



# *Private Mobile Radio Network Planning*

## *Laboratory Guide*

### **Previous preparation**

- Read description of [Radio Mobile](#) application.
- Read this guide carefully.

### **Objectives**

Students will plan a simple Private Mobile Radio Network using Radio Mobile application. The network is assumed to be located in the north of Portugal, along the Douro River, providing communications in the 170 MHz band with 20 W transmitters. Initially, only three sites constitute the fixed network, but it is recognized that these sites result into insufficient coverage for mobiles. Students should then find suitable locations for two additional sites, to obtain adequate coverage of the area.

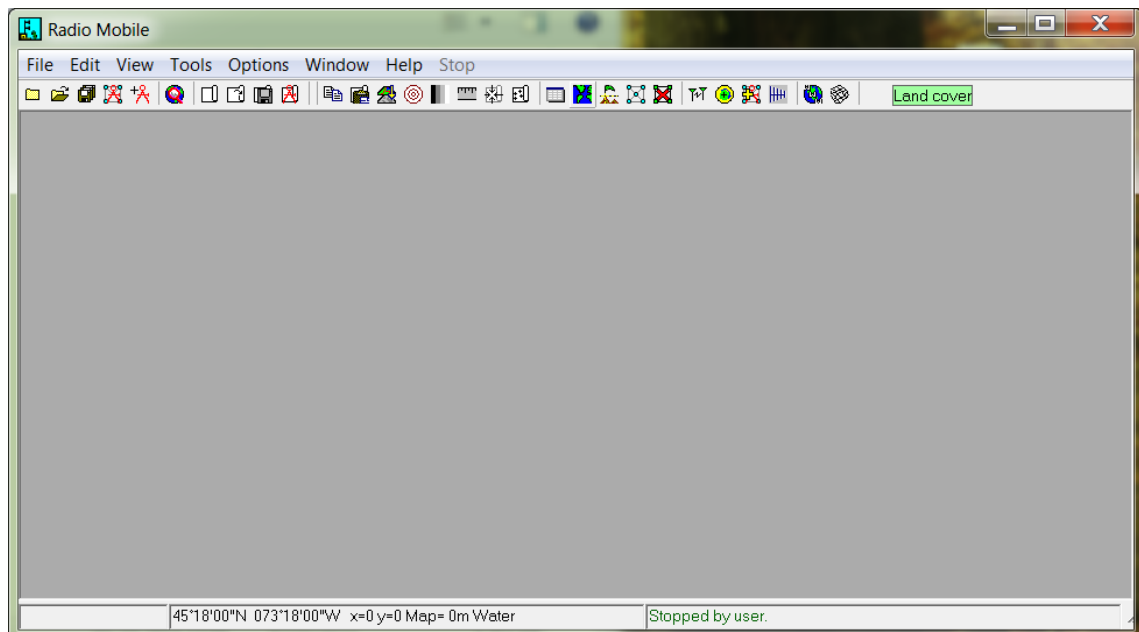
The Radio Mobile application is a tool used to predict the performance of a radio system. It uses digital terrain elevation data for automatic extraction of path profile between an emitter and a receiver. This data is added to system considering environmental and statistical parameters to feed the Irregular Terrain Model (ITS) radio propagation model. The ITS model of radio propagation for frequencies between 20 MHz and 20 GHz (the Longley-Rice model) is a general purpose model that can be applied to a large variety of engineering problems. The model, which is based on electromagnetic theory and on statistical analyses of both terrain features and radio measurements, predicts the median attenuation of a radio signal as a function of distance and the variability of the signal in time and in space. Elevation data is also used to produce altimetry maps in background, which can be merged with other maps from various sources, adding populated places, roads and other geographical features to facilitate location in the area.

This laboratory work will consist of 3 major steps: a) setup and initial radio network; b) analyse coverage of initial network; c) improve the coverage of the radio network. At the end, students have to produce a focused report and submit it via moodle.



### Step A – Setup initial network

1. Install in your PC the Radio Mobile application. If you download the software from moodle you should uncompress the file *rm-software.7z*. If you download from the Radio Mobile site you should follow the site instructions. You may, in alternative, use the Radio Mobile application installed in the laboratory.
2. Open the application by selecting the file *rmweng.exe*. You should obtain the following window

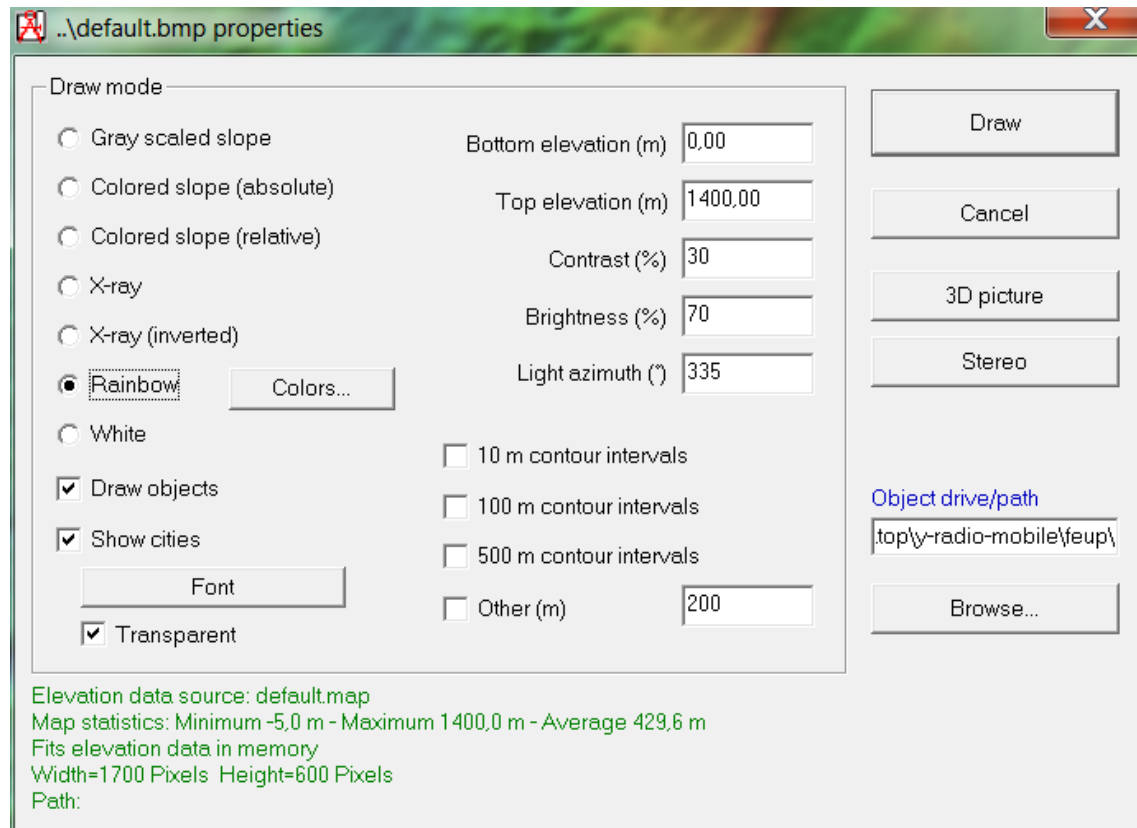


3. Define the map properties for the region of Douro Valley (“File” + “Map Properties”): centre point, size of picture (in pixels), size of map (in km).

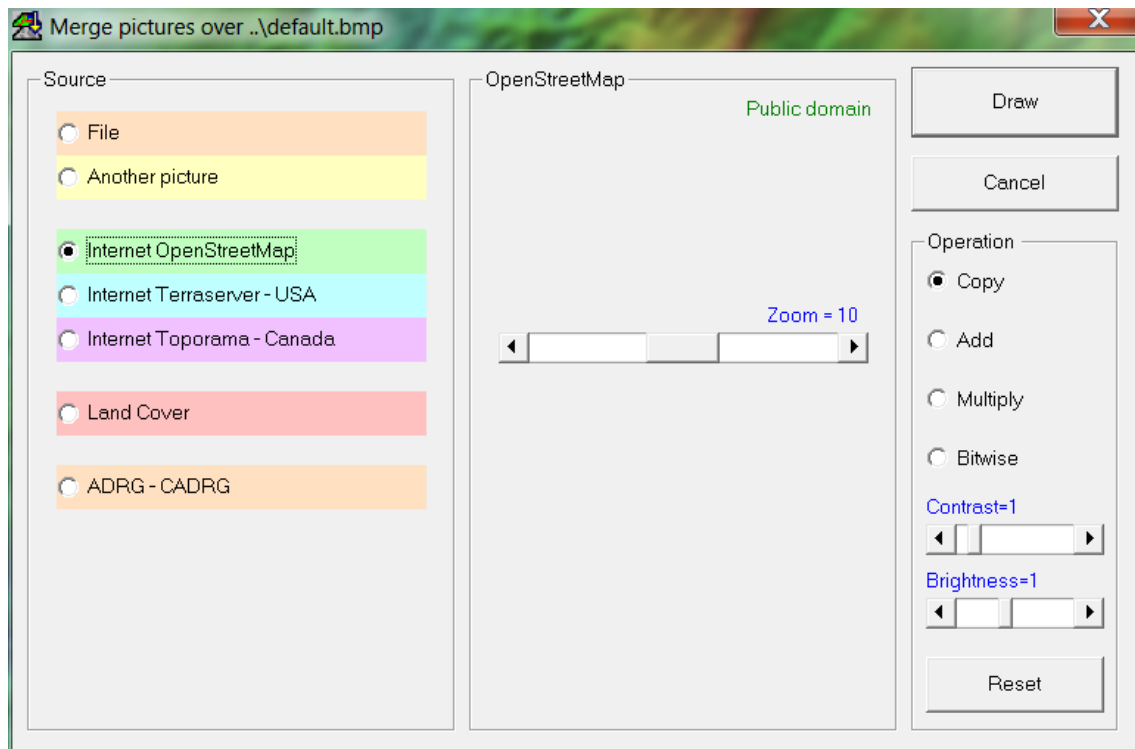




4. Define picture properties ("File" + "Picture Properties"). This option allows to show altimetry data



5. Insert geographic references in the picture. "Edit" + "Merge pictures" and then "Keep in a new picture": this step allows to show populated places and roads to facilitate location of sites. After clicking in "Draw" you will have multiple inter-related pictures.



6. Enter units properties (“File” + “Unit Properties”)

- Mobile Terminal: input the name but no location (this will be a running unit used for coverage analysis).
- Monte da Virgem: LAT=41,11313; LON= -8,59838
- Sardoura: LAT=41,04918; LON= -8,311708
- Resende: LAT= 41,1341; LON= -7,980184



**Units properties**

Mobile Terminal

MonteVirgem VHF  
Sardoura VHF  
Resende VHF

Name: Mobile Terminal Elevation (m): 0

Position: 41°08'52.6"N 008°39'57.7"W IN51QD

Copy Paste

☐ Locked

Enter LAT LON or QRA

Place unit at cursor position

Place cursor at unit position

Style

☒ Enabled ☐ Left ☒ Centre ☐ Right

☐ Transparent

☐ No label

BackColor ForeColor

Icon 16x16 pixels

☒ Small font

Example

☐ Show only units that are members of a visible network

OK Clear Undo unit Move up Move down Export Import Sort Apply style

7. Define network properties ("File" + "Network Properties") - network basic parameters

**Networks properties**

List of all nets

VHF Network

Net 3  
Net 4  
Net 5  
Net 6  
Net 7  
Net 8  
Net 9  
Net 10  
Net 11  
Net 12  
Net 13  
Net 14  
Net 15  
Net 16  
Net 17  
Net 18  
Net 19  
Net 20  
Net 21  
Net 22  
Net 23  
Net 24  
Net 25  
Net 26  
Net 27  
Net 28  
Net 29

Default parameters Copy Net Paste Net Cancel OK

Parameters Topology Membership Systems Style

Net name: VHF Network

Minimum frequency (MHz): 155

Maximum frequency (MHz): 159

Polarization: ☒ Vertical ☐ Horizontal

Mode of variability: ☐ Spot ☐ Accidental ☐ Mobile ☒ Broadcast

% of time: 50

% of locations: 50

% of situations: 70

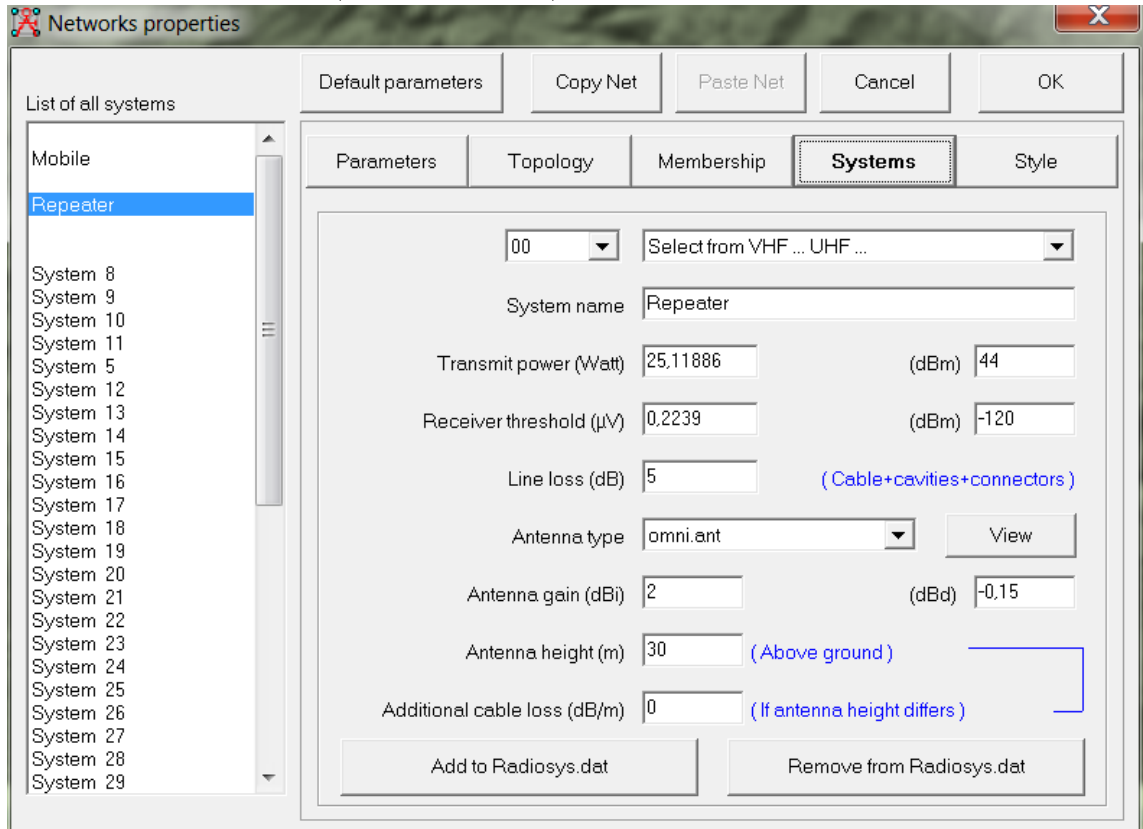
Surface refractivity (N-Units): 301

Ground conductivity (S/m): 0.005

Relative ground permittivity: 15

Climate: ☐ Equatorial ☐ Continental sub-tropical ☐ Maritime sub-tropical ☐ Desert ☐ Continental temperate ☒ Maritime temperate over land ☐ Maritime temperate over sea

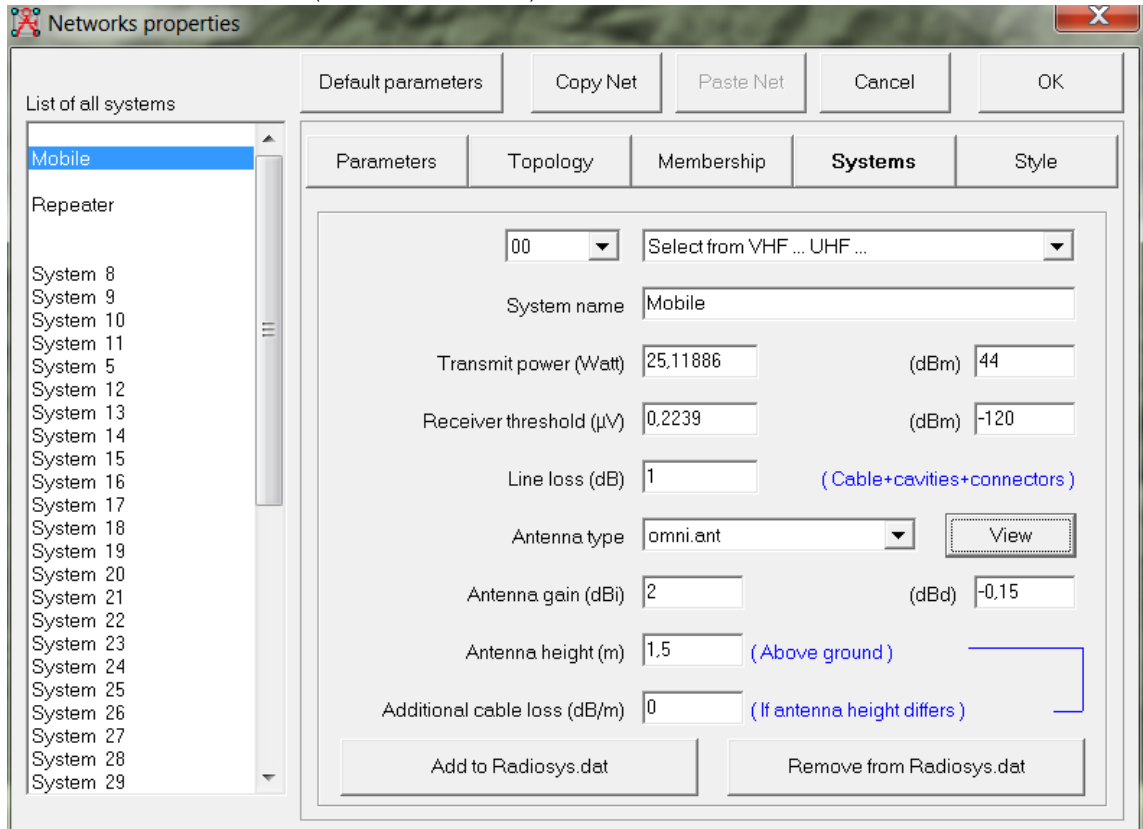
- Repeater parameters (under “Systems”)



The screenshot shows the 'Networks properties' dialog box with the 'Systems' tab selected. The 'List of all systems' on the left includes 'Mobile' and 'Repeater'. The 'Repeater' system is selected, and its parameters are displayed on the right:

- Channel: 00 (dropdown)
- Frequency: Select from VHF ... UHF ... (dropdown)
- System name: Repeater (text field)
- Transmit power (Watt): 25.11886 (text field) (dBm): 44 (text field)
- Receiver threshold ( $\mu$ V): 0.2239 (text field) (dBm): -120 (text field)
- Line loss (dB): 5 (text field) (Cable+cavities+connectors)
- Antenna type: omni.ant (dropdown) (View button)
- Antenna gain (dBi): 2 (text field) (dBd): -0.15 (text field)
- Antenna height (m): 30 (text field) (Above ground)
- Additional cable loss (dB/m): 0 (text field) (If antenna height differs)
- Buttons: Add to Radiosys.dat, Remove from Radiosys.dat

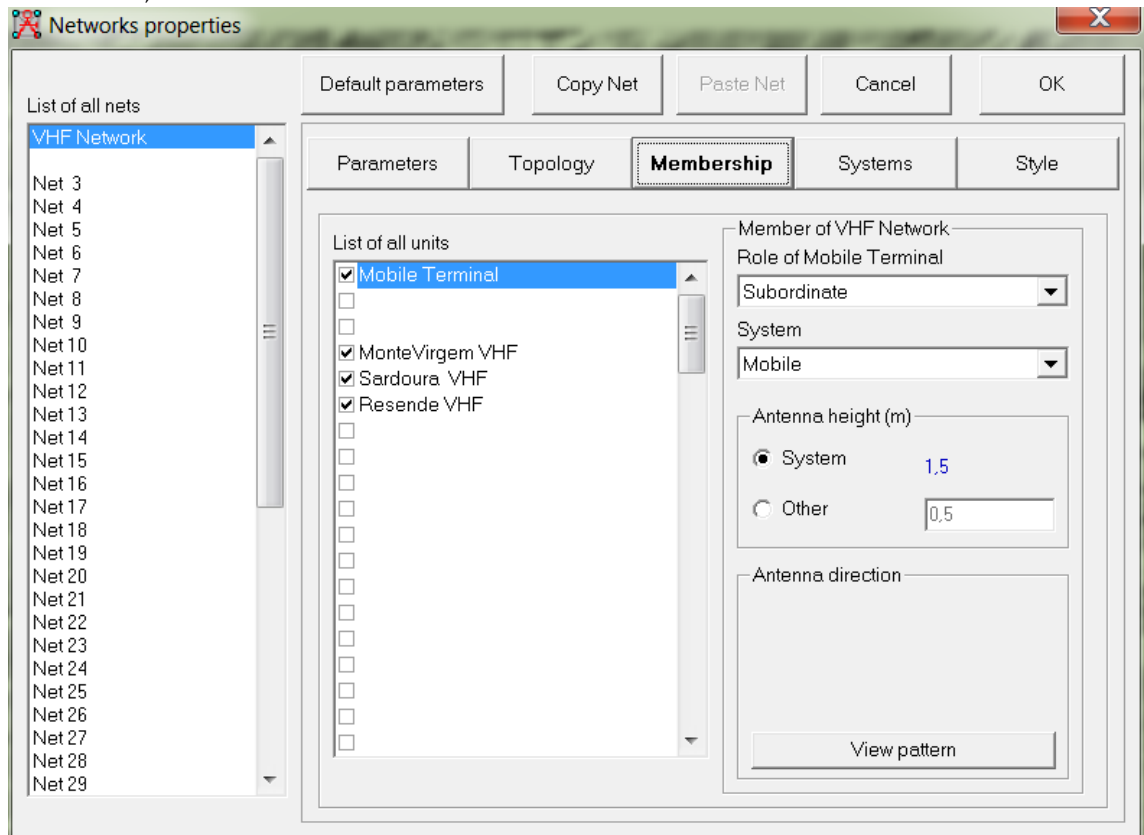
- Mobile parameters (under “Systems”)



The screenshot shows the 'Networks properties' dialog box with the 'Systems' tab selected. The 'List of all systems' on the left includes 'Mobile' and 'Repeater'. The 'Mobile' system is selected, and its parameters are displayed on the right:

- Channel: 00 (dropdown)
- Frequency: Select from VHF ... UHF ... (dropdown)
- System name: Mobile (text field)
- Transmit power (Watt): 25.11886 (text field) (dBm): 44 (text field)
- Receiver threshold ( $\mu$ V): 0.2239 (text field) (dBm): -120 (text field)
- Line loss (dB): 1 (text field) (Cable+cavities+connectors)
- Antenna type: omni.ant (dropdown) (View button)
- Antenna gain (dBi): 2 (text field) (dBd): -0.15 (text field)
- Antenna height (m): 1.5 (text field) (Above ground)
- Additional cable loss (dB/m): 0 (text field) (If antenna height differs)
- Buttons: Add to Radiosys.dat, Remove from Radiosys.dat

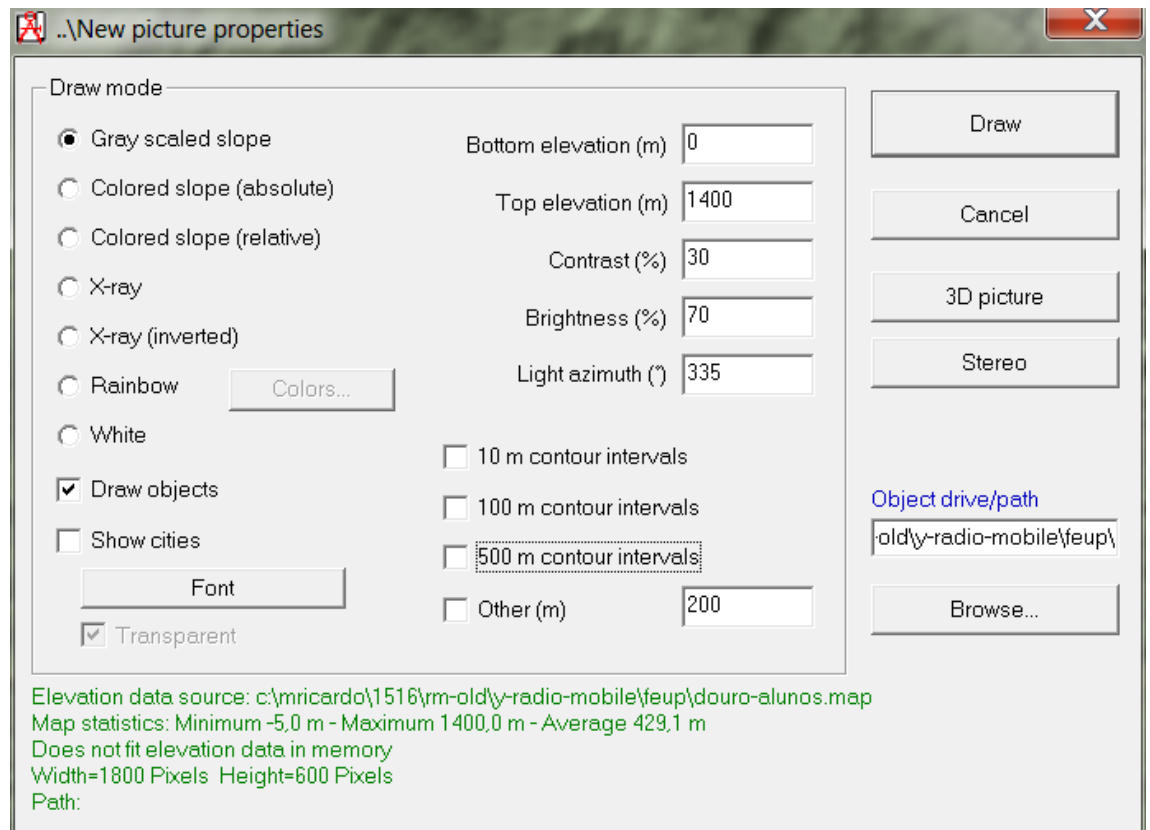
- membership (units vs. role+systems: mobile terminal is subordinate and belongs to Mobile system; other units are command and belong to Repeater system)



### Step B – Analyse coverage of initial network

#### 8. Define new picture properties (“File” + “New Picture”)

- this new picture uses a grey scaled slope to obtain suitable coverage maps
- this option may be used without additional geographic references, since visible slopes provide information about elevation



9. Insert geographic references in the picture, as before

- "Edit" + "Merge pictures" and then "Keep in actual picture" to preserve the geographic references in the subsequent coverage analysis

10. Obtain the radio coverage of the three sites

- "Tools"+"Radio coverage"+"Combined cartesian" and then and then "Keep in a new picture"+"Save coverage data": this step allows to obtain a single map with best received signal for each point
- areas with no coverage are shown without any colour, i.e., left in grey scale as in the original picture
- draw size specifies detail of the coverage, from 1 pixel to a few pixels (say 5) depending on the processing power of your computer and in the phase of your analysis (initial viewing may be low resolution, say 10, but the final coverage map should have the highest possible resolution allowed by your computer)



#### 11. Derive the cumulative distribution of radio coverage levels

- consider the range value appearing in the coverage data file as  $10 \cdot \log_{10}(P_r/P_{\min})$  where  $P_{\min}$  is -120 dBm defined in the window above (below "From ( $\geq$ )"), which is the same as the receiver sensitivity. That is, if in the coverage file appears a  $R_x$  (dB) value equal to 44 dB, that means that in the current point the power received was in fact  $-120 \text{ dBm} + 44 \text{ dB} = -76 \text{ dBm}$ .
- write a small program to read the file and obtain the cumulative coverage distribution, considering the following intervals relative to the minimum receiver sensitivity (-120 dBm):  $<0 <10 <20 <30 <40 <50 <60$
- define the percentage of values  $P_r < -120 \text{ dBm}$  ( $R_x < 0 \text{ dB}$ ), in the coverage file, as the percentage of area without coverage
- define the percentage of values  $P < -110 \text{ dBm}$  ( $R_x < 10 \text{ dB}$ ) as the percentage of area below good coverage (10 dB margin relative to minimum receiver sensitivity)

#### Step C – Setup initial network

12. Find the location of a) one and b) two extra sites to obtain an improved coverage, i.e., minimize the area without coverage (or below good coverage) calculated as before. For this step, use the application in "What-if" mode (Tentativa-erro),

analysing the effect of each site located in a suitable elevation (to speed up the process, you may use less resolution when testing alternatives). Obtain the cumulative distribution of radio coverage levels when each of the two sites is added individually and when both sites are added to the network.

### Report structure

Report should not exceed **three A4 pages in 10pt font**, including text, tables, figures, and the coverage maps. Coverage maps should be included right after the question they are related to. The CoverageData.txt files should not be added in the report: please upload them separately in one zipped file to the designated location in moodle.

### Questions

- 1) Based on the radio coverage results you obtained for the initial network with three sites (paragraphs 9 and 10), what are the percentages of:
  - a) Area without coverage  $Pr < -120$  dBm?
  - b) Area below good coverage  $Pr < -110$  dBm?
  - c) Which of the coverage intervals (in dB with respect to  $-120$ dBm:  $[0,10[$ ,  $[10,20[$ ,  $[20,30[$ ,  $[30,40[$ ,  $[40,50[$ ,  $[50,60[$ ,  $[60, \dots[$ ) defines the largest area? What is the percentage of the area that has coverage within that interval?
- 2) Find the best location and add one new site to the network (total of four sites). What is the location of the site? What is the new percentage of area below good coverage  $Pr < -110$  dBm? Please include the coverage map and the CoverageData.txt file.
- 3) Find the best location for two new sites to the network (total of five sites: note that both of the two new sites you created can be different from the new site you created in question 2). What is the location of the sites? What is the new percentage of area below good coverage  $Pr < -110$ dBm? Please include the coverage map and the CoverageData.txt file.
- 4) By setting the “Draw size” resolution to 5 pixels (“Tools”+“Radio coverage”+“Combined cartesian”), there are a set of distinct locations evaluated for coverage within the map. The CoverageData.txt log file (text file you get when you perform radio coverage test) has a distinct column named “Best unit” which determines the site (base station) which gives the best coverage for a given location. Once you determine the best position for the two new sites (question 3), parse the CoverageData.txt and determine:
  - a) How many locations have the newly added sites (either of the two new sites) as the “Best unit”?



- b) Calculate the number of locations that are assigned to each new site (i.e., number of locations that have NewSite1 as “Best unit” and number of locations that have NewSite2 as “Best unit”. In your opinion, is it better if the new sites you created have approximately the same number of locations or not? Explain.
- 5) Explain briefly the method you used for deciding where to locate the two new sites (i.e., point out the most important factors in determining the location of new sites).
- 6) Discuss briefly how Radio Mobile program could be used to evaluate the carrier to interference ratios between two sites operating at the same frequency.