Lodz University of Technology

Institute of Electronics

Instruction for Laboratory classes on Wireless Communications

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Exercise 2. Antennas in wireless communication systems

The aim of this exercise is to:

- learn about the influence of the antenna parameters on the wireless link coverage,
- learn how to define antenna radiation pattern in Radio Mobile software.

1. References:

1. Gordon L. Stüber, "Principles of Mobile Communication", Second Edition, Kluwer Academic Publishers, 2002
2. Sophocles J. Orfanidis, "Electromagnetic Waves and Antennas", Rutgers University, 2016
3. Peter Scholz, "Basic Antenna Principles for Mobile Communications", KATHREIN-Werke KG, 2001

2. The scope of the exercise.

In this exercise you will learn on the influence of antenna parameters on base station (BTS) coverage.

Antenna is that part of a transmitting or receiving system that is designed to radiate or to receive electromagnetic waves. Simply, you may say that an antenna is the transducer that converts high frequency currents to the electromagnetic waves (transmitting mode) and electromagnetic wave to currents (receiving mode). This concept is shown in Fig.1.

The gain of the antenna is the ratio of the radiation intensity in a given direction to the radiation intensity that would be produced if the power would be isotopically (i.e. evenly in all directions) radiated. If the antenna gain is given as the single number it is then the maximum gain over all the angles around the antenna.

The radiation pattern of the antenna is the spatial distribution of a quantity that characterizes the electromagnetic field. In telecommunication systems radiation pattern

presents the variation of antenna gain for different angles around the antenna. Although Radiation pattern characterize the antenna radiation in all directions, it is usually presented in horizontal and vertical planes.

The directional antenna is an antenna having the property of radiating or receiving electromagnetic waves more effectively in some direction than others. Its radiation pattern is presented in Fig. 2. In contrast, omnidirectional antenna has an essentially non-directional pattern in a given plane of the antenna and a directional pattern in any orthogonal plane. The radiation pattern of omnidirectional is shown in Fig.3.

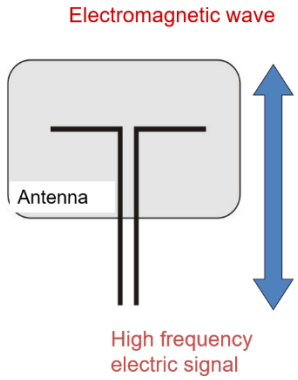
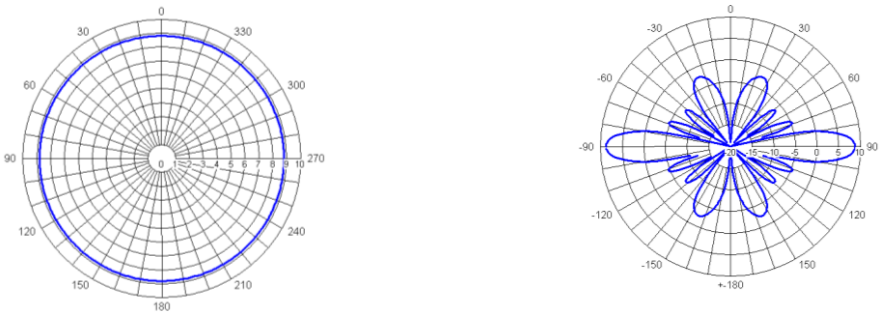


Fig.1 The antenna as the transducer of currents to the electromagnetic waves.

Horizontal *Vertical*

Fig.2 Radiation pattern of directional antenna.



Horizontal *Vertical*

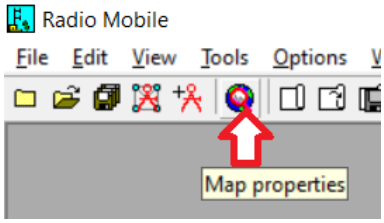
Fig.3 Radiation pattern of omnidirectional antenna.

In this exercise you will analyze how the radiation pattern and the gain of the antenna influences the coverage of base transmitting station. The antenna down-tilt (that is the tilt of antenna in vertical plane) will be also presented.

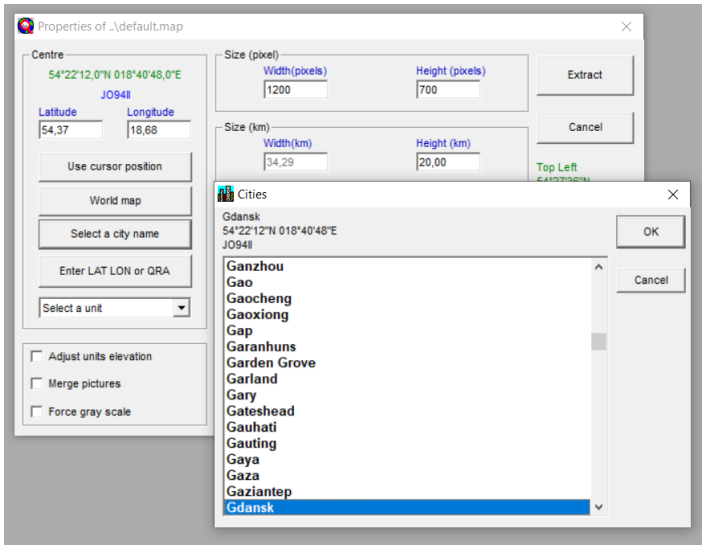
3. The course of the exercise

3.1. Map configuration in Radio Mobile

Click the "Map Properties" button:

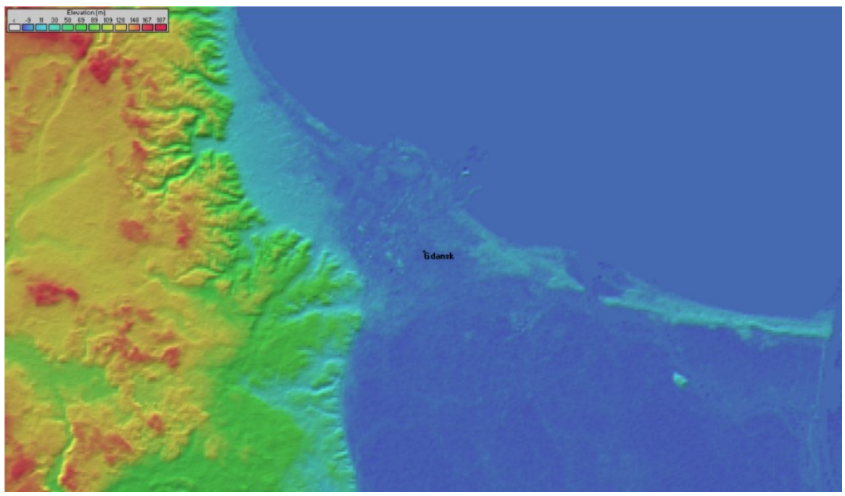


Then choose the city of Gdansk, around which the analysis will be carried out. The list of cities is available after pressing the "Select a city name" button. Then enter "Gd" and select Gdansk from the list.



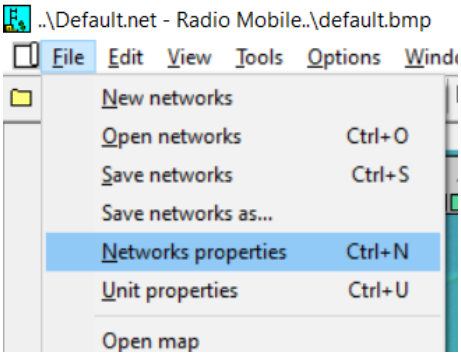
The size of the map in pixels (Size (pixel)) is set to Width = 1200, Height = 700 pixels. The map area defined in pixels can be assigned to the appropriate terrain area. We set the size of the analyzed area vertically on the map at 20 km (Size> Height> 20 km). Then press the "Extract" button.

A map showing the height of the land above sea level will be presented, with some areas located at sea (constant height 0 m a.s.l.) and on the land.

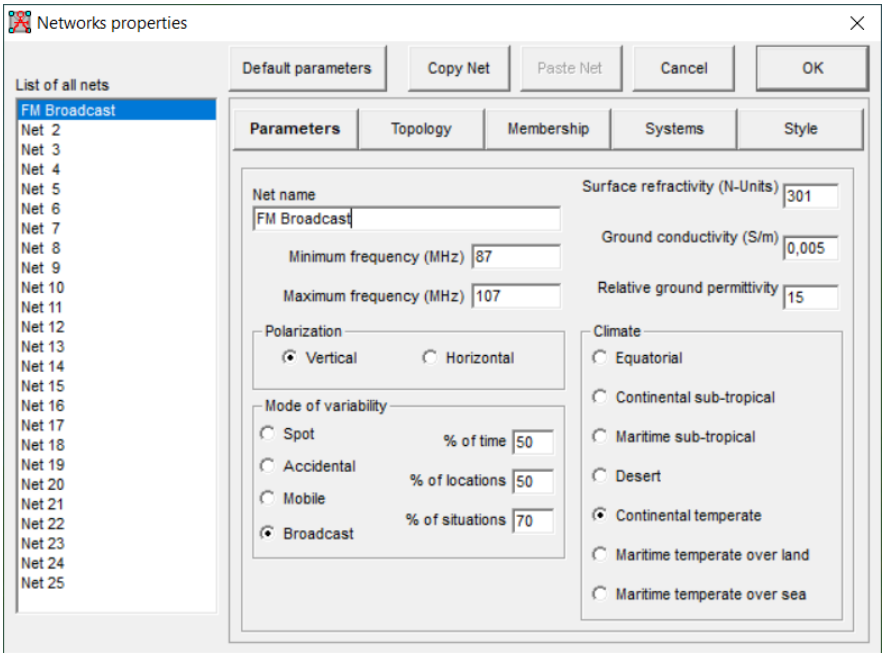


3.2.Transmission system configuration

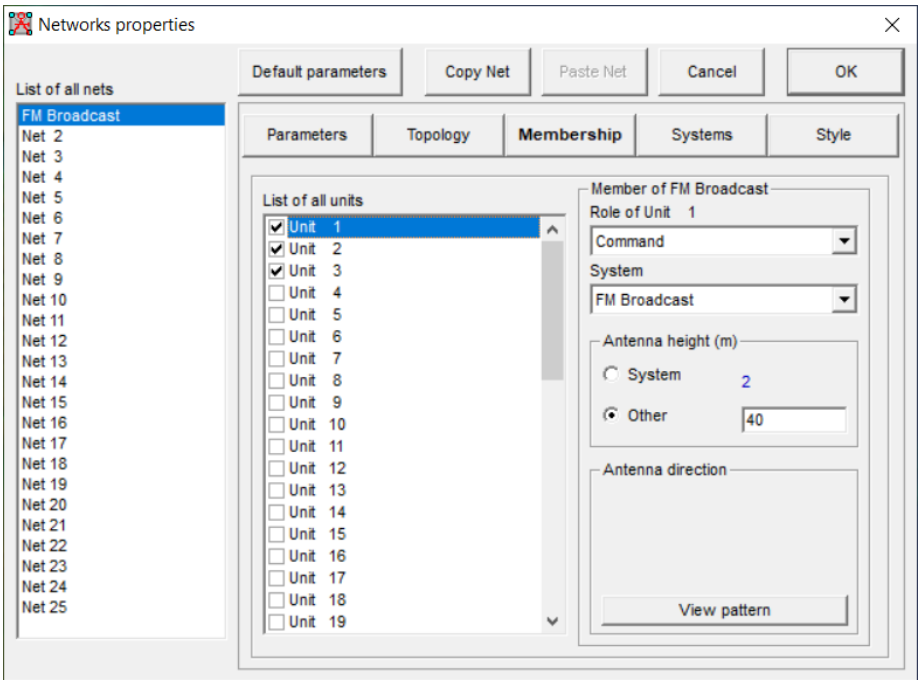
Transmission system parameters should be configured in the File> Networks properties menu:



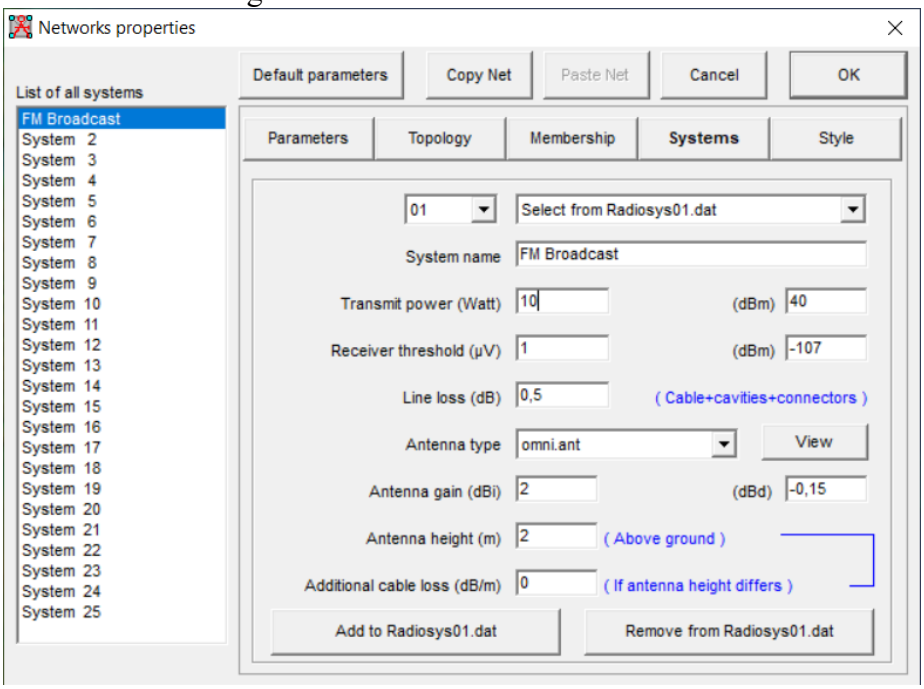
Then, in the "Network Properties" window, select the Net 1 network name in the left panel and define its parameters, as shown in the window below. The network name is defined as (Net name): FM Broadcast, Frequency range 87 - 107 MHz, type of analysis (Mode variability) Broadcast.



In the "Memebership" tab, mark which base stations (not defined yet) belong to the selected system. We mark 1, 2 and 3.
"Unit 1" and "Unit 2" will act as transmitters, whose antennas will be located 40 m above the ground (option> "antenna height"> "Other" 40m). The "Unit 3" terminal will have the function of a mobile terminal. In his case, select "Antenna height"> System.



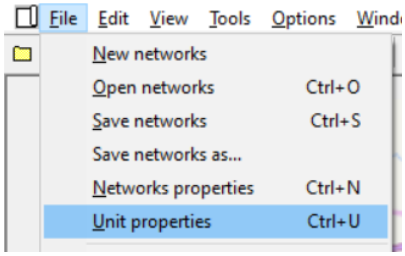
In the Systems tab, enter the following values. For the FM system, we choose the default antenna height of 2m.



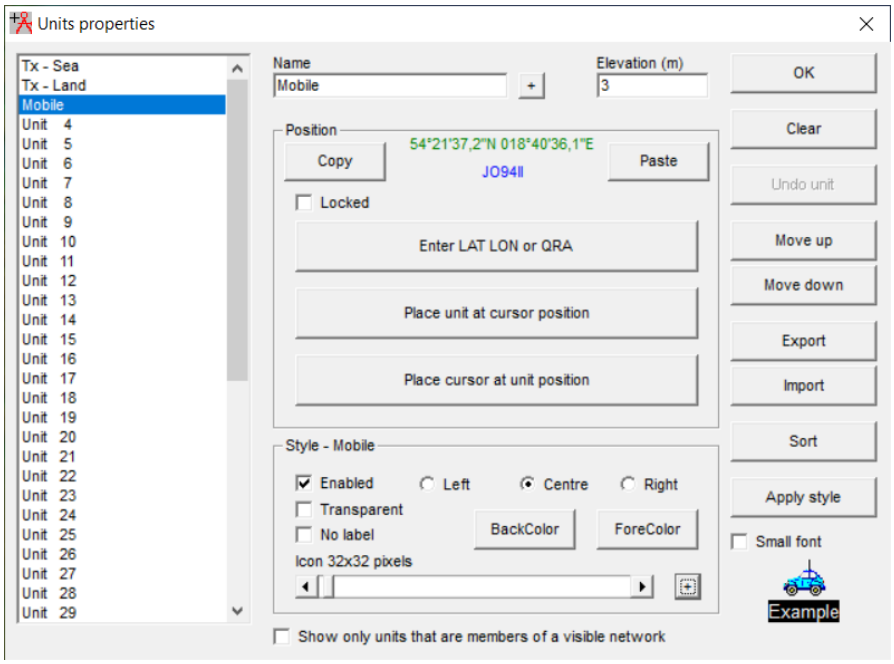
3.3.Simulation of base station coverage

Two transmitters will be used to analyze the impact of the antenna radiation pattern on the transmitter coverage. One will be placed at the sea so its coverage is not affected by the terrain, and the other will be placed on the land. In the selected place on the map where the base station is to be located, place the cursor and click the left mouse button. Choose the center of the water region for the first transmitter (Unit 1) and any point on the land for the second transmitter (Unit 2).

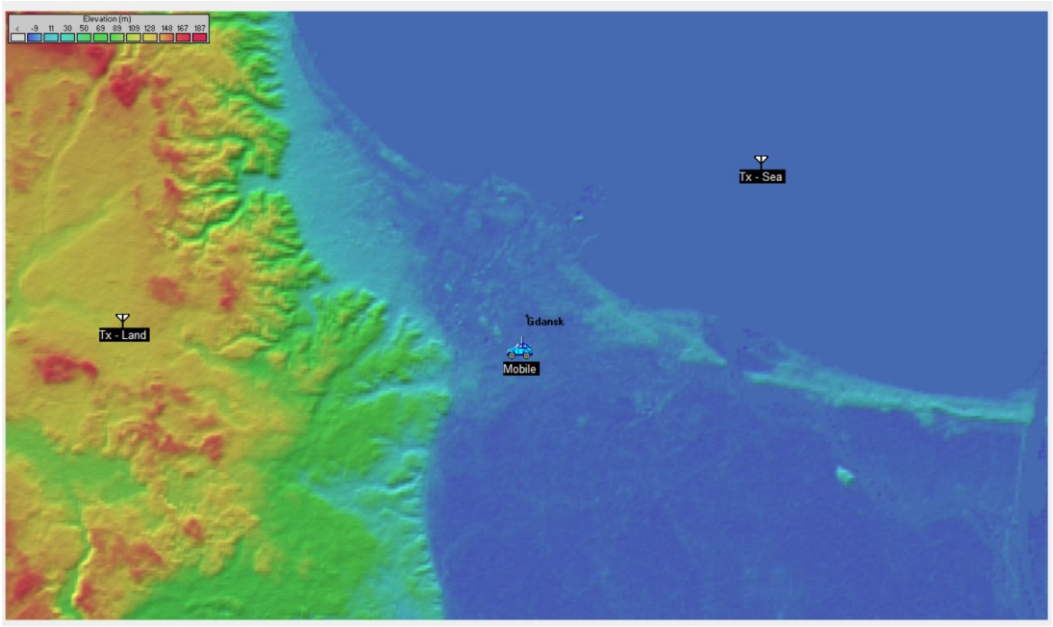
From the File menu choose the option Unit properties



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



Similarly, we configure the transmitter on land (Tx - Land) and the mobile terminal (Mobile).

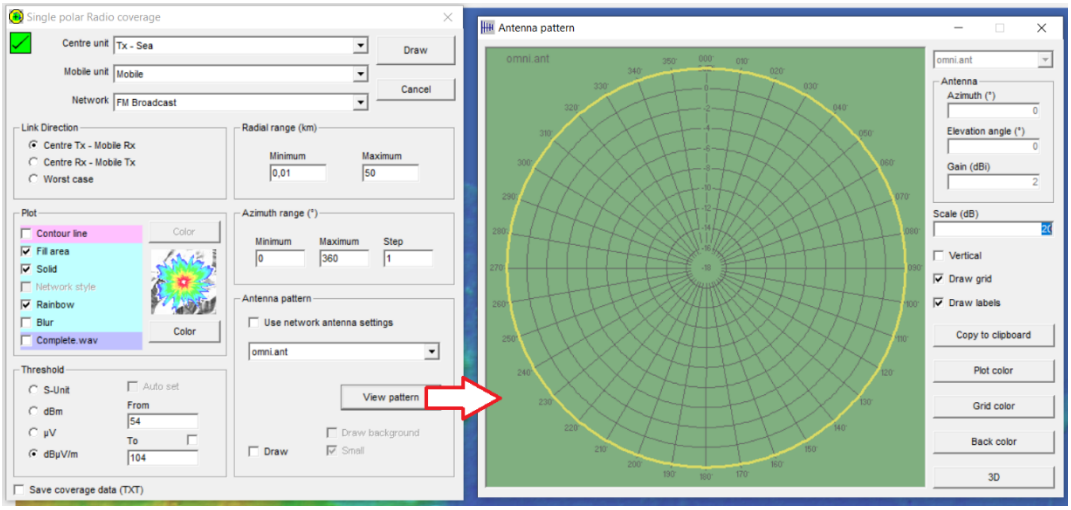


3.4.Simulation of coverage of stations equipped with omnidirectional antennas

In the menu: Tools> Radio coverage select Single polar. Using this menu, we will simulate the coverage of a transmitter set up on land and at sea, equipped with an omnidirectional antenna.

In the "Single Polar radio coverage" window, select "Center Unit" as "TX Sea". The "Threshold" parameter is set in dBµV / m from 54 to 104.

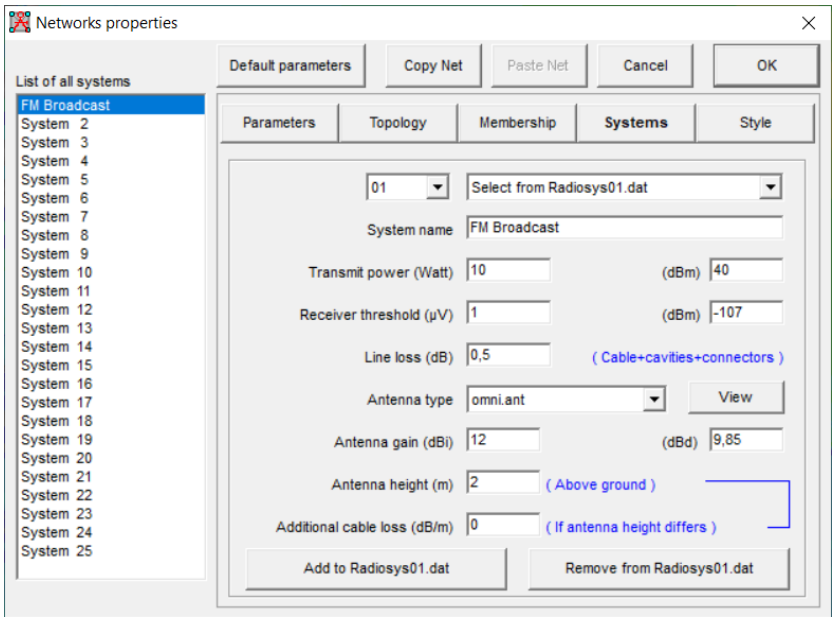
For this transmitter, we can choose the type of antenna used if the "Use network antenna settings" option is not selected. We choose the omnidirectional antenna from the "omni.ant" file. Then press the "View pattern" button to see the graphs of the antenna radiation pattern in the "Antenna pattern" window.



After approving the omnidirectional antenna, we simulate the coverage of the transmitter. Repeat the simulation for a transmitter located on land equipped with an analogue antenna. The report should include the results of both simulations.

3.5. Simulation of coverage of stations with omnidirectional antennas and different gain values

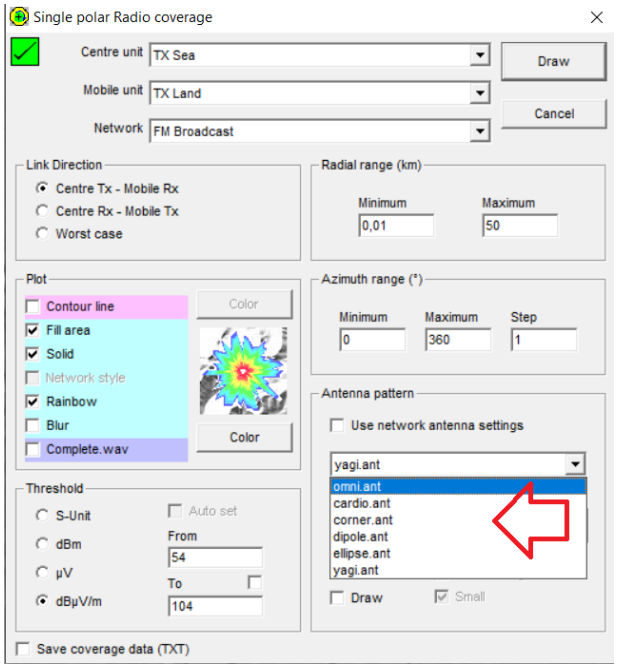
Repeat the simulations from step 3.4 using omnidirectional antennas with different values of antenna gain. Antenna gain value is set in the network properties window:



Simulations should be carried out for antennas at sea and on land for a gain value of 0, 5, 15 dBi.
The report should include the coverages of base stations equipped with antennas with different gain values.

3.6.Simulation of the coverage of a station equipped with a directional antenna

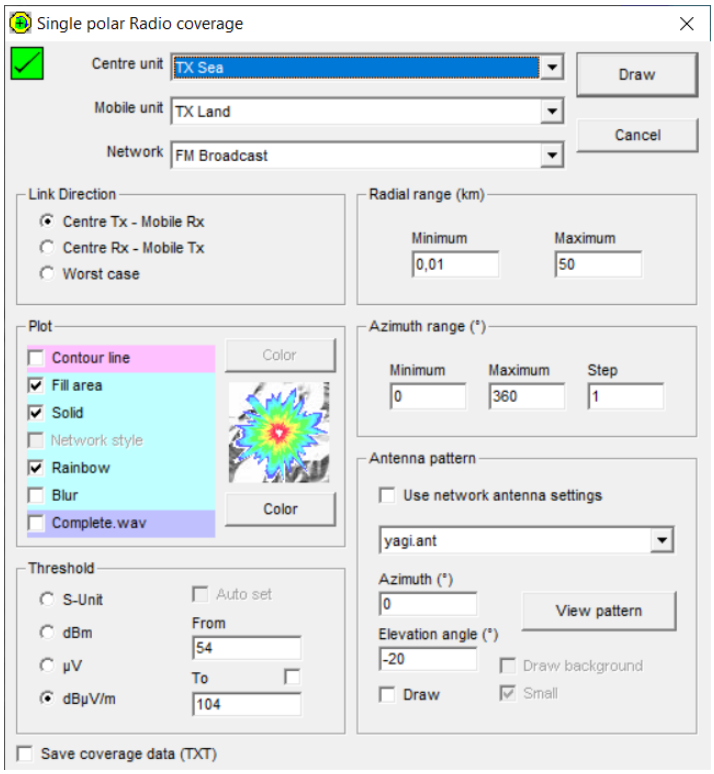
Repeat the simulations from step 3.4 using antennas with different radiation patterns. Test all antennas available in the drop-down list in the "Single polar Radio coverage" window:



The report should include for each antenna a graph of radiation pattern and the coverage of base stations equipped with this antenna (stations at sea and on land).

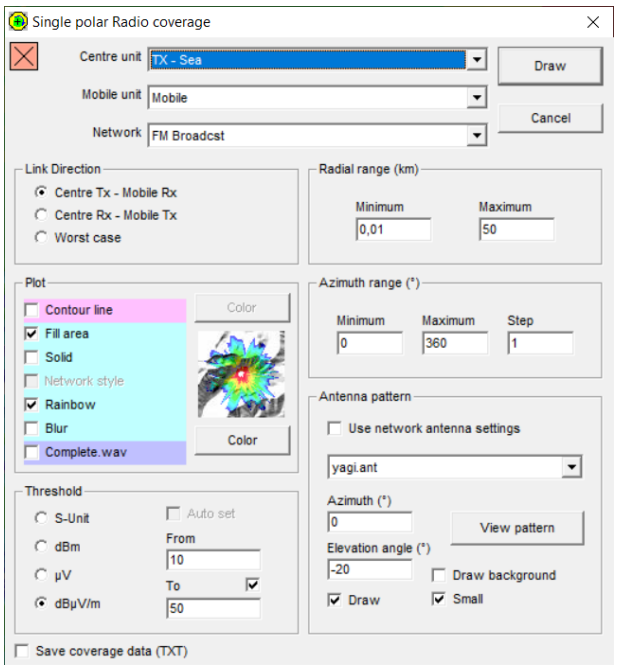
3.7.**Simulation of base station coverage with antenna down-tilt**

A coverage of base station should be simulated with a yagi antenna that has a down-tilt of 20° and without down-tilt. The main beam angle (down-tilt) is controlled by the "elevation angle" parameter in the "Single polar Radio coverage" window. We set negative values for down-tilt.



Then simulate the Yagi antenna facing east (Azimuth = 90°) and west (Azimuth = 270°).
The report should include relevant results.

Make another simulation, to analyze the radiation in the back direction, with and without the down-tilt. Adjust the threshold values to see the differences in the back radiation:



Summarizing the report, please describe how the radiation characteristics and the gain of the base station antenna affect its coverage.