



Plánovanie mobilných rádiových sietí

KIS FRI UNIZA



Vytvorené v rámci projektu **KEGA 026TUKE-4/2021**

Agenda

- Inštalácia programu
- Vytvorenie podkladovej mapy s výškovým profilom
- Konfigurácia bezdrôtovej mobilnej siete

Simulačný program Radio Mobile

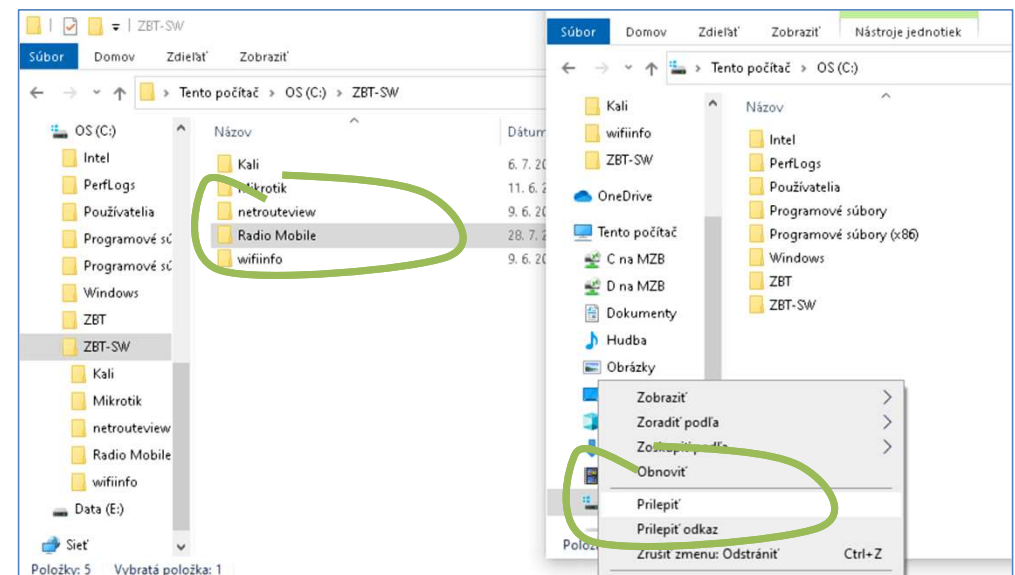
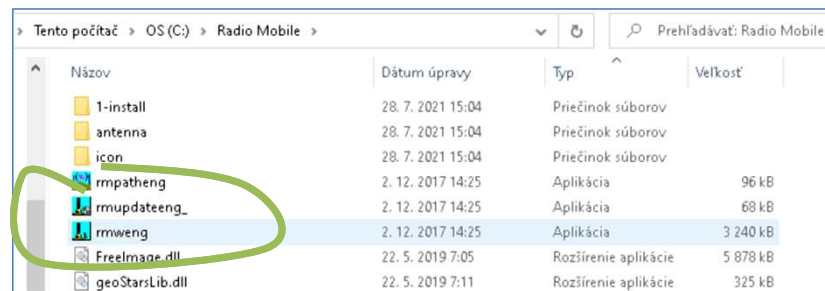
- Radio Mobile je voľne dostupný simulačný nástroj na simulovanie šírenia mobilného signálu v teréne
 - Ian D. Brown, Roger Coudé
 - “Radio Mobile is dedicated to Amateur Radio and humanitarian use. Although commercial use is not prohibited, the author cannot be held responsible for its usage or the data it provides.”*
- Longley-Rice irregular terrain model pre frekvenčný rozsah 20MHz - 20GHz
- [https://en.wikipedia.org/wiki/Longley%E2%80%93Rice_model#:~:text=The%20Longley%E2%80%93Rice%20model%20\(LR,irregular%20terrain%20model%20\(ITM\).](https://en.wikipedia.org/wiki/Longley%E2%80%93Rice_model#:~:text=The%20Longley%E2%80%93Rice%20model%20(LR,irregular%20terrain%20model%20(ITM).)

Inštalácia alebo overenie inštalácie:

- Prekopírovať adresár “Radio Mobile” z adresára “ZBT-SW” na disk C:\

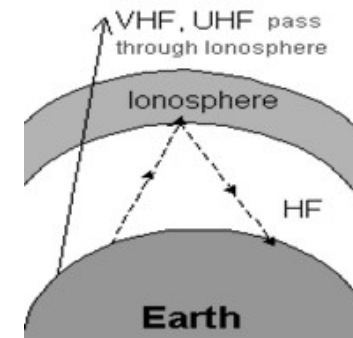
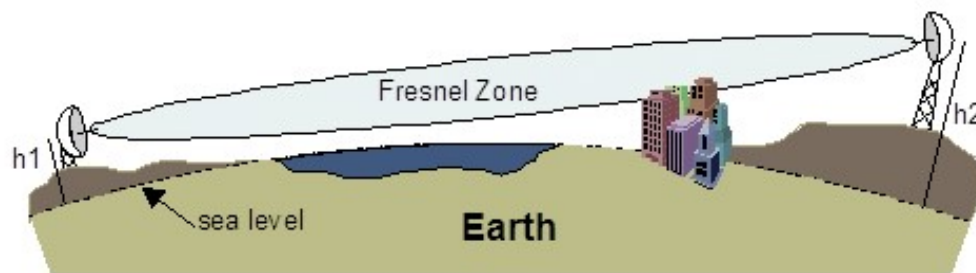
Spustenie programu:

- Rmweng.exe



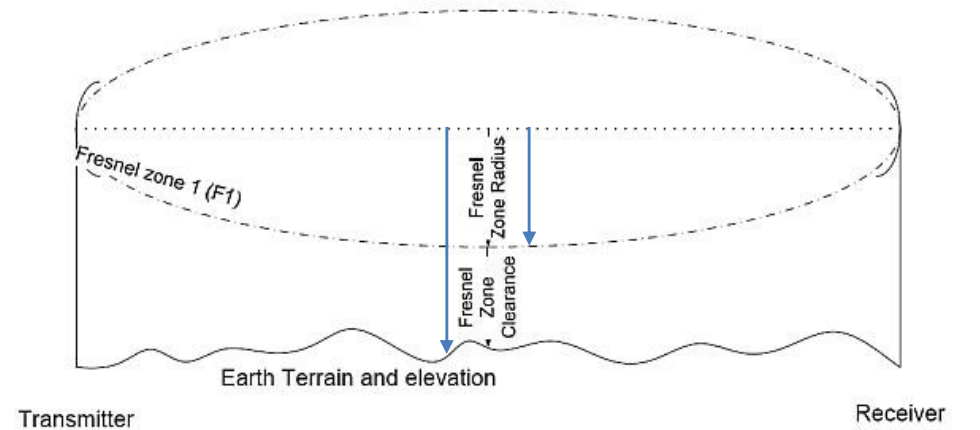
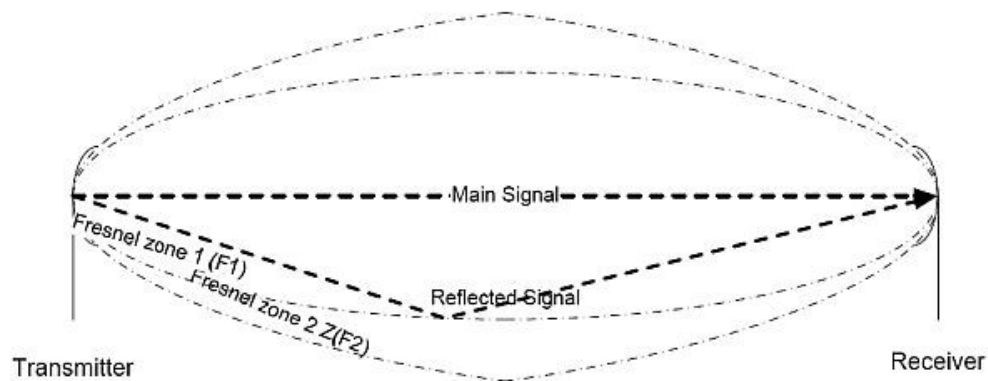
Irregular Terrain Model (ITM) Longley-Rice

- Model of radio propagation for frequencies between 20 MHz and 20 GHz
- named for Anita Longley & Phil Rice ; 1968
- predicts the median attenuation of a radio signal as a function of distance and the variability of the signal in time and in space
- Signal propagation is influenced by:
 - Free space loss EIRP [W], atmospheric attenuation (typically depends on water vapour content of the atmosphere)
 - Ground wave propagation (ground conductivity and permittivity). Diffraction around a smooth earth. Ground reflections.
 - Effect of terrain (Terrain features, trees and buildings, usually attenuate signals).
 - Tropospheric refraction (ionosphere above reflects HF radio waves (3-30MHz) back to Earth)
 - Ionospheric propagation (layer of conductive gas at heights between 70 and 400 km)
 - Diffraction over “knife edge”



Fresnel zones

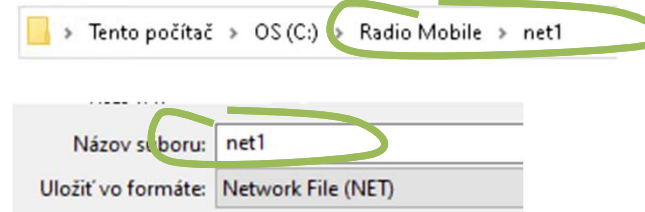
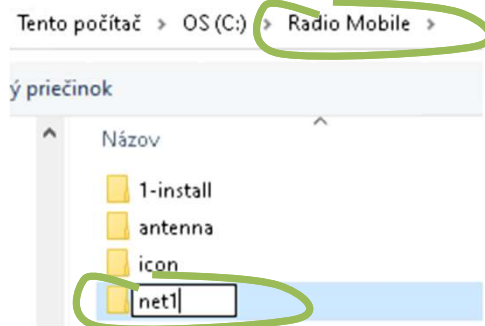
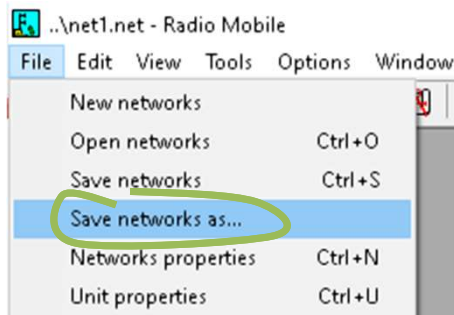
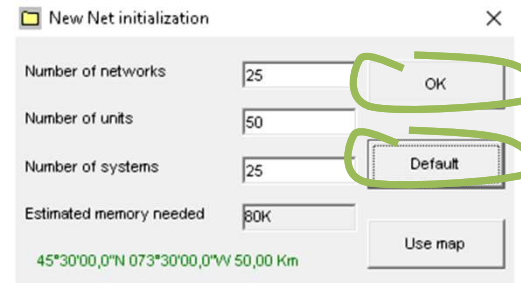
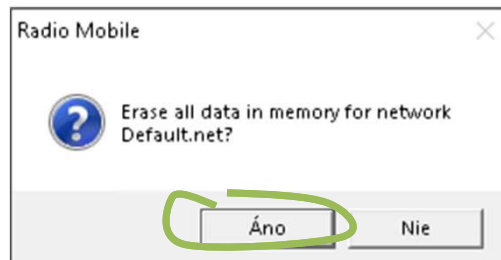
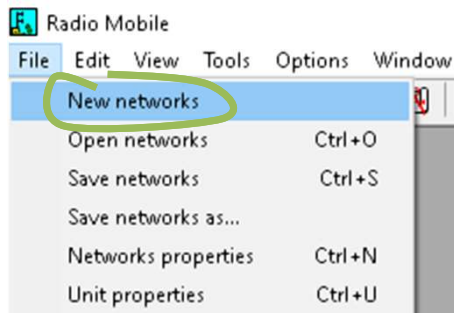
- There are an infinite number of Fresnel zones, however, only the first 3 have any real effect on radio propagation (F1, F2, F3). The size of the 3D ellipse is determined by the frequency of operation and the distance between the two sites.
- The signal can go directly between transmitter and receiver (main signal). Signal can reflect off the ground and then carry on to the distant receiver.
- F1 zone is determined by the calculation so that the difference in path length between the main signal and a reflected signal from the F1 radius distance is 180° . A reflected signal shifted by 180° of path distance plus 180° from the actual reflection point totals 360° of phase shift. The 2 signals, main and reflected, arrive at the antenna 360° apart or in phase. They will add together and not affect receiver performance.
- Fresnel zone earth clearance – the clearance between Fresnel zone cylinder (its line of sight) and the earth. Optimal clearance requires 60% or more of the first Fresnel zone ($0.2F1$)
 - Note: Worst Fresnel 1F1 means earth or obstacle at the edge of Fresnel Zone (FZ Clearance /FZ Radius)





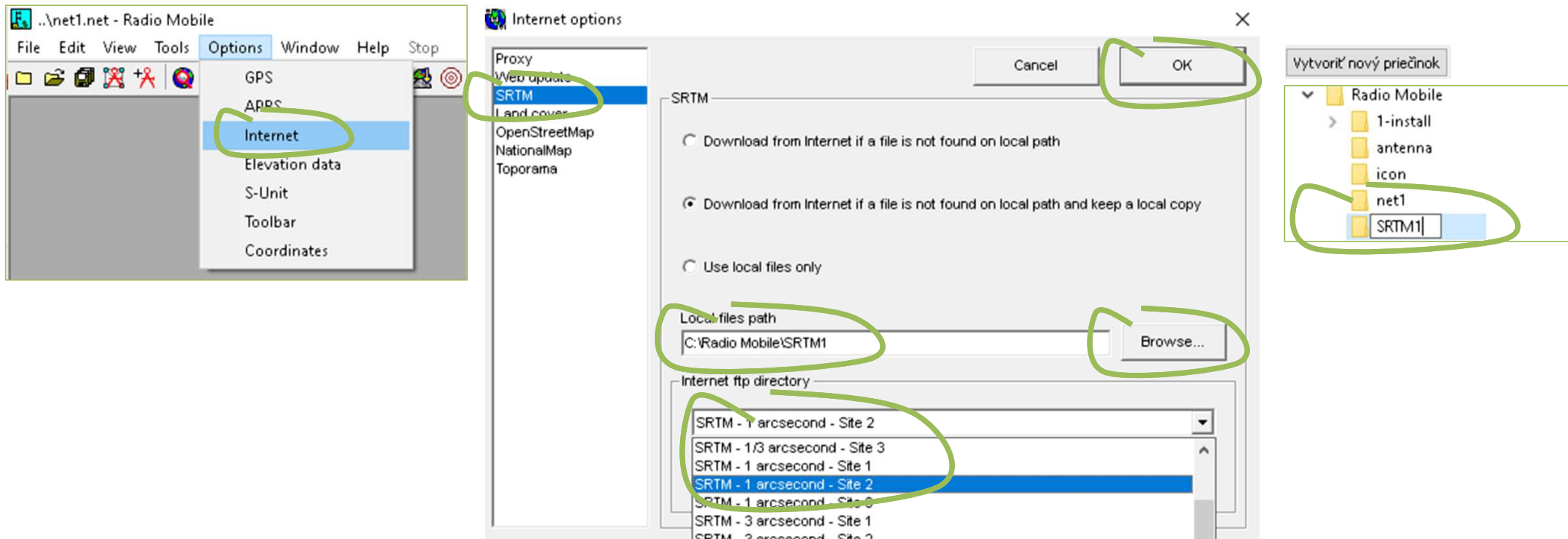
Vytvorenie podkladovej topologickej mapy

Vytvorenie a uloženie nového projektu



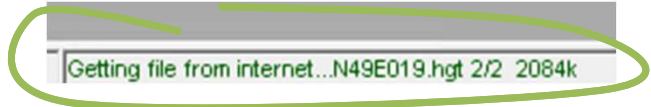
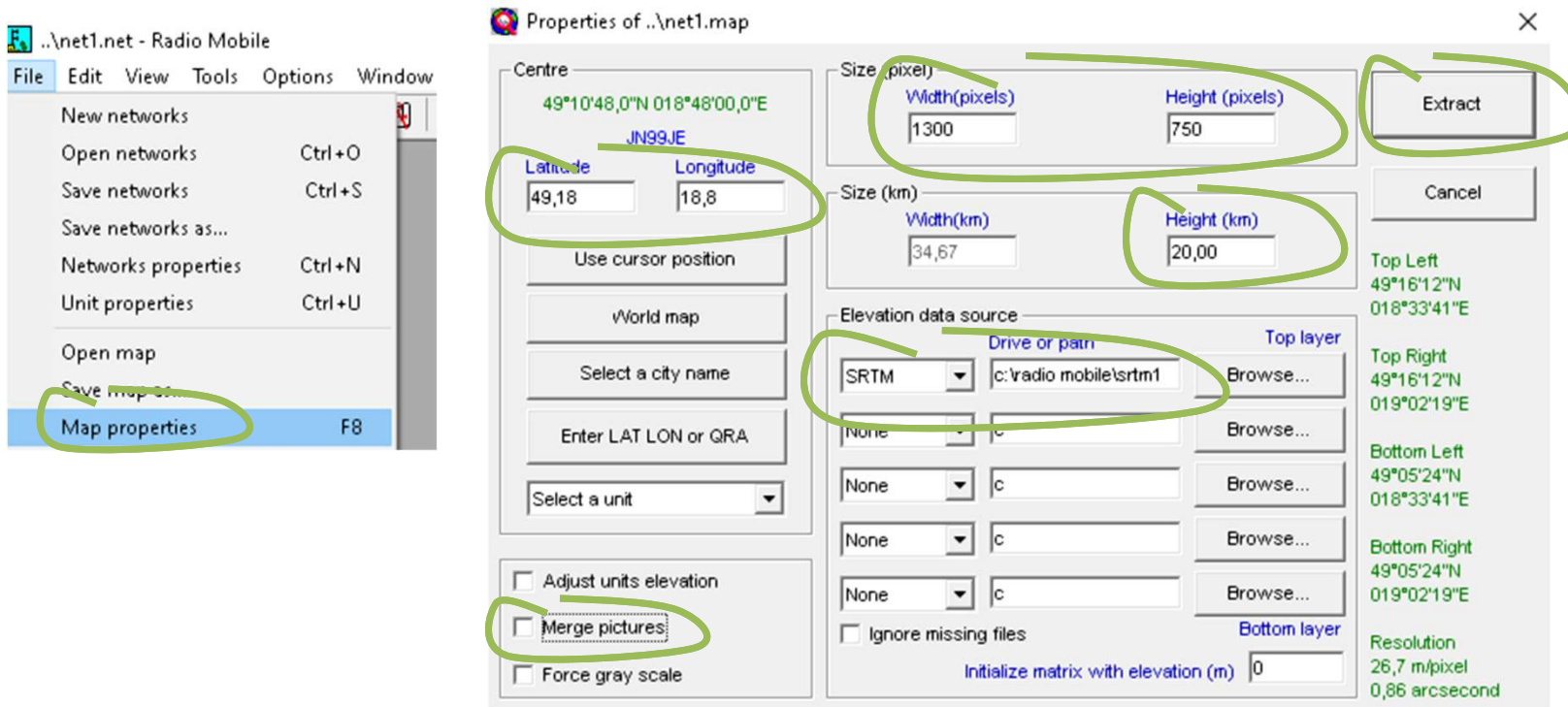
- New project NET1 saved in new directory **C:\Radio Mobile\net1**

Nastavenie internetovej konektivity na stiahnutie výškových profilov



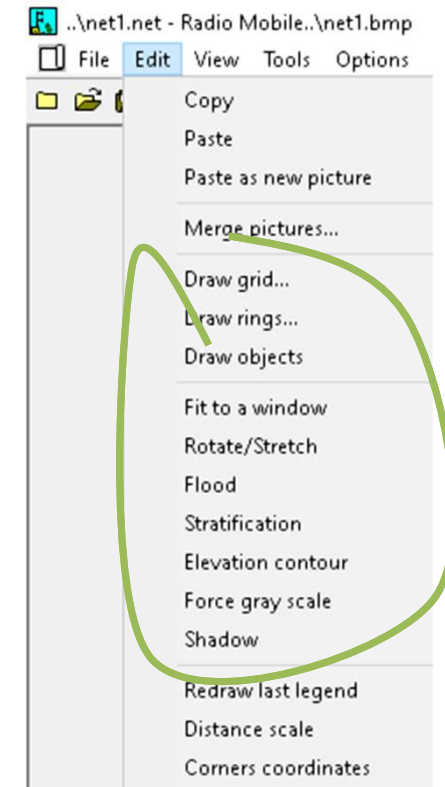
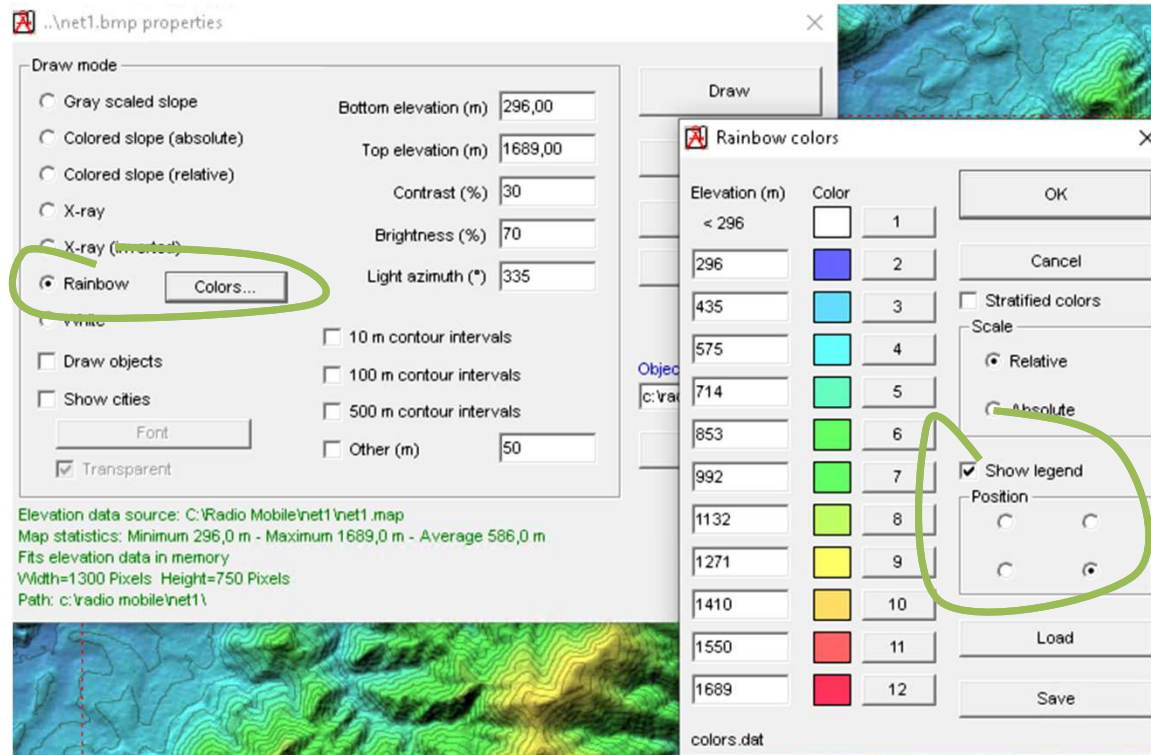
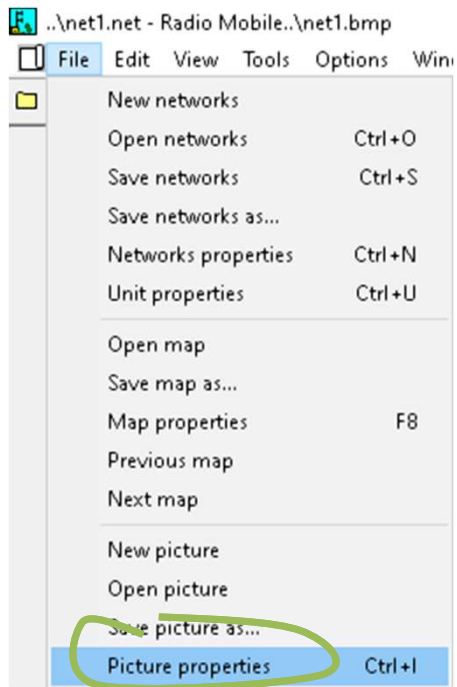
- The Shuttle Radar Topography Mission (SRTM) is an international research effort that obtained digital elevation models, relevant files need to be downloaded from Internet for the selected region (region definition on the next slide)
- Downloaded files locally stored in the **C:\Radio Mobile\SRTM1** directory

Definovanie vytvárajúcej podkladovej mapy s výškovým profilom pre zvolený región – GPS coord

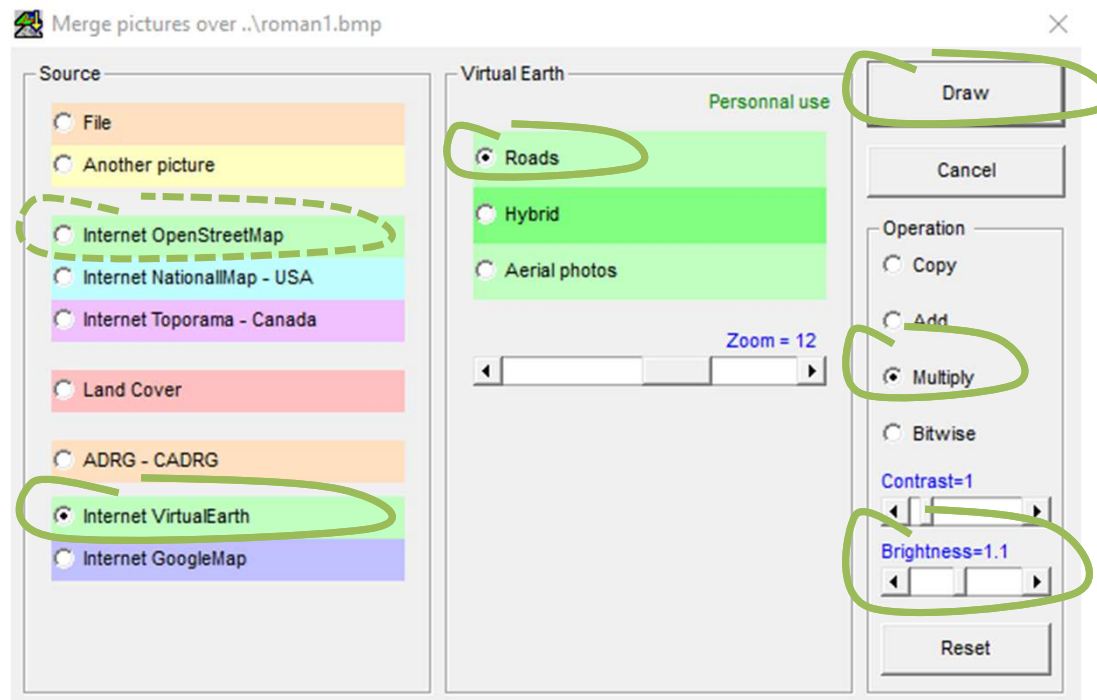
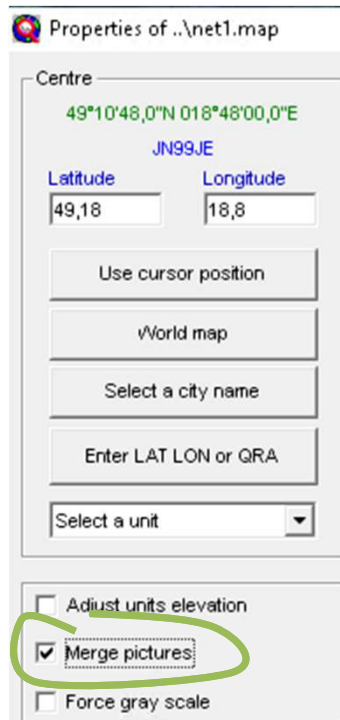
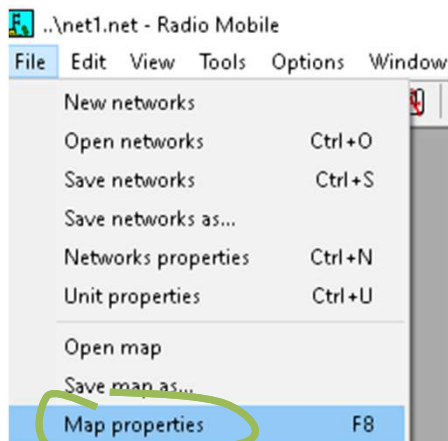


- New SRTM based map will be merged with topographic information

Úprava zobrazovania podkladovej mapy s výškovým profilom a pozícia legendy; ďalšie voliteľné úpravy mapového obrazu .BMP

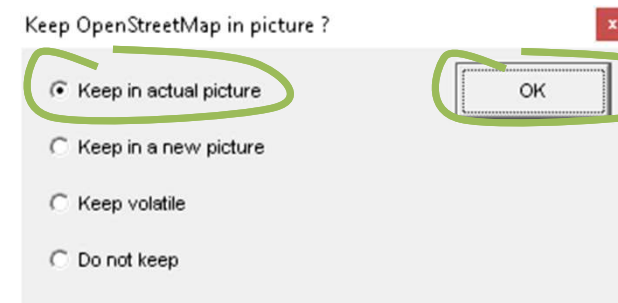


Spojenie topografických informácií s podkladovou mapou s výškovým profilom

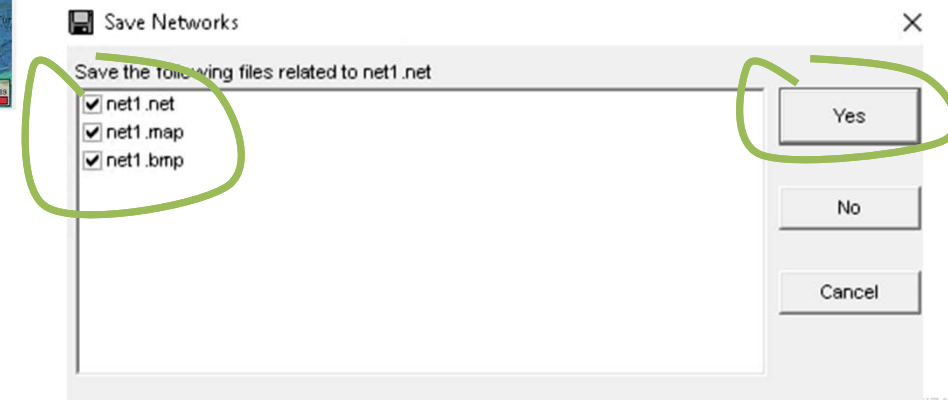
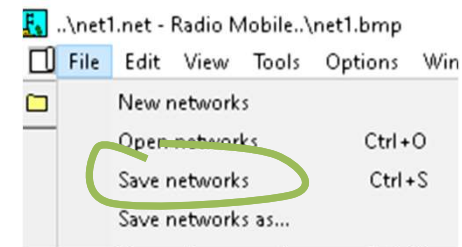
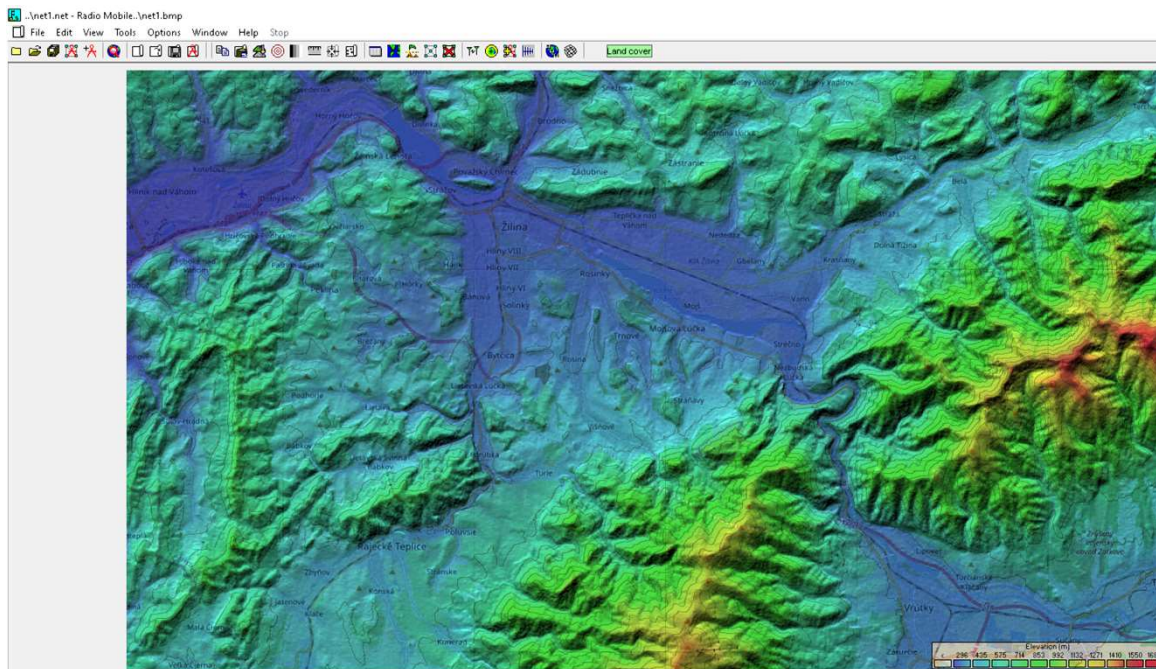


Povoliť v súbore "Map_Link.txt" MS mapy alebo zvoliť v menu OpenStreetMap

```
Radio Mobile restricted merge sources (this line for alternate OSM style server)  
virtualearth.net
```

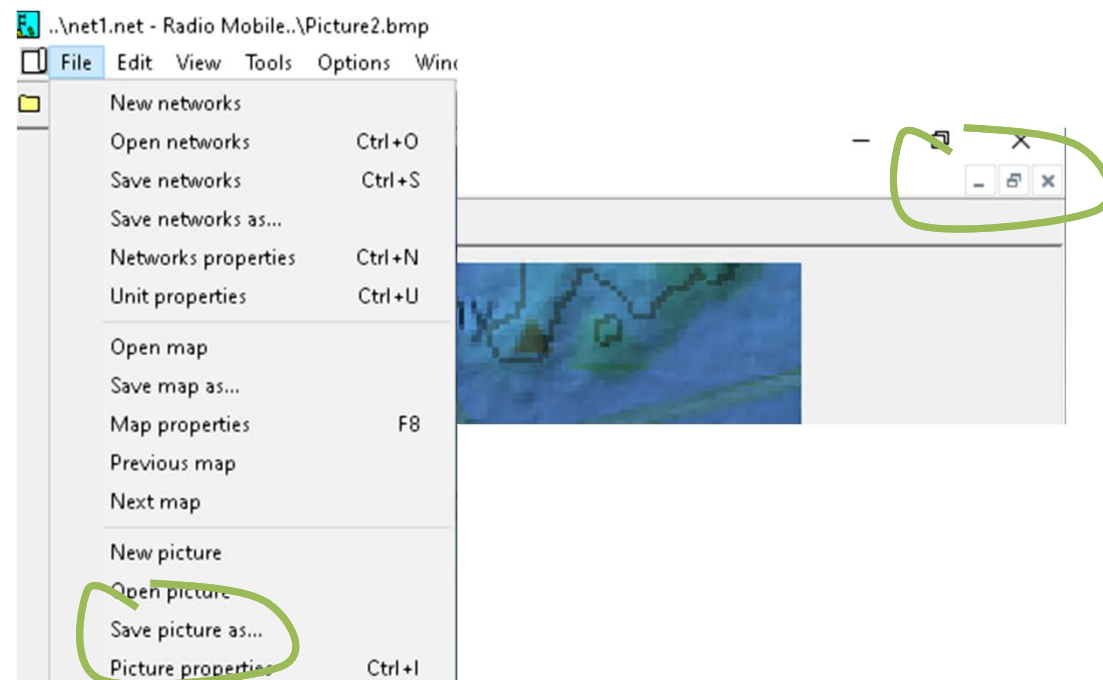
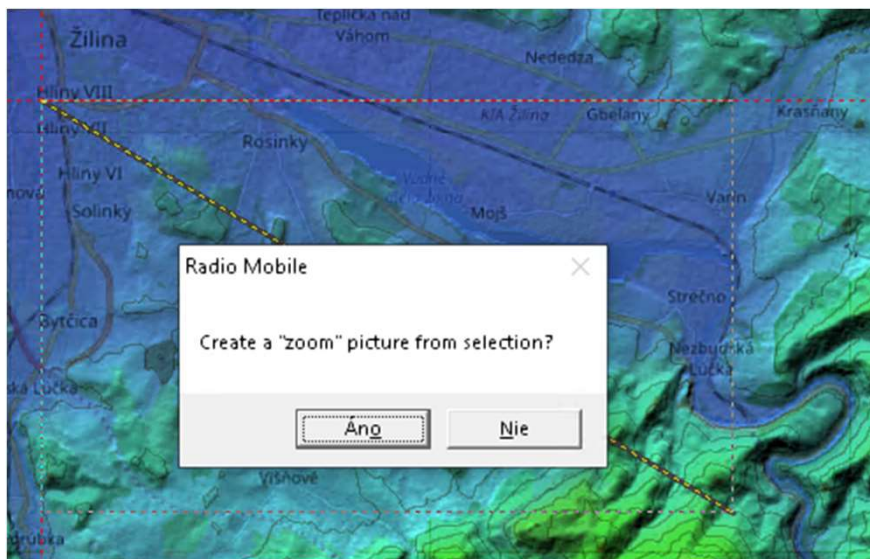


Príklad finálnej podkladovej mapy; uloženie atribútov mapy, BMP obrazového súboru a sieťových prvkov do adresára **C:\Radio Mobile\net1**



Zoom – možnosť vytvorenia nového obrazu z výberu

- Right-click na obrazový súbor a potiahnutím zvoliť výsek pôvodného podkladu
- Right-click na výber spustí proces vytvorenia nového obrazového súboru

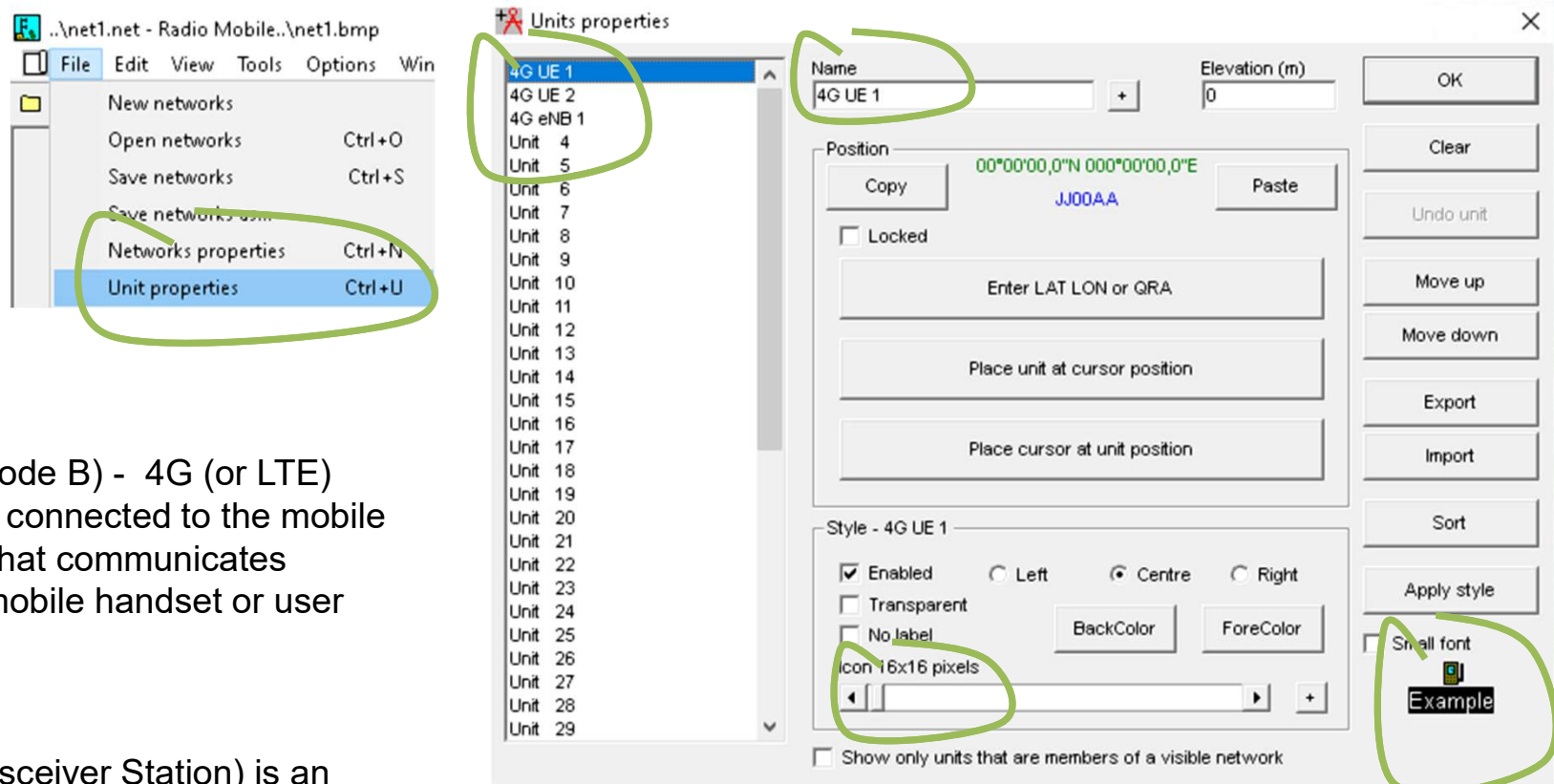


- Novovytvorený obrazový súbor je možné kedykoľvek uložiť alebo zavrieť bez uloženia



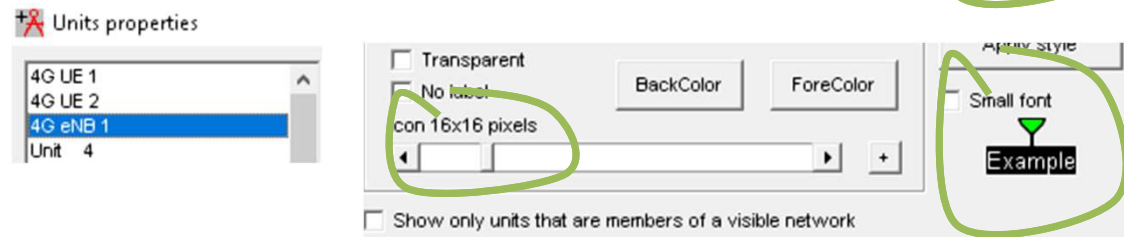
Konfigurácia bezdrôtovej mobilnej siete

Konfigurácia jednotlivých prvkov mobilnej komunikácie - 4G/LTE základňovej stanice eNB a 2x koncového zariadenia UE (User Equipment)



eNB (Evolved Node B) - 4G (or LTE) hardware that is connected to the mobile phone network that communicates wirelessly with mobile handset or user equipment (**UE**)

BTS (Base Transceiver Station) is an equivalent to eNB but in 2G (GSM) technology



Konfigurácia parametrov mobilnej siete a typov komunikačných prvkov

The image displays the 'Networks properties' dialog box for configuring a mobile network. The 'List of all nets' on the left shows '4G Net 1' selected. The 'Parameters' tab is active, and the 'Topology' sub-tab is selected. The configuration includes:

- Net name:** 4G Net 1
- Minimum frequency (MHz):** 1800
- Maximum frequency (MHz):** 1870
- Surface refractivity (N-Units):** 301
- Ground conductivity (S/m):** 0,005
- Relative ground permittivity:** 15
- Polarization:** Vertical (selected)
- Mode of variability:** Spot (selected), with % of time set to 50.
- Climate:** Desert (selected), with 'Continental temperate' selected.

The 'Topology' sub-tab shows the following options:

- Visible
- Voice net (Command/Subordinate/Rebroadcast)
- Data net, star topology (Master/Slave)
- Data net, cluster (Node/Terminal)

A file explorer window is also visible on the left, showing the 'File' menu with 'Networks properties' (Ctrl+N) highlighted.

Zisk antény a súvislosť s vysielačím výkonom

Effective Isotropic Radiated Power (EIRP)

- The hypothetical power that would have to be radiated by an isotropic antenna to give the same (or "equivalent") signal strength as the actual source antenna in the direction of the antenna's strongest beam

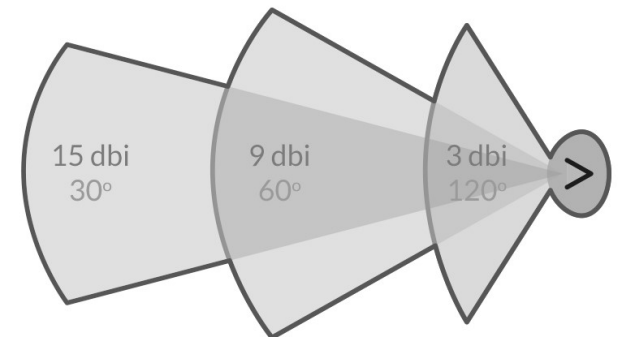
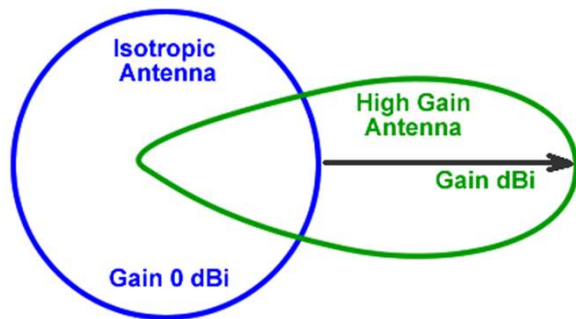
$$EIRP = P_T - L_C + G_a$$

P_T = Output power of the transmitter (dBm)

L_C = Cable Loss (dB)

G_a = Antenna Gain (dBi)

	Omni	Dipole	Yagi (60°)	
Tx Power	1600	1000	200	W
Tx Power	62.0	60.0	53.0	dBm
Ant. gain	0	2	9	dBi
Cable loss	2	2	2	dBm
EIRP	60.0	60.0	60.0	dBm
EIRP	1009.5	1000.0	1002.4	W
dBm = 10 log P₁/1mW				
P₁ = 1mW*10^{dBm/10}				



eNB a UE prvky; nastavenie anténnych a vysielacích charakteristík, citlivosť prijímača

Networks properties

List of all systems: 4G-eNB-1000W-dipole, System 3, System 4, System 5, System 6, System 7, System 8, System 9, System 10, System 11, System 12, System 13, System 14, System 15, System 16, System 17, System 18, System 19, System 20, System 21, System 22, System 23, System 24, System 25

Default parameters Copy Net Paste Net Cancel OK

Parameters Topology Membership **Systems** Style

00 Select from VHF ... UHF ...

System name: 4G-eNB-1000W-dipole

Transmit power (Watt): 1000 (dBm): 60

Receiver threshold (µV): 0,1585 (dBm): -123

Line loss (dB): 2 (Cable+cavities+connectors)

Antenna type: dipole.ant View

Antenna gain (dBi): 2 (dBd): -0,15

Antenna height (m): 10 (Above ground)

Additional cable loss (dB/m): 0 (If antenna height differs)

Add to Radiosys.dat Remove from Radiosys.dat

Green annotations highlight: 'Systems' tab, '00' dropdown, 'System name', 'Transmit power', 'Receiver threshold', 'Line loss', 'Antenna type', 'Antenna gain', and 'Antenna height'.

Networks properties

List of all systems: 4G-eNB-1600W-omni, 4G-UE-type-1, System 3, System 4, System 5, System 6, System 7, System 8, System 9, System 10, System 11, System 12, System 13, System 14, System 15, System 16, System 17, System 18, System 19, System 20, System 21, System 22, System 23, System 24, System 25

Default parameters Copy Net Paste Net Cancel OK

Parameters Topology Membership **Systems** Style

00 Select from VHF ... UHF ...

System name: 4G-UE-type-1

Transmit power (Watt): 0,2 (dBm): 23

Receiver threshold (µV): 1,122 (dBm): -106

Line loss (dB): 0,5 (Cable+cavities+connectors)

Antenna type: omni.ant View

Antenna gain (dBi): 0 (dBd): -2,15

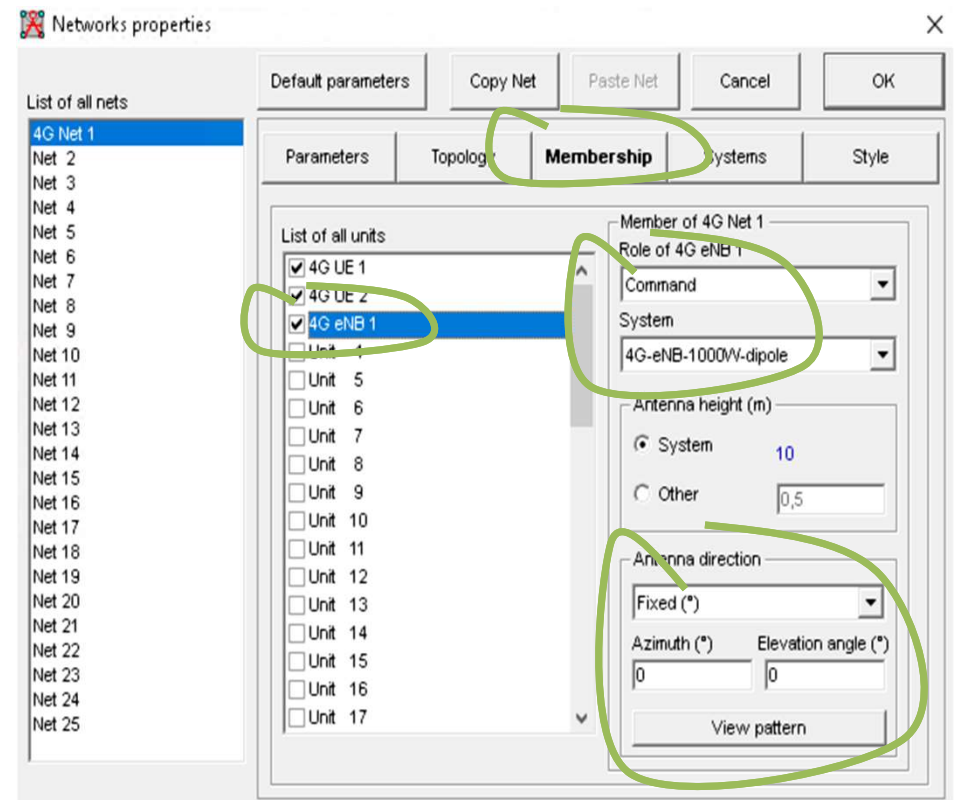
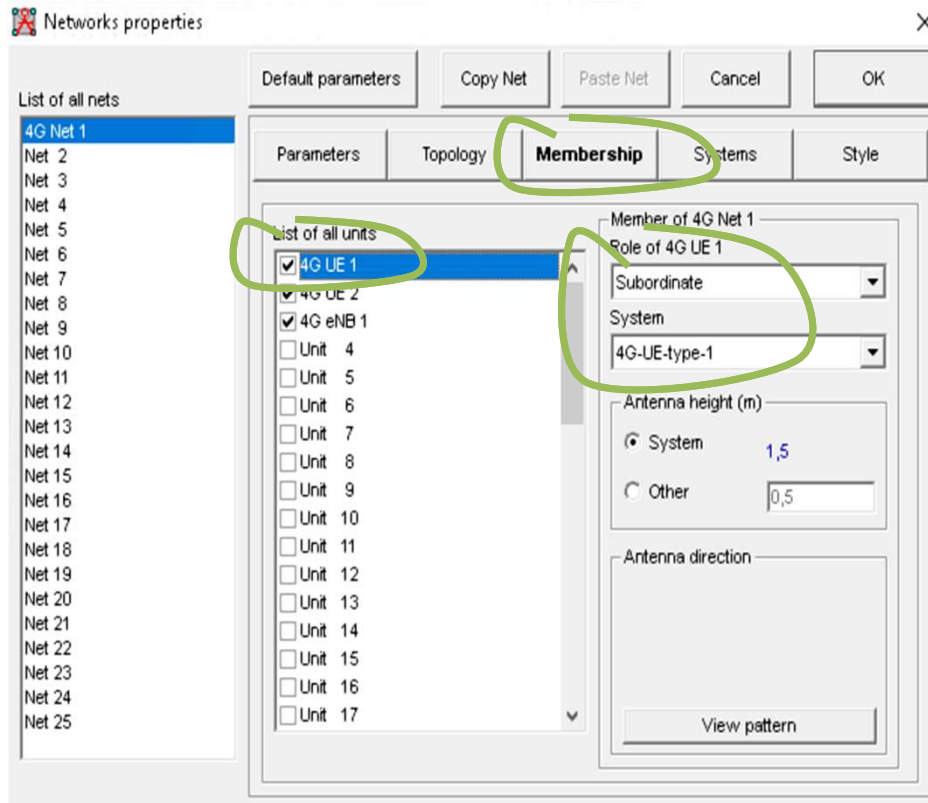
Antenna height (m): 1,5 (Above ground)

Additional cable loss (dB/m): 0 (If antenna height differs)

Add to Radiosys.dat Remove from Radiosys.dat

Green annotations highlight: 'Systems' tab, '00' dropdown, 'System name', 'Transmit power', 'Receiver threshold', 'Line loss', 'Antenna type', 'Antenna gain', and 'Antenna height'.

Konfigurácia konkrétnych komunikačných zariadení

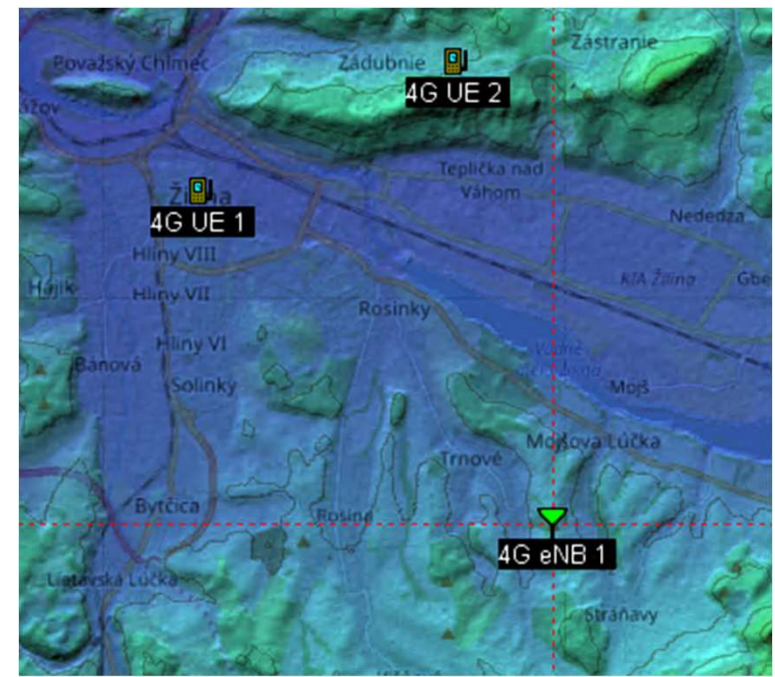
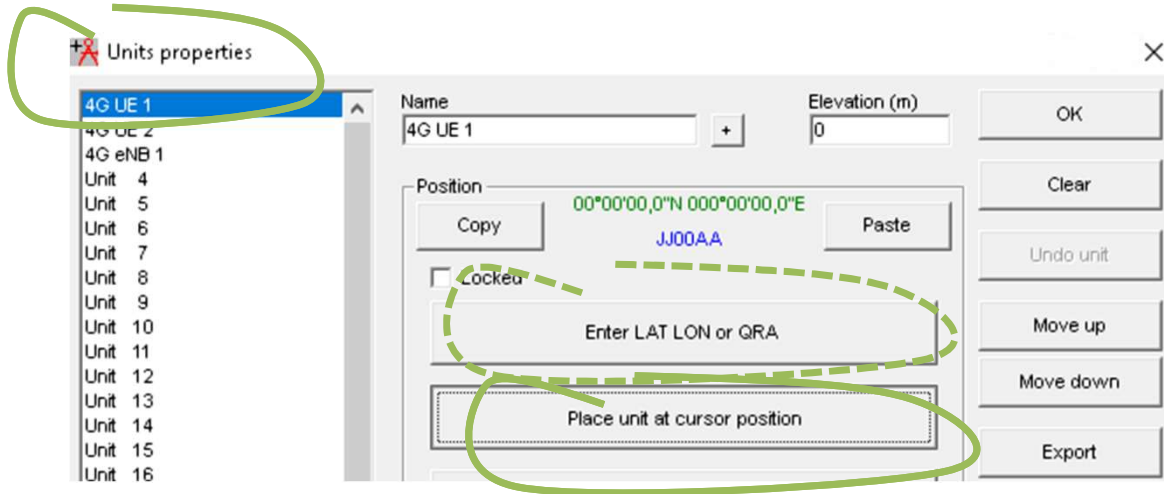


- Voľba zariadení, ktoré patria do konfigurovanej mobilnej siete
- eNB základňová stanica je nastavená do módu Command, hand-held zariadenie je v móde Subordinate
- Priradenie predkonfigurovaných charakteristík konkrétnemu zariadeniu



Umiestnenie zvolených zariadení do topologickej mapy

Umiestnenie komunikačných prvkov do vytvorenej topologickej mapy

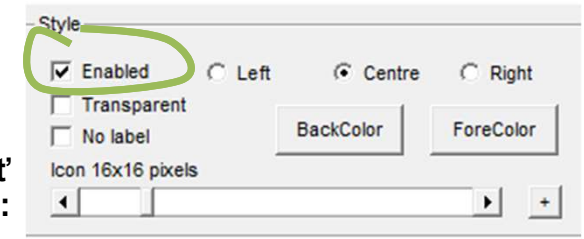


- Left-click na mapový podklad, kam chcem umiestniť zariadenie (resp. zadať súradnice)
- File - Unit Properties - Place unit at cursor position
- Viacero možností modifikovať pozíciu na mape; jedna možnosť je označiť novú pozíciu left-clickom a right-click na ikonu zariadenia



eNB: 49.18293 N , 18.80587 E
 UE1: cca centrum Žiliny

Možnosť aktivovať/deaktivovať zariadenie:

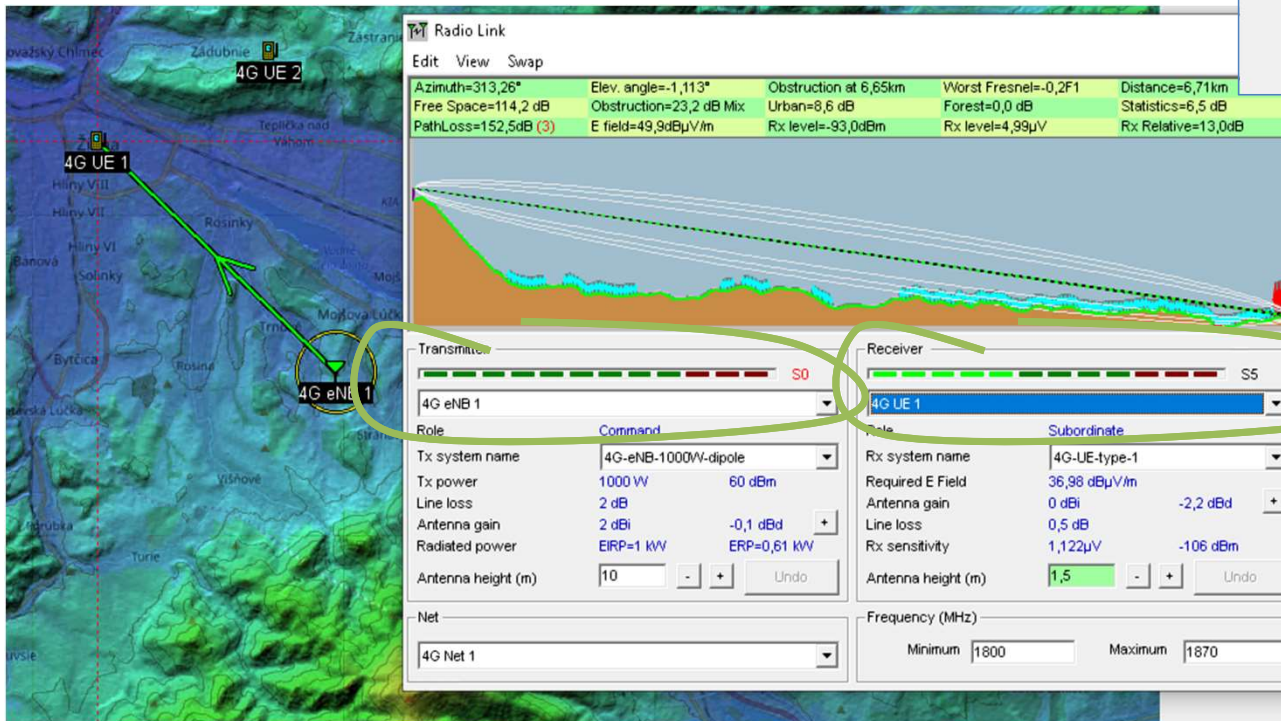
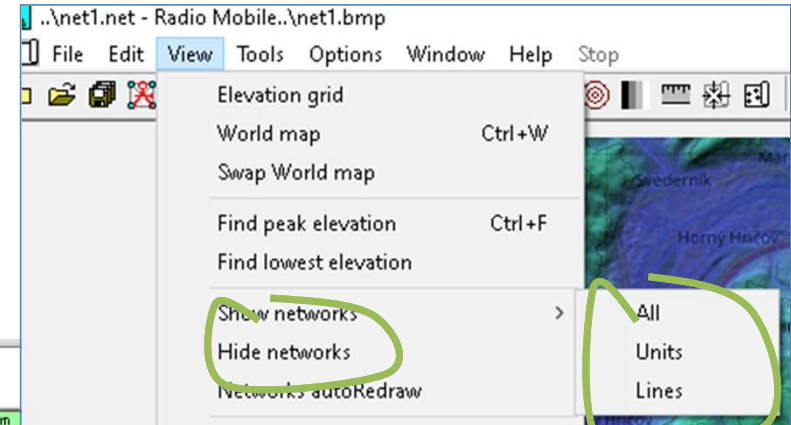
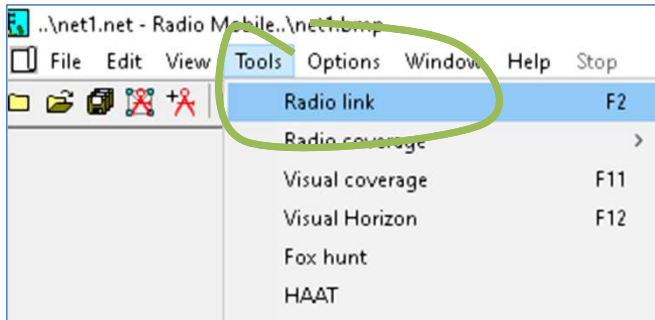




Radio Link

Charakteristika bezdrôtovej rádiovkej linky

Radio Link - zobrazenie charakteristiky spojenia medzi eNB a zvoleným UE



Signal level; S-Units:

- S9 level is 5,01 uV (-93 dBm at 50 ohm, 0dBd)
- 3 dB per S-point
- Nižšia hodnota, slabší signál

Radio Link parameters: 4G eNB -> 4G UE 1

Radio Link

Edit View Swap

Azimuth=313,26°	Elev. angle=-1,113°	Obstruction at 6,65km	Worst Fresnel=-0,2F1	Distance=6,71km
Free Space=114,2 dB	Obstruction=23,2 dB Mix	Urban=0,0 dB	Forest=0,0 dB	Statistics=6,5 dB
PathLoss=152,5dB (3)	E field=49,9dBuV/m	Rx level=-93,0dBm	Rx level=4,99uV	Rx Relative=13,0dB

Transmitter

4G eNB 1

Role: **Command**

Tx system name: 4G-eNB-1000W-dipole

Tx power: **1000 W** (60 dBm)

Line loss: 2 dB

Antenna gain: 2 dBi (-0,1 dBd)

Radiated power: **EIRP=1 kW** (ERP=0,61 kW)

Antenna height (m): 10

Net: 4G Net 1

Receiver

4G UE 1

Role: **Subordinate**

Rx system name: 4G-UE-type-1

Required E Field: 36,98 dBuV/m

Antenna gain: 0 dBi (-2,2 dBd)

Line loss: 0,5 dB

Rx sensitivity: **1,122uV** (-106 dBm)

Antenna height (m): 1,5

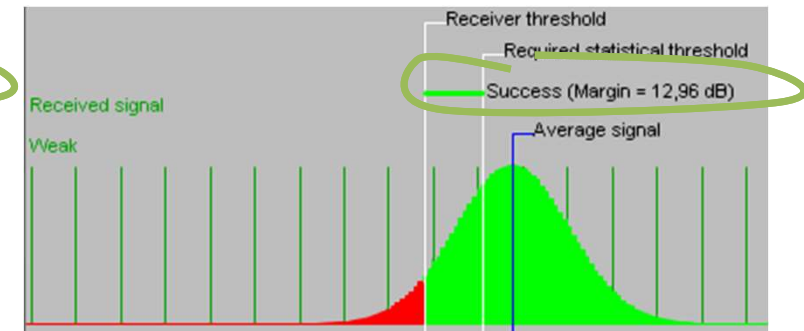
Frequency (MHz): Minimum 1800, Maximum 1870

Radio Link

Edit View Swap

- Profile
- Details**
- Range
- Distribution

Distance between 4G eNB 1 and 4G UE 1 is 6,7 km (4,2 miles)
 True North Azimuth = 313,26°, Magnetic North Azimuth = 308,14°, Elevation angle = -1,1134°
 Terrain elevation variation is 113,8 m
 Propagation mode is diffraction, single obstruction, 0,2F1 at 6,7km
 Average frequency is 1835,000 MHz
 Free Space = 114,2 dB, Obstruction = 23,2 dB Mix, Urban = 8,6 dB, Forest = 0,0 dB, Statistics = 6,5 dB
 Total propagation loss is 152,5 dB
 System gain from 4G eNB 1 to 4G UE 1 is 165,5 dB (dipole.ant at 313,3 °-1,11° gain = 2,0 dBi)
 System gain from 4G UE 1 to 4G eNB 1 is 145,5 dB
 Worst reception is 7,0 dB below the required signal to meet
 70,000% of situations



$$60 \text{ (EIRP)} - 114.2 \text{ (free space)} - 23.2 \text{ (obstruction)} - 0 \text{ (forest)} - 8.6 \text{ (urban)} - 6.5 \text{ (stat)} - 0.5 \text{ (UE line loss)} = -93 \text{ dBm}$$

Opačný smer: 4G UE 1 -> 4G eNB

Radio Link

Azimuth=133,21° Elev. angle=1,053° Obstruction at 0,05km Worst Fresnel=-0,2F1 Distance=6,71km
 Free Space=114,2 dB Obstruction=23,2 dB Mix Urban=8,6 dB Forest=0,0 dB Statistics=6,5 dB
 PathLoss=152,5dB (3) E field=12,5dBµV/m Rx level=-130,0dBm Rx level=0,07µV Rx Relative=-7,0dB

Transmitter

4G UE 1

Role: Subordinate

Tx system name: 4G-UE-type-1

Tx power: 0,2 W 23,01 dBm

Line loss: 0,5 dB

Antenna gain: 0 dBi -2,2 dBd

Radiated power: EIRP=0,18 W ERP=0,11 W

Antenna height (m): 1,5

Receiver

4G eNB 1

Role: Command

Rx system name: 4G-eNB-1000W-dipole

Required E Field: 19,48 dBµV/m

Antenna gain: 2 dBi -0,1 dBd

Line loss: 2 dB

Rx sensitivity: 0,1585µV -123 dBm

Antenna height (m): 10

Frequency (MHz): Minimum 1800 Maximum 1870

Radio Link

Edit View Swap
 Profile
 Details
 Range
 Distribution

Distance between 4G UE 1 and 4G eNB 1 is 6,7 km (4,2 miles)
 True North Azimuth = 133,21°, Magnetic North Azimuth = 128,10°, Elevation angle = 1,0530°
 Terrain elevation variation is 113,8 m
 Propagation mode is diffraction, single obstruction, 0,2F1 at 0,1km
 Average frequency is 1835,000 MHz
 Free Space = 114,2 dB, Obstruction = 23,2 dB Mix, Urban = 8,6 dB, Forest = 0,0 dB, Statistics = 6,5 dB
 Total propagation loss is 152,5 dB
 System gain from 4G UE 1 to 4G eNB 1 is 145,5 dB
 System gain from 4G eNB 1 to 4G UE 1 is 165,5 dB (dipole.ant at 313,3°-1,11° gain = 2,0 dBi)
 Worst reception is 7,0 dB below the required signal to meet
 70,000% of situations

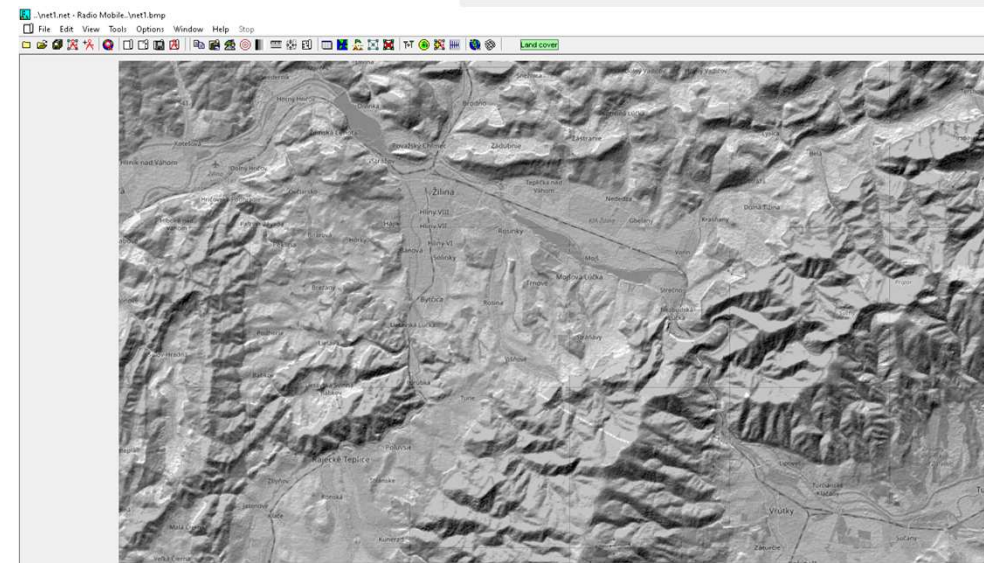
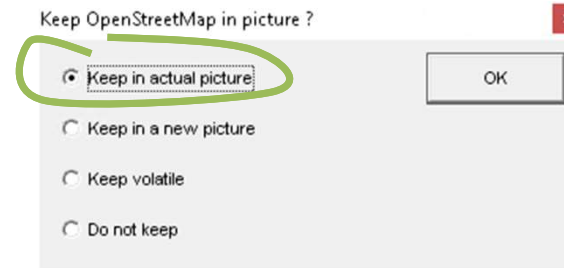
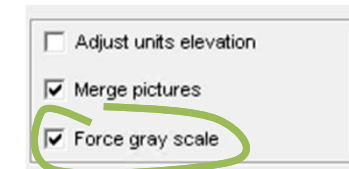
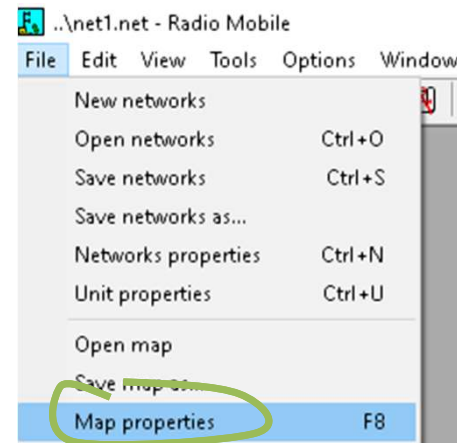
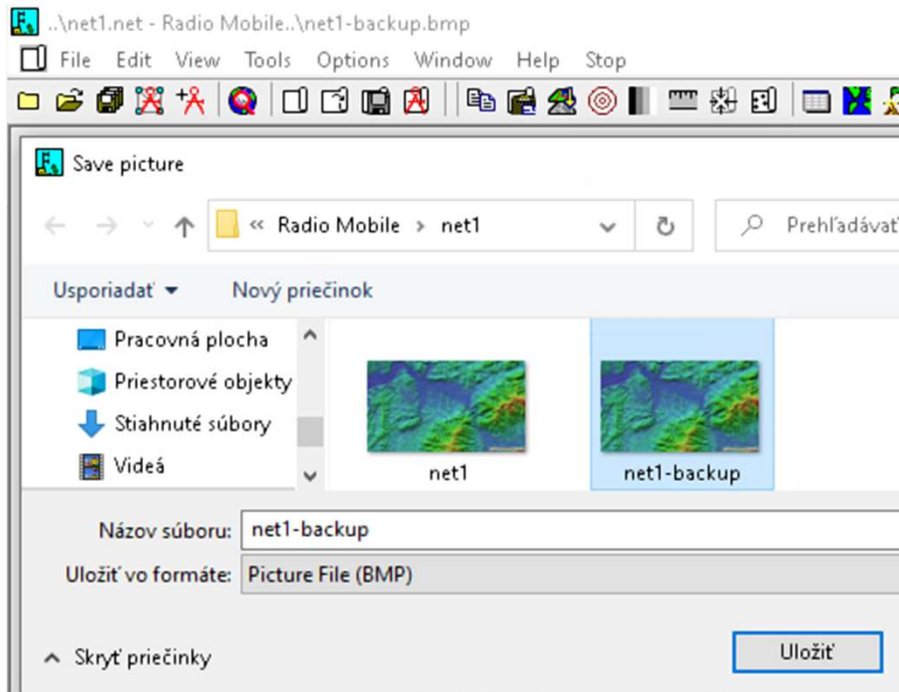


$$22.5 \text{ (EIRP)} - 114.2 \text{ (free space)} - 23.2 \text{ (obstruction)} - 0 \text{ (forest)} - 8.6 \text{ (urban)} - 6.5 \text{ (stat)} - 2 \text{ (UE line loss)} + 2 \text{ (ant.gain)} = -130 \text{ dBm}$$



Radio Coverage Simulácia pokrytia zvoleného územia mobilným signálom

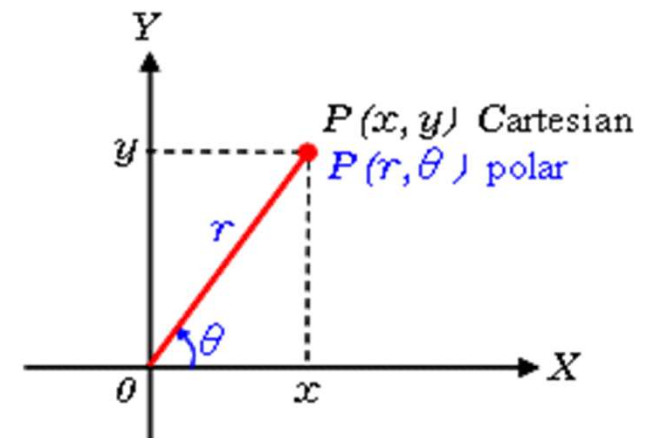
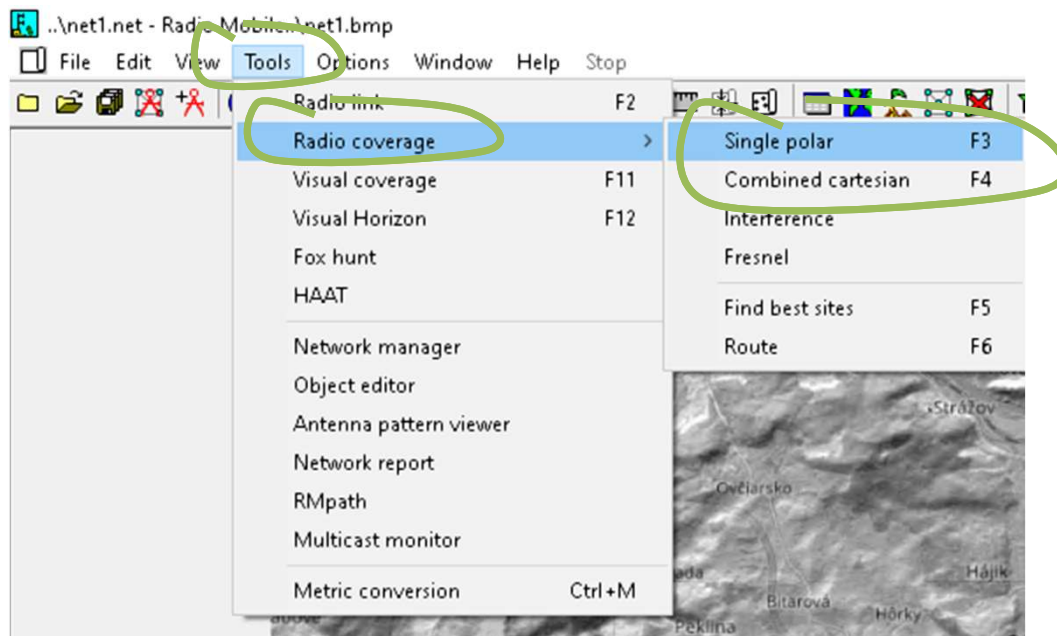
Vytvorenie novej podkladovej mapy; výškový profil v odtieni šedej farby



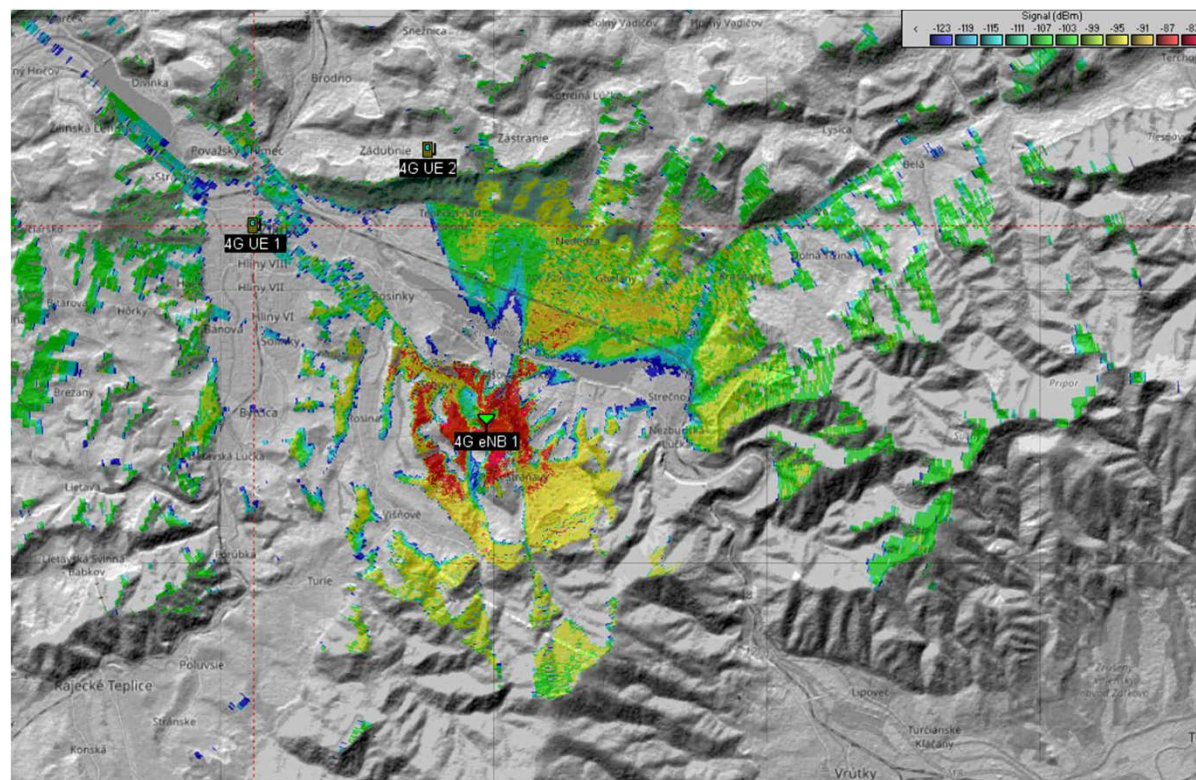
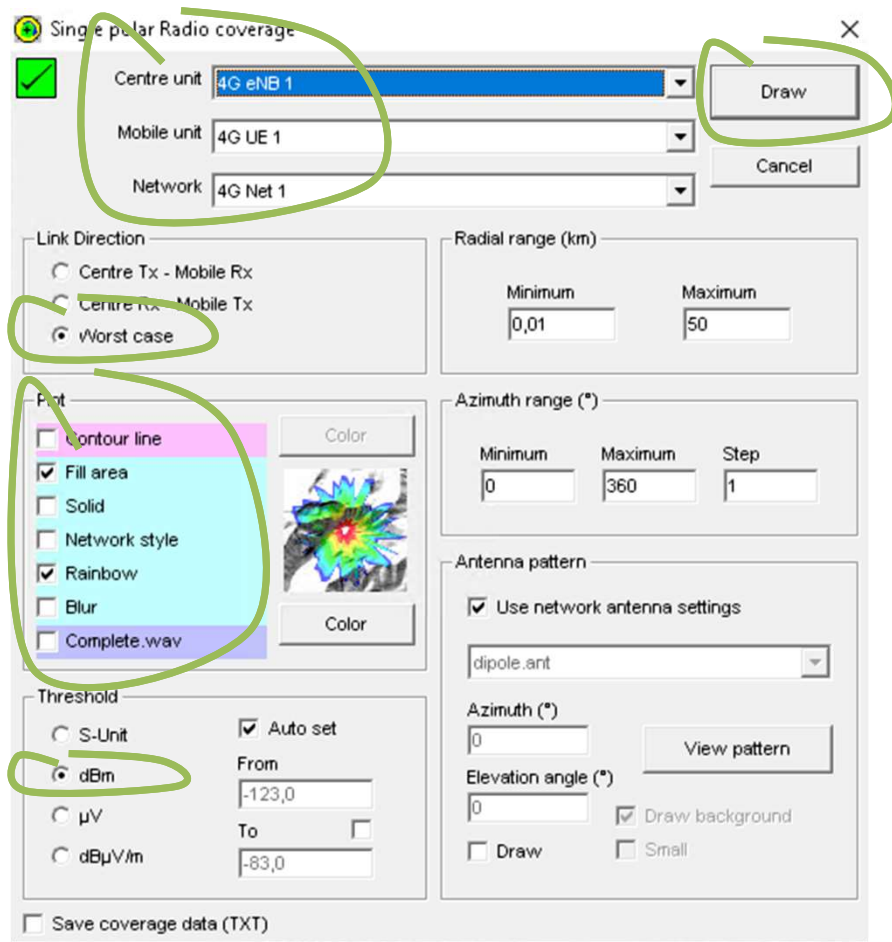
1. Záloha originálneho podkladového obrázku
2. Vytvorenie šedej verzie podkladovej mapy vo formáte BMP
3. Spojenie s topografickou mapou
4. Uložiť BMP súbor do pôvodného názvu "net1.BMP"

“Polar” coverage plot versus “Cartesian” coverage plot

- A Polar plot has been seen to be a very useful tool capable of producing rapid coverage data for a single central unit to or from a specified moving mobile unit
- Poorer accuracy plot simulations towards the outside of the plot (greater distance from the central unit)
- With Cartesian plot the whole map area is covered by defined 'square pixel' areas for signal evaluation



“Single Polar” zobrazenie pokrytia signálom jednou základňovou stanicou

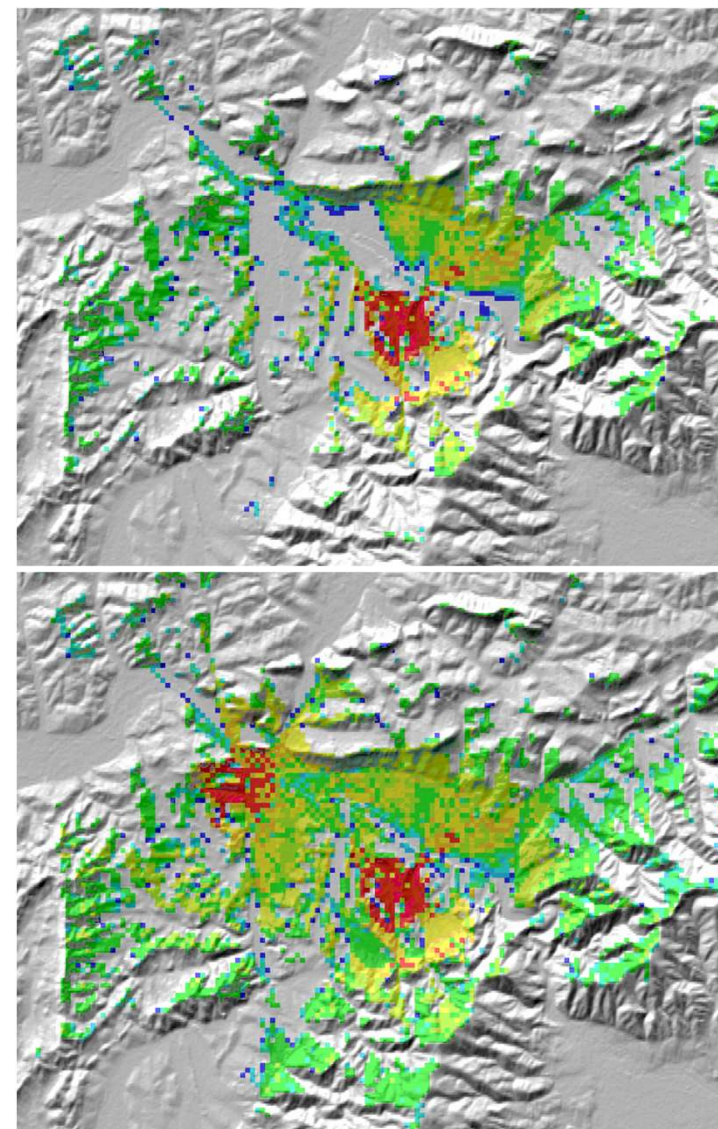
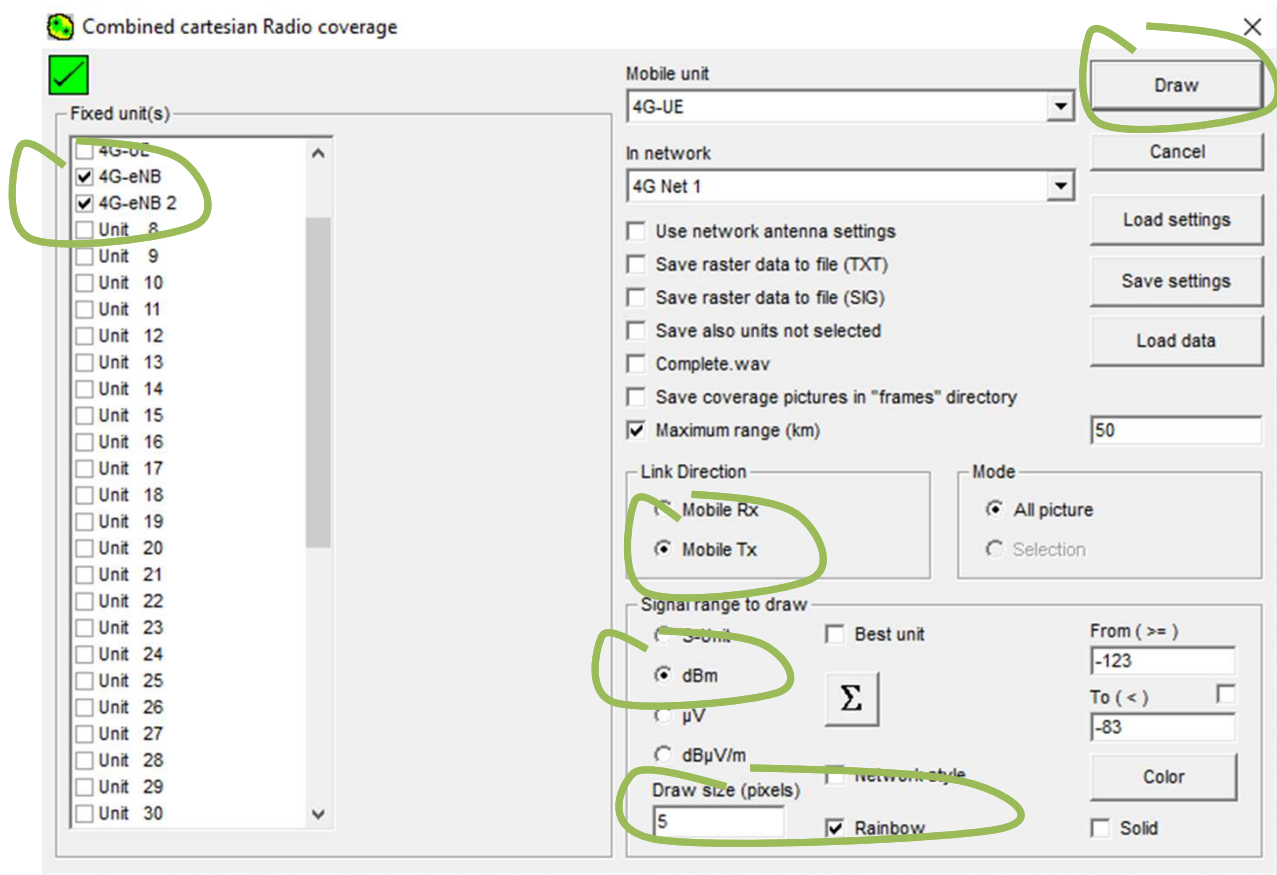


“Worst Case” knob - two way communication performance has to be used for the plots

“Mobile unit” – na vykreslenie pokrytia použije parametre zvoleného UE

“Combined Cartesian” zobrazenie pokrytia signálom jednou alebo viacerými základňovými stanicami

- Fixed unit(s) – voľba, ktoré základňové stanice budú použité na vykreslenie pokrytia
- Vysielací výkon UE je zvyčajne limitujúci (Mobile Tx)





Úlohy

A. Základňová stanica 4G eNB so smerovou anténou 60 stupňov

1. Vytvoriť nový typ základňovej stanice

- 4G eNB charakteristika
 - Transmit power 50W ~~1000W~~
 - Receiver threshold -123dBm
 - Yagi (60 st)
 - High 10m
 - Line loss 2dB

2. Zistiť a zdôvodniť

- Vysielačový výkon v dBm jednotkách
- Zisk antény
- EIRP

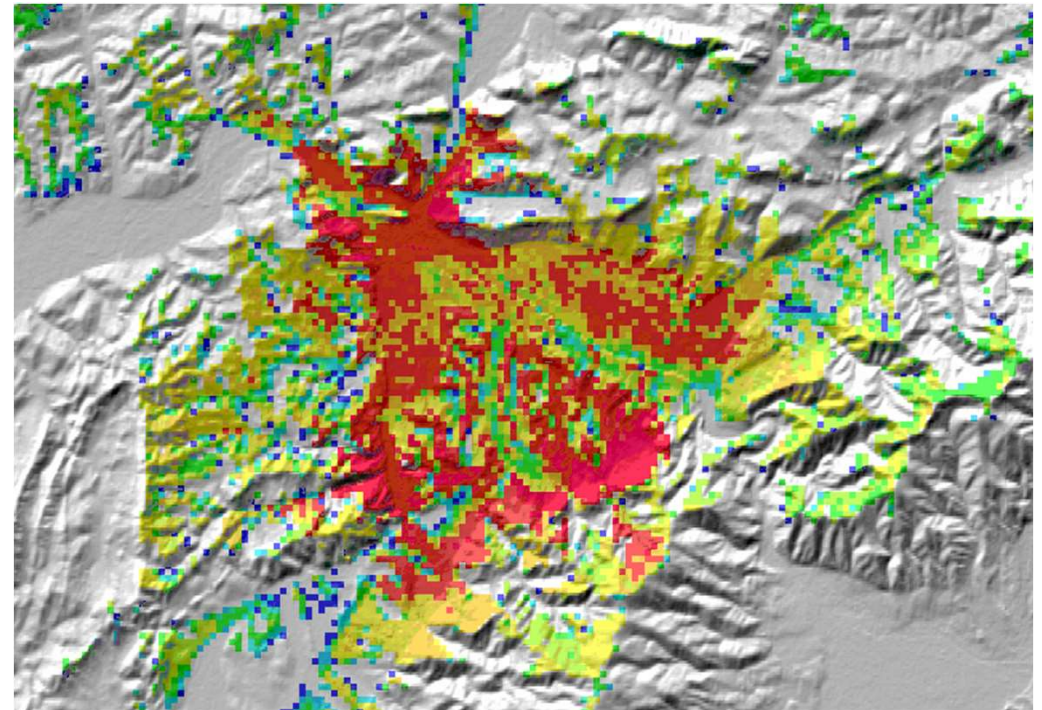
3. Porovnať pokrytia všesmerovej a smerovej vysielačovej stanice

- “Single Polar” zobrazenie, “Worst Case”
- Súradnice: 49.18293 N , 18.80587 E
- Smerovanie antény na mesto alebo na UE (Network properties, Membership, Antenna direction)

4. Zhodnotiť

B. Vytvorte čo najlepšie pokrytie žilinskej kotliny mobilným signálom

1. Vytvorte novú 2G sieť
 - min a max freq 930 a 960 MHz
2. Použite 3x 2G BTS a nájdite pre ne najvhodnejšie umiestnenie
 - 2G BTS charakteristika
 - Transmit power 1000W (60dBm)
 - Receiver threshold -114dBm
 - Dipole
 - High 20m
 - Line loss 2dB
 - 2G UE charakteristika
 - Transmit power 1W (30dBm)
 - Receiver threshold -104dBm
 - Omni
 - High 1.5m
 - Line loss 3dB
3. Porovnať s už vytvorenou 4G sieťou
 - Doplniť chýbajúce eNB
 - Použiť nájdene lokality pre eNB
 - Vytvoriť mapu pokrytia



C. Radio link

1. Porovnajte charakteristiky Fresnelových zón pre nakonfigurované 2G a 4G frekvencie
 1. 2G a 4G základňové stanice - súradnice: 49.18293 N , 18.80587 E
 2. 2G a 4G UE - súradnice: 49.2130 N , 18.7789 E
2. Aký je “The worst case Fresnel” parameter? Vysvetlite.
3. Aký je mód šírenia signálu? Priamy alebo difrakčný?
4. Aká je vypočítaná hodnota signálu vysielaného UE zariadením v mieste základňovej stanice? Je ešte nad úrovňou citlivosti prijímača? Uveďte vplyv a hodnoty v dBm jednotlivých komponentov, okolia a prenosového média.



Ďakujem za pozornosť.



■ Vytvorené v rámci projektu KEGA 026TUKE-4/2021