordinates: N59º 17' 45'', E18º 10'33''.
For simulating the reception in Kista and Arlanda create a receiver unit at each location (see appendix). Also, make sure that you create separate systems for the transmitter and for the receiver units so that you can assign different parameters to these systems. To identify the units easily, give them different names. Make sure that all units are members of the same network, otherwise you will not be able to see results. The coordinates of the Electrum building in Kista is N59º 24'16'', E17º 56'57'' and Arlanda airport is N59º38'58'', E17º55'45''.

Answer the following questions:

- How is the coverage in Kista area according to your simulation results? What is the received signal level in Kista?
- What is the received signal level in Arlanda? Can you listen to the P4 radio at Arlanda airport?
- What is the reception limit in kilometers approximately? To find the approximate coverage radius, you can drag your mouse across the screen to make a line segment. Then you can read out the length of the segment in the information bar at the bottom of the screen.
- Briefly explain your solution method and results.
- Include screenshots of the Radio Link results for both links as well as Single Polar radio coverage plot of the Nacka transmitter (see Appendix on how to produce the polar coverage plot).

2.2 Avoiding interference in a data network

In this exercise you have to design a radio network with four nodes, at the positions given in the map. All nodes are using the same frequency channel in 430 MHz. The configuration of the system must be such that the links A→D and B→C can be operated simultaneously. Other links can be neglected; for example disregard the links D→A, A→B, etc. Receiver threshold is 0.7μV, and a signal-to-interference ratio (SIR) of 10dB is required for successful operation. You can load the network you have to use in this exercise by opening the file ex-interf.net. Start by first investigating the interference at the receiver nodes. You can calculate the interference using Tools→Radio Coverage→Interference tool. See the appendix for details of performing the interference calculation.

Provide your solution in terms of:

- Antenna height, type and orientation for each transmitter and receiver.
- EIRP for each transmitter.
- Numerically show that SIR is greater than 10dB at both receivers. Note that you do not need to calculate the received powers analytically in order to do this task. Simply use the signal and interference levels that you obtained in your simulation results. Also, be careful about the units when you calculate the signal-to-interference ratio.
- Briefly explain your solution method and results. In your explanation, use the screenshots of *Radio Link* profiles of both links and *Interference* plots at both receivers.

APPENDIX - Using Radio Mobile

This section contains brief information about the most common simulation features of Radio Mobile.

Looking at the link between two stations

To obtain the radio link profile between two stations:

- Select Tools → Radio link
- Select the two stations you wish to observe
- Note that you can now adjust aerial heights and system types

If you click on the terrain profile diagram, a cursor is placed on the main map also, so that you can see where the objects that obstruct the path are.

Adding radio stations and units

To add units to the simulation environment:

- Select File → Unit properties
- Enter the name of the unit
- You can either enter the latitude and longtitude manually, or if you have already generated a map picture, you can place the cursor at the desired location and then select Place unit at cursor position.

Adding a network

Before you can see the coverage of the various stations, they have to be in a radio network.

- Select File → Network properties
- Enter the network name, e.g. Sveriges Radio, the frequency of operation and polarisation.
- Go to Systems tab and enter a system name, power level and aerial height, etc.
- Create another system name and enter the data in the same way, if necessary
- Go to the Membership tab and select the units you want to be in this network. Then assign these units the systems they are supposed to carry.

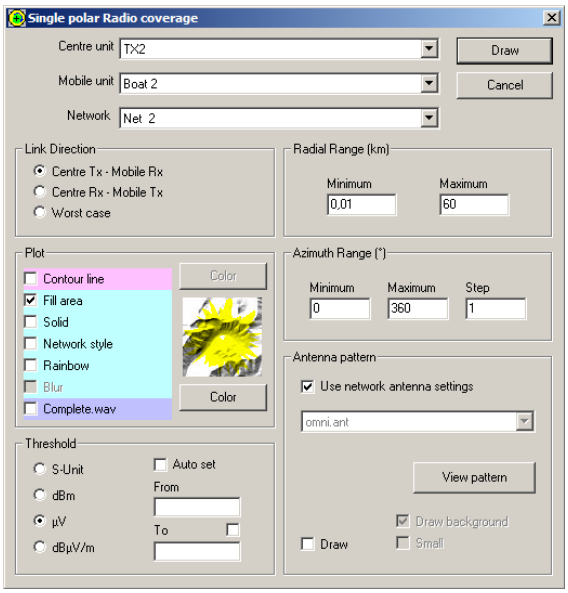
After you have created the network and assigned the units, paths between the stations will be drawn on the map.

Coverage prediction

To perform a coverage prediction:

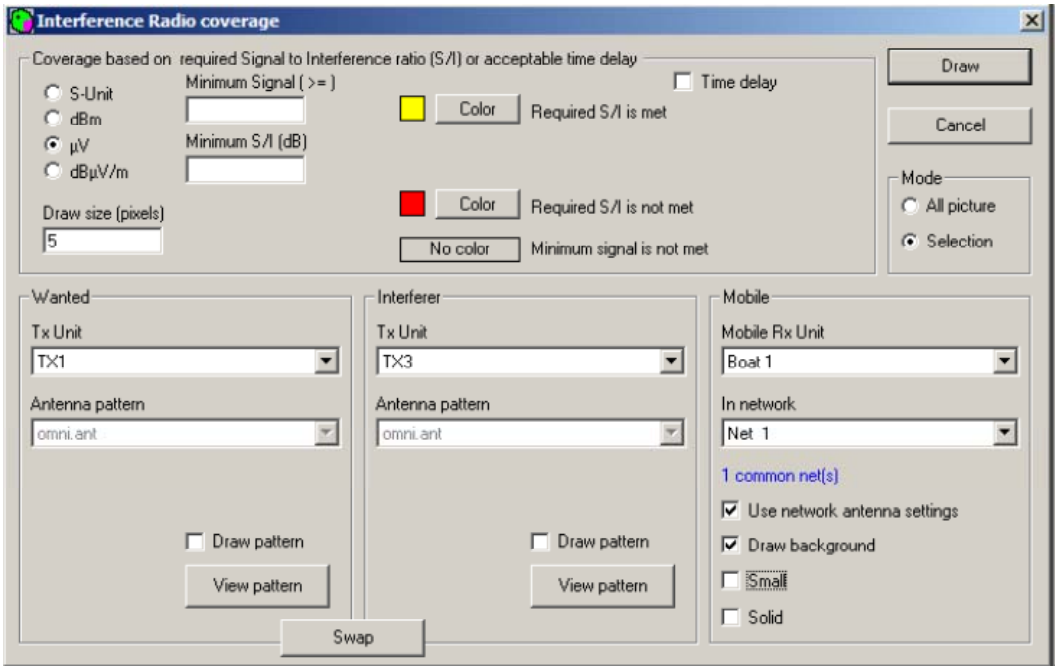
- Select File →New picture and choose Grey scaled slope.
- Select Tools → Radio coverage→Single polar
- Select Centre Tx – Mobile Rx
- Choose the centre unit (i.e. transmitter) and the mobile unit, the color to draw coverage plot and the upper/lower signal levels. For example, to plot the area which has signal reception stronger than 200μV adjust lower threshold to 200μV and leave the upper threshold unselected.

The program will produce the coverage plot and ask whether to leave the result plot in the picture. It is good practice to keep each plot in a new picture so that the results do not get cluttered.



Interference analysis

- Select Tools → Radio coverage → Interference
- Specify minimum signal strength requirement (pay attention to the units)
- Specify signal-to-interference requirement on the link
- Specify the transmitter, receiver and the interfering units
- If you have selected an area of interest on the map, you can choose to perform the interference calculation on this Selection, which will speed up the simulations.



Drawing a map

The map you will work on during the lab is automatically loaded when Radio Mobile starts. If you want to load this map, go to File → Open map and select default.map. If you want to create a map of a different location do the following:

- Go to File → Map properties
- Click Select a city name, then enter name of the city.
- Set pixels to desired map size, e.g. 800 * 600
- Height controls the distance of point of view to the map.
- Select Ignore missing data
- Select SRTM and enter the location of the map data file.

Then click apply and the program should draw a default map centered on the selected city.
Select File → New picture . Try choosing different types of pictures, for example, Colored slope (relative). Note that you when you click on the map a cursor is shown. You can read the latitude and longtitude of the selected position. If you select View → Elevation grid a small grid is also displayed so that you can accurately move the cursor to the correct height position. The actual area which the map covers is determined by the height you enter in the map properties field.

Overlaying a road map on the coverage plot
You can use this function to merge a map picture with road information. This step is not needed for the
lab exercises, though.

- Select Edit → Merge pictures
- Select *Internet OpenStreetmap* and choose *Multiply*.