



## Instruction for Laboratory classes on Wireless Communications

Łukasz Januszkiewicz

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### Exercise 1. The coverage of FM broadcast station

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The aim of this exercise is to:

- get familiar with Radio Mobile software,
- learn which factors influence the coverage of transmitter.

#### 1. References:

1. W. Stallings, C. Beard, "Wireless communication networks and systems", Pearson, 2015
2. RECOMMENDATION ITU-R BS.412-9 Planning standards for terrestrial FM sound broadcasting at VHF

#### 2. The scope of the exercise.

In this exercise you will learn how to predict the coverage area of FM broadcast station using Radio Mobile software. The coverage area of the transmitter is the area where the station can communicate with receiver. The minimum requirement of successful transmission in FM broadcast system is to provide the receiver with suitable energy of received signal [1]. A satisfactory service requires than a given value median field strength that is defied in the ITU-R recommendation for particular wireless system.

In this exercise we will apply ITU-R recommendation for FM sound broadcasting at VHF [2]. It defines minimum usable field strength in terms of its median value measured at 10 m above the ground level. For transmitter coverage simulation we will assume that receiver antenna is located 10m above the ground.

For different areas on which you will simulate the coverage please apply the values of minimum field strengths given in Table 1[2].

Tab. 1. Minimum field strengths for coverage planning

Areas	Services	
	Monophonic dB( $\mu$ V/m)	Stereophonic dB( $\mu$ V/m)
Rural	48	54
Urban	60	66
Large cities	70	74

### 3. Radio Mobile software

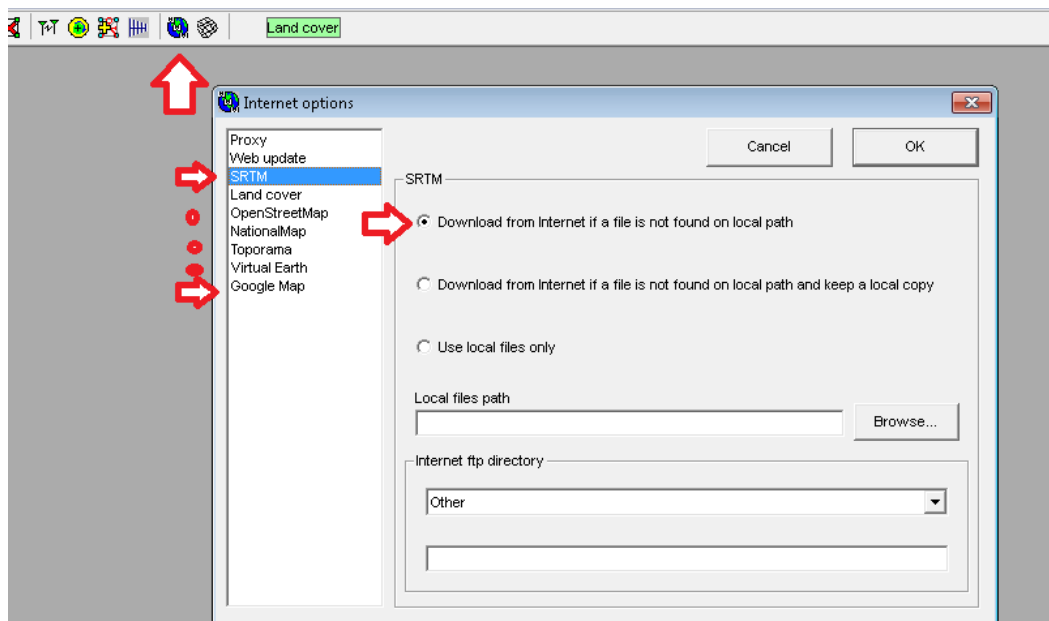
Radio Mobile is a free computer program developed by Roger Coudé that allows you to simulate the coverage area of wireless systems. At <http://radiomobile.pelmew.nl> you will find a lot of information about this project. The Radio Mobile program performs simulations using the Irregular Terrain Model - ITM that is a very popular propagation model. The Irregular Terrain Model (ITM), also known as the Longley-Rice model, allows you to determine the average path loss for long-range radio signal transmission taking into account atmospheric and geographical conditions.

The program in the installation version is available at: <http://radiomobile.pelmew.nl/?Installation>

To complete the exercise, install the program according to the instructions on the project page. You must download the "rmwcore.zip" file and then the language pack from <http://www.ve2dbe.com/download/download.html>.

In the instructions to this laboratory I give the names of the program menu with the English package installed. The downloaded program files should be unpacked into the installation folder.

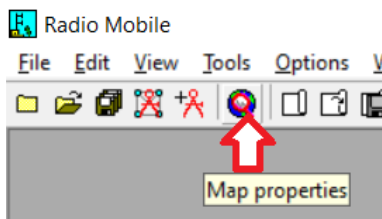
In the simplest version of the program installation it is not necessary to download the digital terrain maps yourself and copy them to the program folder. The program launched with the default settings will download maps from publicly available web services (e.g. google). You must have Internet access when working with the program. To automatically download the necessary maps from the Internet, the "Map\_Link.txt" file, which is located in the program's installation folder, must be modified. You must remove the apostrophes ' from the first lines from the file and then save the file. After modifying the "Map\_Link.txt" file, start the program and check whether the option of automatic map download from the Internet is set. In the "Internet Options" window, select the "Download from Internet ..." option for all types of data: SRTM, Land cover, OpenStreetMap, NationalMap, Toporama, Virtual Earth, Google Map:



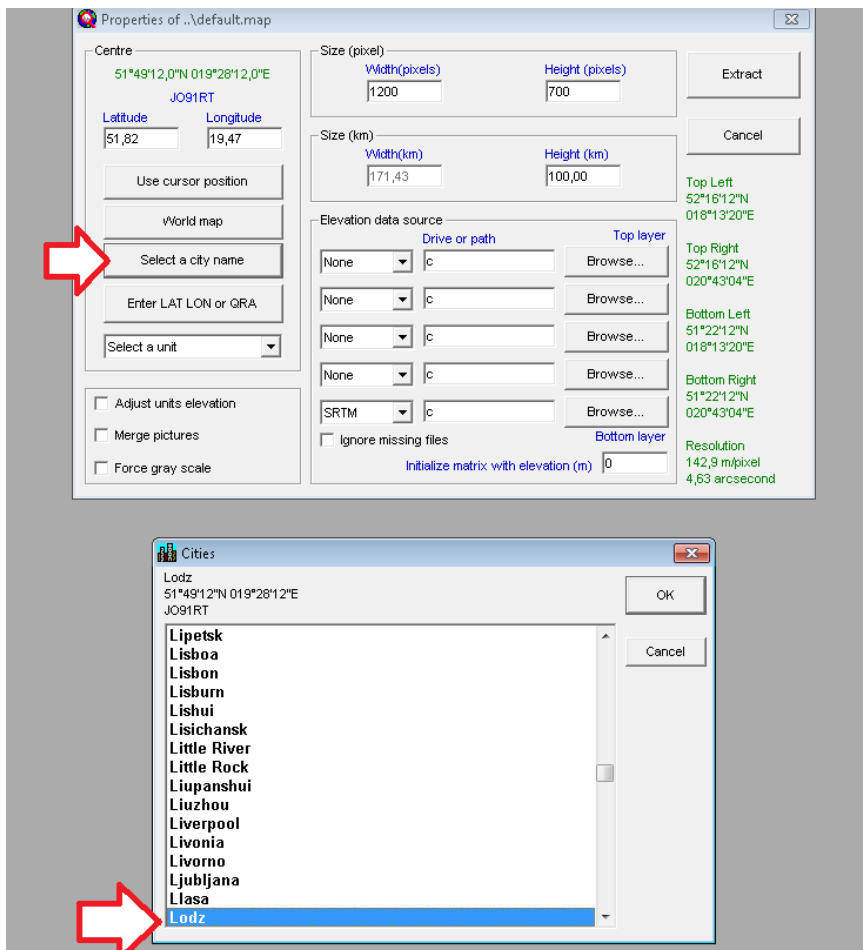
## 4. Course of the exercise

### 1. Create the project in Radio Mobile program

The English version of the program can be started with the rmweng.exe file. Then click on the "Map Properties" button:

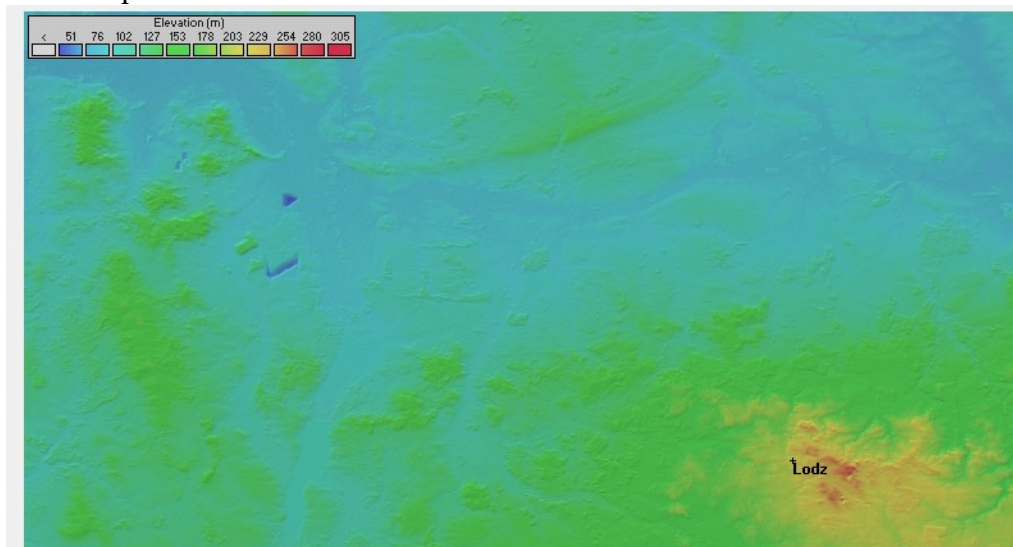


Then choose the city of Lodz, around which the analysis will be carried out. The list of cities is available after pressing the "Select a city name" button. Then enter "Lo" and select Lodz from the list.



The size of the map in pixels (Size (pixel)) is set to Width = 1200, Height = 700 pixels. The map area defined in pixels can be assigned to the appropriate train area. We set the size of the analyzed area vertically on the map to 100 km (Size> Height> 100 km). Then press the "Extract" button.

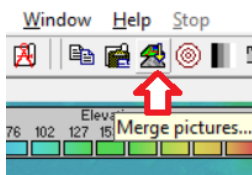
A map presenting the height of the terrain above sea level will be presented, a fragment of which is presented below:



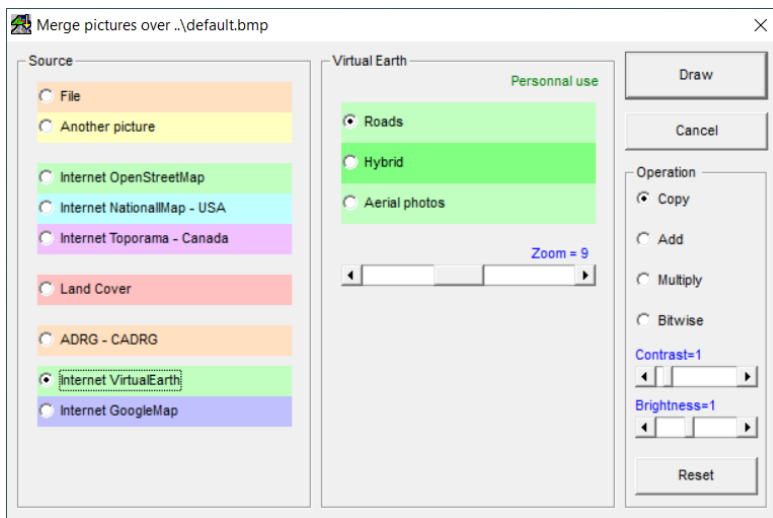
The terrain height map is very important when designing wireless systems because the terrain has a large impact on the range of transmitters. The designer should always be familiar with

the height distribution in the area where he designs the system.

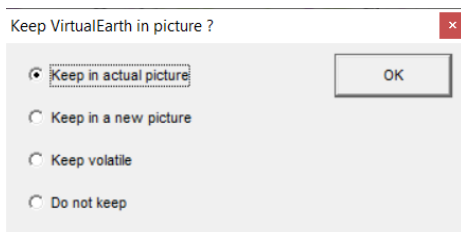
On the altitude map we can display a layer with marked roads and city names, which greatly facilitates orientation in the project. To do this, use the menu: Edit> Merge pictures, or press the button below:



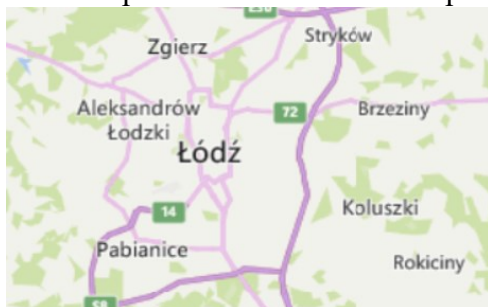
From the Merge pictures window select Source> Internet VirtualEarth, and Virtual Earth> Roads:



If the Copy option is selected, the road layer and place names will replace the altitude map. Other options overlap both maps. The imposition will be done by pressing the Draw button. The map configured in this way can overwrite the existing one or arise as a new object. To overwrite the existing one, select "Keep in actual picture":

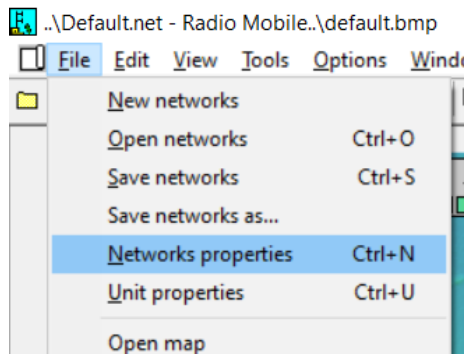


An example of a section of the map with marked roads and place names looks like this:

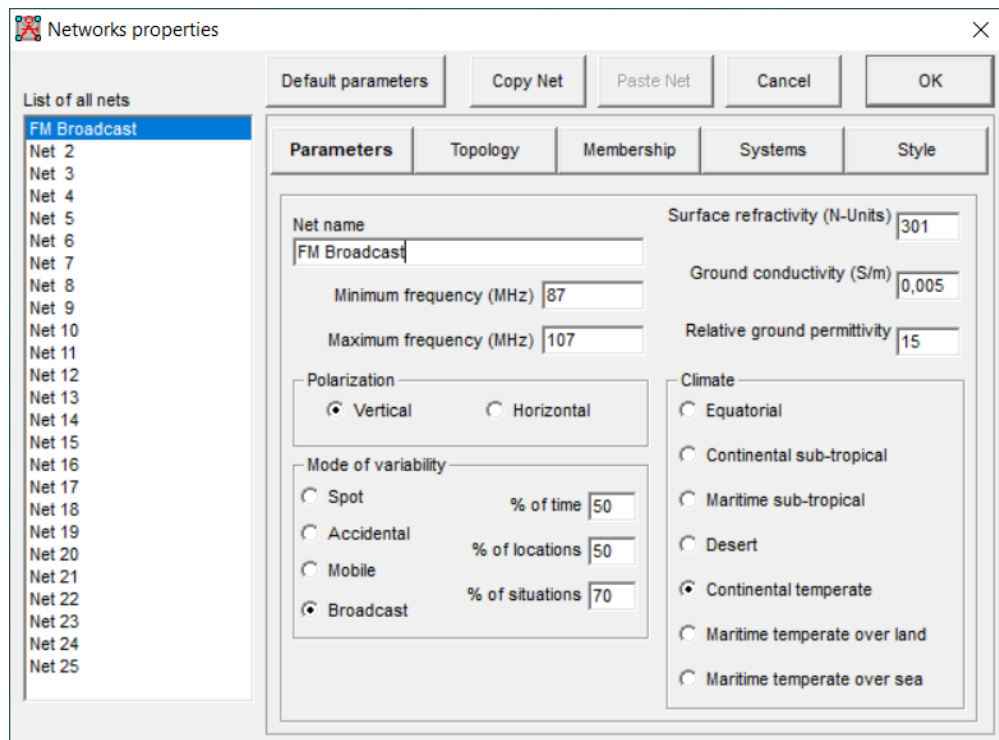


## 2. Transmission system configuration

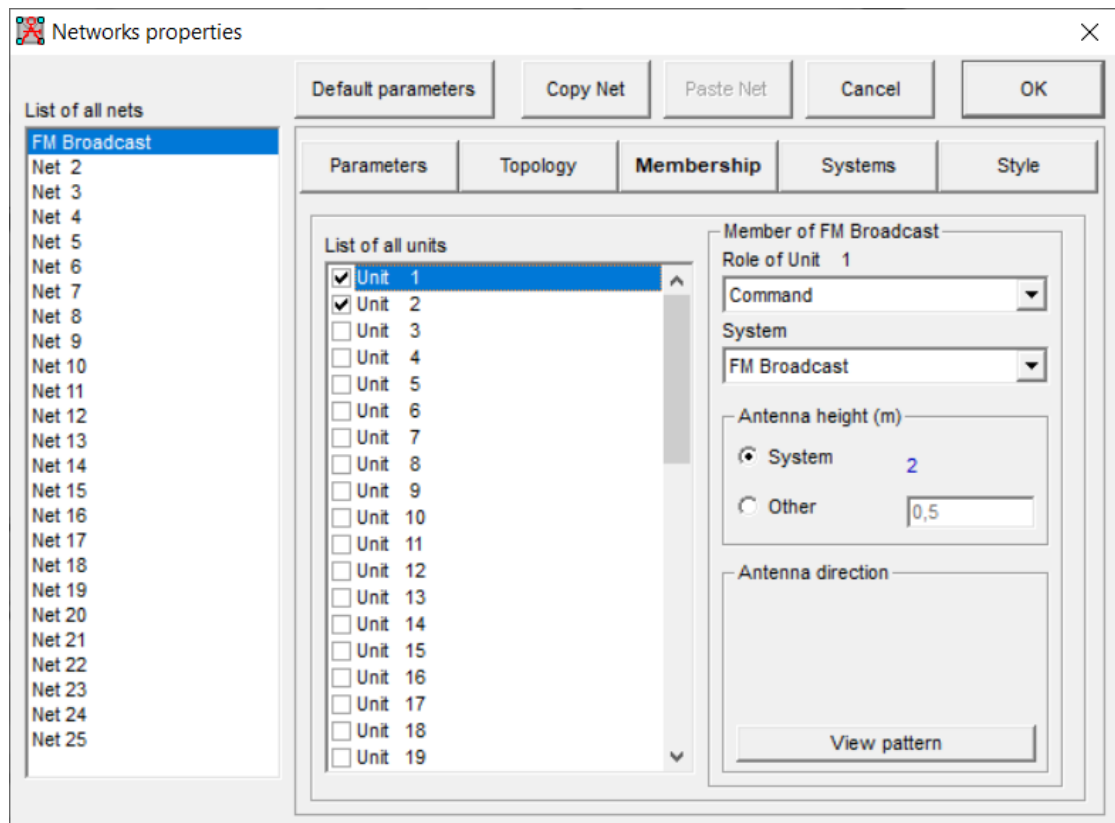
Transmission system parameters must be configured in the File> Networks properties menu:



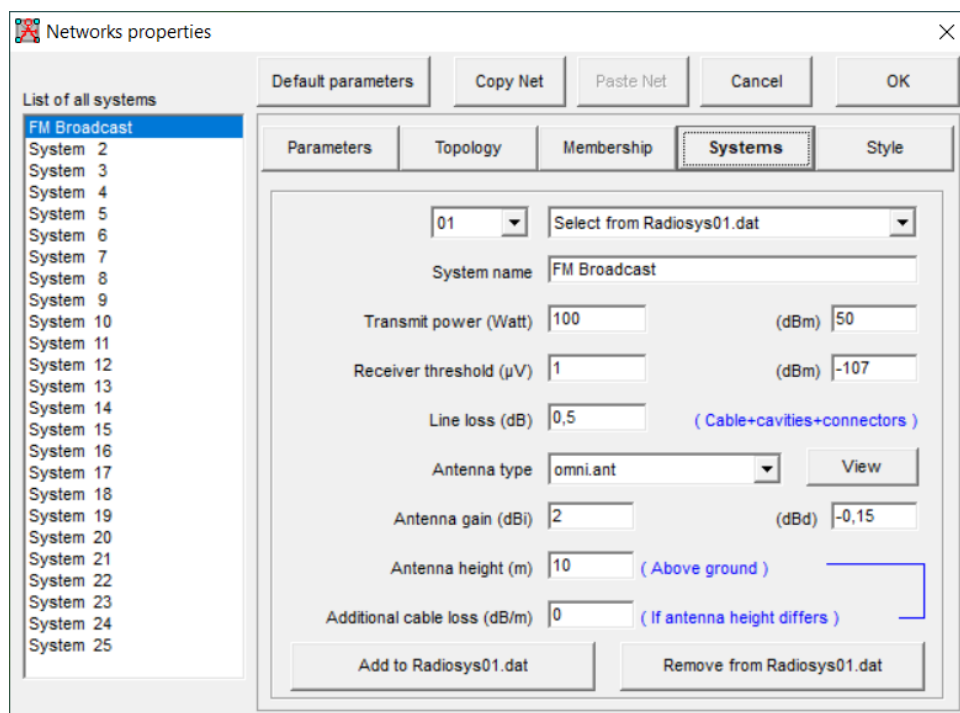
Then, in the "Network Properties" window, select the Net 1 network name in the left panel and define its parameters, as shown in the window below. We define the network name as (Net name): FM Broadcast, Frequency range 87 - 107 MHz, type of analysis (Mode variability) Broadcast.



In the "Memebership" tab, we indicate which base stations (not yet defined) belong to the selected system. We mark 1 and 2.

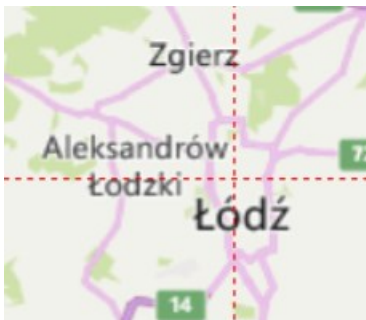


Very important parameters of the transmission system are defined in the Systems tab. They will include transmitter power (Transmit power), receiver sensitivity (Receiver threshold), default antenna height (Antenna height), antenna gain (Antenna gain). Initially enter the following values. For the FM system, we choose the default antenna height of 10m.

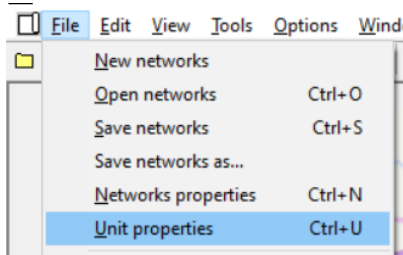


### 3. Simulation of base station coverage area

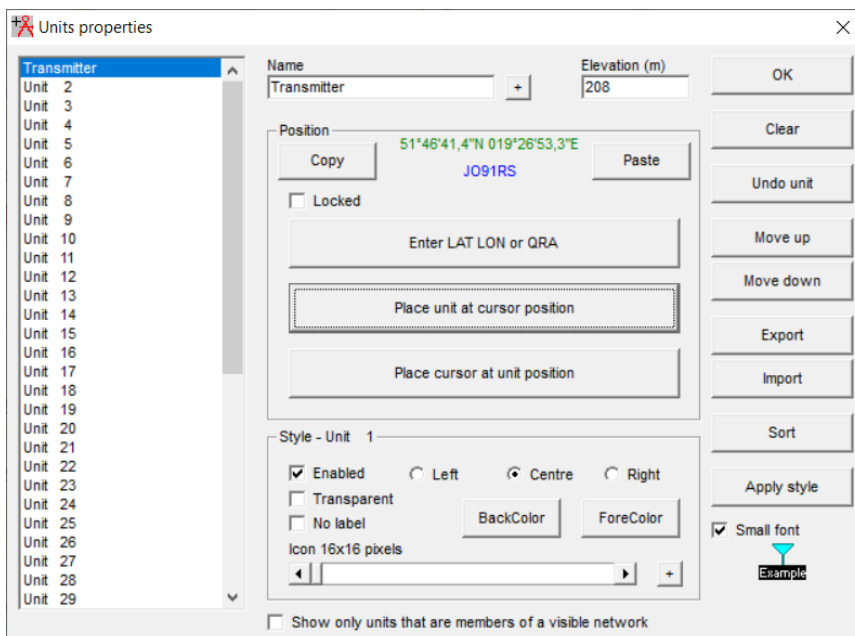
In the selected place on the map, where the base station is to be located, place the cursor and click the left mouse button. Initially, choose the city center.



Then from the File menu, select the "Unit properties" option:



In the "Units properties" window we define base stations and terminals. Select Unit 1 in the left panel and give it a name> Name> "Transmitter". Then press **"Place unit at cursor position"** and confirm with OK.



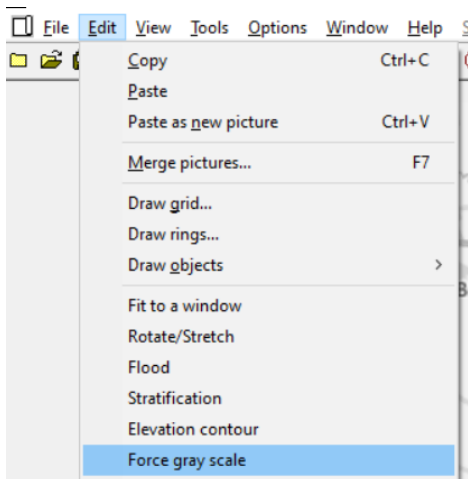
The transmitter was defined in this way.

Then place the cursor anywhere on the map, and define another object (Unit2) as described above, this time naming it Name> "Receiver".

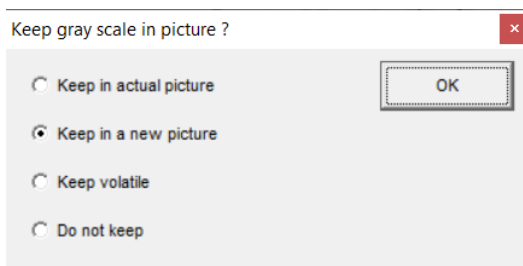
Before performing the simulation, we can convert the map to grayscale, which will facilitate



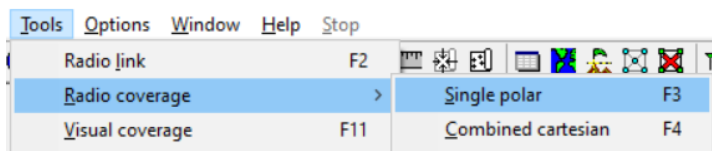
the analysis of simulation data. To do this, select > Force gray scale from the Edit menu:



Select the "Keep in a new picture" option. This will create a map on which we will be able to draw new simulation results every time.



We can simulate the range of a single transmitter by choosing Tools > Radio coverage > Single polar:



Select the station as the Center Unit, which we previously named Transmitter. To do this, select Center Unit > Transmitter from the list. Simulations will be performed for the receiver which is treated as a mobile terminal, which can be located in different places on the map. To do this, select from the list Mobile Unit > Receiver. Simulations will be carried out for each point around the transmitter within a radius from "Radial range" minimum = 0.01 km to Maximum = 50 km.

Data obtained from the simulation will be plotted only for the defined range of values that we can control. Programs for the radio systems design, display areas in which the electric field strength in  $\text{dB}\mu\text{V} / \text{m}$  (or received power  $\text{dBm}$ ) is not less than the minimum value ensuring the system operation. For FM systems, we select the range: Threshold >  $\text{dB}\mu\text{V} / \text{m}$  > from 54 to 74, because the minimum field strength value that will determine the range of the system is  $54 \text{ dB}\mu\text{V} / \text{m}$ .

Select Plot > Fill Area, Solid, Rainbow to draw a map that codes the field strength with colors.

**Single polar Radio coverage**

☒ Centre unit: Transmitter  
 Mobile unit: Receiver  
 Network: FM Broadcast

Link Direction:  
☒ Centre Tx - Mobile Rx  
☐ Centre Rx - Mobile Tx  
☐ Worst case

Radial range (km):  
 Minimum: 0,01 Maximum: 50

Plot:  
☐ Contour line  
☒ Fill area  
☒ Solid  
☐ Network style  
☒ Rainbow  
☐ Blur  
☐ Complete .wav

Threshold:  
☐ S-Unit  
☐ dBm  
☐  $\mu$ V  
☒ dB $\mu$ V/m  
☐ Auto set  
 From: 54 To: 74

Antenna pattern:  
☒ Use network antenna settings  
 omni.ant  
☐ Draw background  
☒ Small  
☐ Draw

☐ Save coverage data (TXT)

Buttons: Draw, Cancel, View pattern

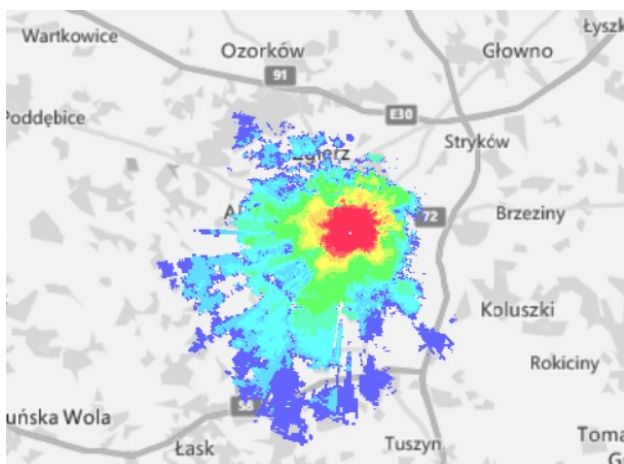
It is convenient to plot the simulation result as a new picture (Keep in a new picture). You can then easily compare the results obtained for different system variants.

Keep coverage in picture ?

☐ Keep in actual picture  
☒ Keep in a new picture  
☐ Keep volatile  
☐ Do not keep

OK

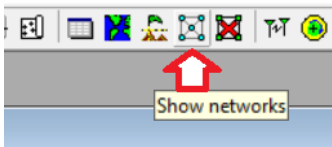
A fragment of the created new map with the range looks like this:



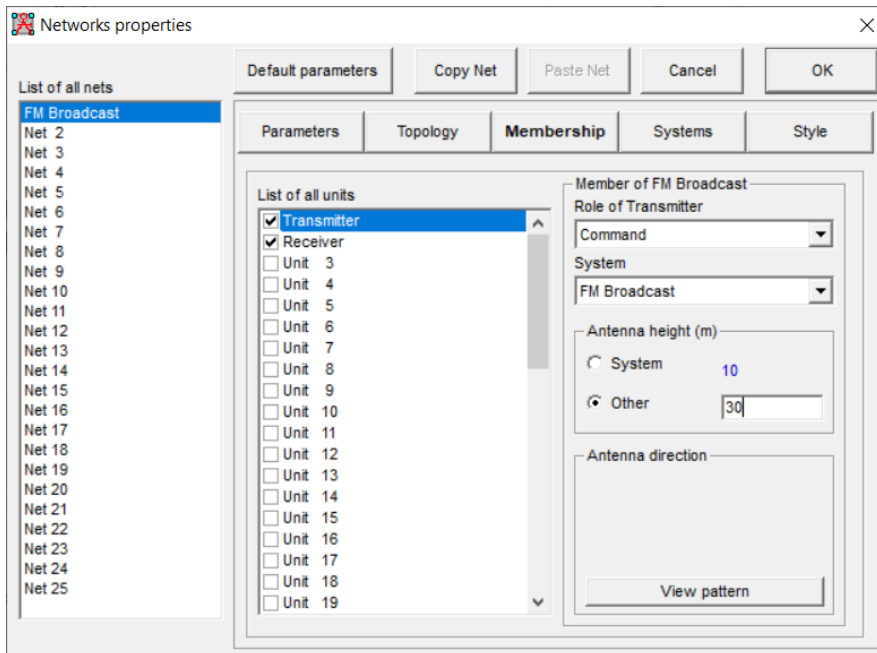
The colors on this map indicate the coverage of the transmitter, i.e. the areas in which it will be possible to receive a signal from the transmitter (the strength of the electric field is greater than the minimum required for reception, as shown in Table 1).

To simulate the transmitter coverage area with the modified parameters, return to the gray

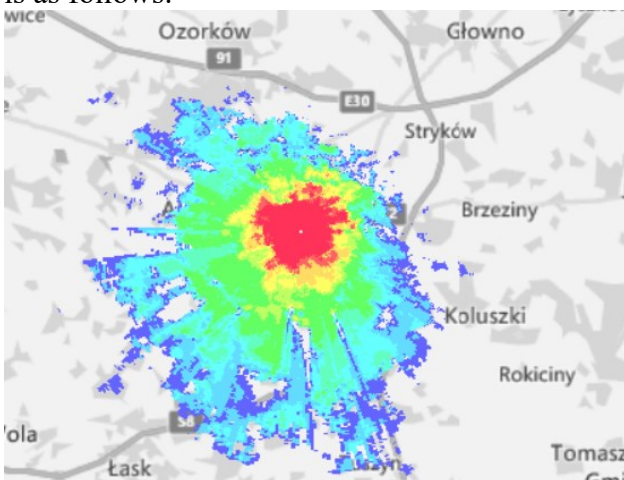
scale map window. The location of the station can be displayed on it using the "Show networks" button:



To simulate a transmitter coverage with modified parameters, make changes in the File> Network properties menu. To change the height of the antenna, select in the Membership> Transmitter tab and change Antenna Height from "System" to "Other" and enter the value 30.



Then select the previously created map showing roads and cities in grayscale. The simulation is carried out by choosing Tools> Radio coverage> Single polar, as described above. The coverage area of the transmitter with the antenna elevated 30 m above the ground is as follows:



#### 4. Analysis of factors influencing the base station coverage (tasks for self-study)

##### a. Testing the transmitter parameters influence on the system coverage

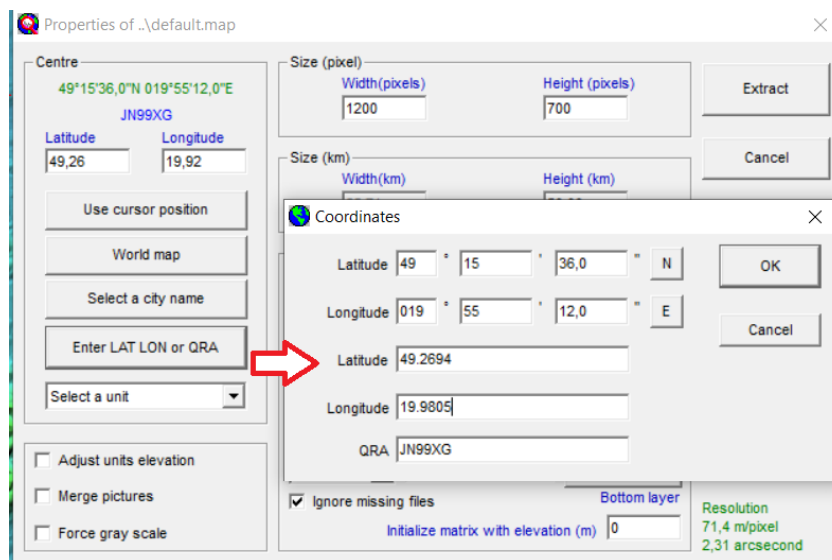
The influence of each transmitter parameter on its coverage should be investigated. Investigate the following parameters:

- Transmitter power - (File menu> Networks properties> Systems tab)
  - Antenna gain - (File menu> Networks properties> Systems tab)
  - Antenna height (File menu> Networks properties> Membership tab)
- Select Other and enter the height in m for the selected transmitter.

The report should include simulation results illustrating the dependence of the transmitter coverage area on the above parameters.

##### b. Investigating the influence of terrain profile on the transmitter's coverage.

A new project should be created with a map in which Zakopane city is located in the center (e.g. entrance point to the blue tourist trail 49.2694, 19.9805). In the "Map Properties" window, enter the coordinates of the map center. The map height should be 50 km.



The map will include mountain areas. Place the base station at the foot of the selected mountain, another on its slope and another on the top. Next, compare the coverage of such located transmitters by simulating the coverages of each transmitter separately, for different antenna heights.

##### c. Investigating the impact of urban buildings on the transmitter's coverage

Further simulations should be carried out using the map on which the large city located on the flat terrain (with its surroundings) is located. The choice of the city is free (it can be your capital city, for example). The suggested map height is 100 km. Place the base station in the suburb area, the next in the city center and the next one outside the city on the map prepared in this way.

For transmitters in the city area, use the appropriate minimum field strength values in accordance with Table 1 (Tools> Radio coverage> Single polar> Threshold> dB $\mu$ V / m).

Next, compare the coverage areas of such located transmitters by simulating the

coverages of each transmitter separately, for different antenna suspension heights.

The report should include the necessary simulation results, on the basis of which it should be determined how the factors described in points a-c affect the coverage areas of the wireless system.