WIRELESS AND MOBILE PROPAGATION PROJECT

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1. Introduction

Now a days many of the daily jobs are done with the help of Nomadic and Mobile systems. These system access to radio channels which is controlled by a radio base station which sends and receives digital signals from base stations to mobile and nomadic units in order to implement connections (Benelli, Cau, & Radaelli, 1994).

Locating these stations are hard and expensive job if we need to take in to account propagation in a place concentrated with obstacles. To ease this process, we decided to use an amateur software named RadioMobile. RadioMobile is a computer simulation program used for predicting radio coverage of a base station, repeater, or other radio network tools. Ground elevation and various radio parameters are taken into account to predict radio coverage around a single or multiple radio sites (Roger Coudé, 2019).

2. Map Properties

Initially, we need a map to understand the geometry of our area so, according to the project definition we must upload the map of Perugia from the center part and cover an area of 100km × 100km. To achieve this, we have to select the center point that we want to work with.

Two ways proposed for this reason:

1. Select the name of the city (preferred approach).
2. Enter the latitude and longitude from the google map.

According to needed dimension we change the *size* to 100km×100km. [Figure 1]

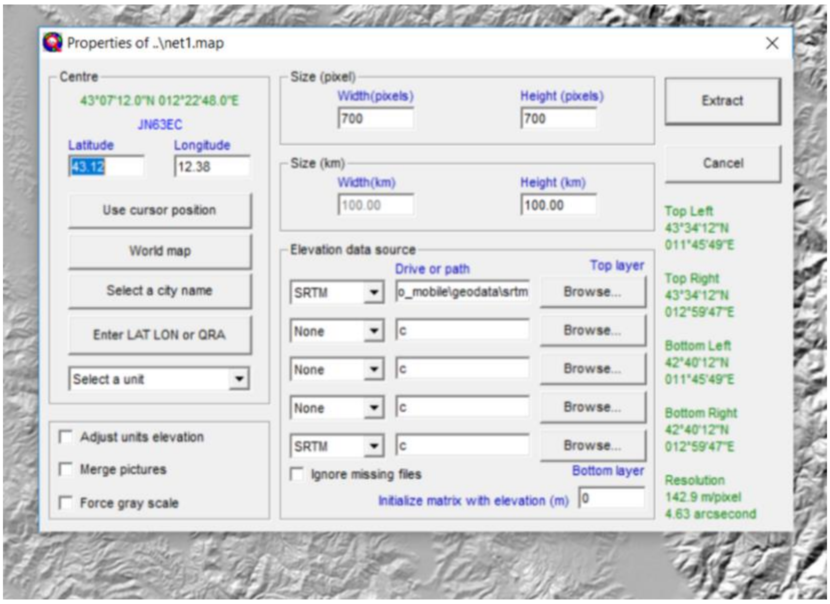

Figure 1. Loading map centered in Perugia with 100km×100 km covered area

According to the map [Figure 2], we decided to put our station on the peak areas. We used the button peak elevation on the tool; evaluating the peak elevations is also possible using the elevation guide on the top of the map.

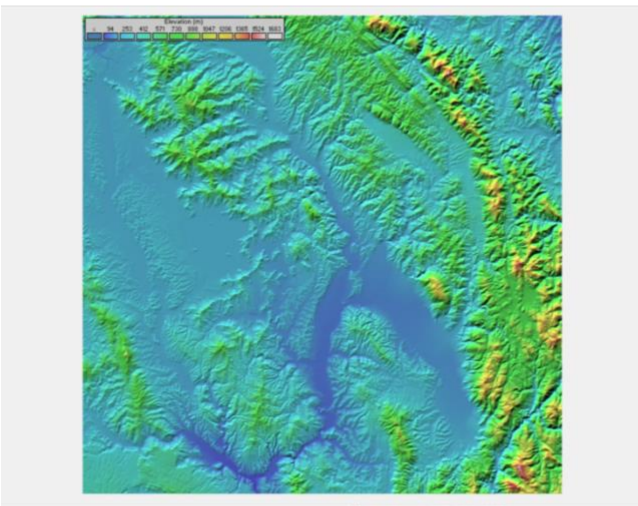

Figure 2. Map of Perugia

3. Network definition

Before implanting the base stations, we must define our networks. We decided to have two networks, one for interconnection (interconnecting network) and, one for the vehicular (broadcasting network).

1- Specifications for *interconnecting* network according to the datasheet of Antenna THP 03 275 S:

Frequency range	27.5 - 29.5 GHz
Gain, low band	37.2 dBi
Gain, mid band	38.0 dBi
Gain, top band	38.5 dBi
Return Loss	17.7 dB
VSWR	1.3
HPBW	2.2 deg
Front to back ratio	64 dB
Isolation	NA
XPD	30 dB
Electrical Compliance	Class 3B
	ETSI 302 217

Frequency range: 27.5-29.5 GHZ
Gain: 38 dBi
Line loss is negligible
Front to back ratio: 64dB

Figure 3. Antenna THP 03 275 S specifications

General Parameters	
Type	Point-to-Point
Application	2G, 3G, 4G, LTE
Frequency	27.5 to 28.35 GHz
Throughput	515 to 630 Mbps
T/R Spacing	450 MHz
Frequency Band	Ka Band
Band	Licensed Band
Latency	Ethernet Latency : 40 to 125µs, TDM Latency : 250µs
Modulation	QPSK, 16QAM, 32QAM, 64QAM, 128QAM, 256QAM, 256QAM
Transmission Power	14 to 19 dBm
Configuration	Outdoor
Integrated Antenna	Yes
Interface	Ethernet : RJ48C/RJ45 Female (x4), Interface Speed : 10/100/1000BaseT (PoE or PoE + ETH2 + ETH3), Duplex : Half, Full, Auto, Compliance: 802.3 with MDIX, VLAN : 802.1q, transparent, trunk, and management only, QoS6 : 8 priority levels, 8 queues 802.1p, 8
Security/Encryption	AES 128-bit and 256-bit
Voltage	48 Vdc
Dimensions	23.9 cm x 23.9 cm x 13.3 cm

Figure 4. Microwave link specifications

To specify the power we should find a microwave link, the specification of the link is shown in [Figure 4]. According to [Figure 4], we have Pmin and Pmax also, after some calculation which is specified below, we can find Rx Sensitivity:
We assume carrier of 100 MHz and Noise Figure of 10dB
Rx Sensitivity = -174 + $10 * log\ (BW)$ + Noise Figure
=$-174\ +\ 10 * log(100 * 10^6)\ +\ 10$
= $-174\ +\ 80\ + 10$
= $-84\ dBm$
Definition of other parameters of the system:

receiver sensitivity: $-84\ dBm$
max power: 19dB (Kong, Mellios, Halls, Nix, & Hilton, 2011)

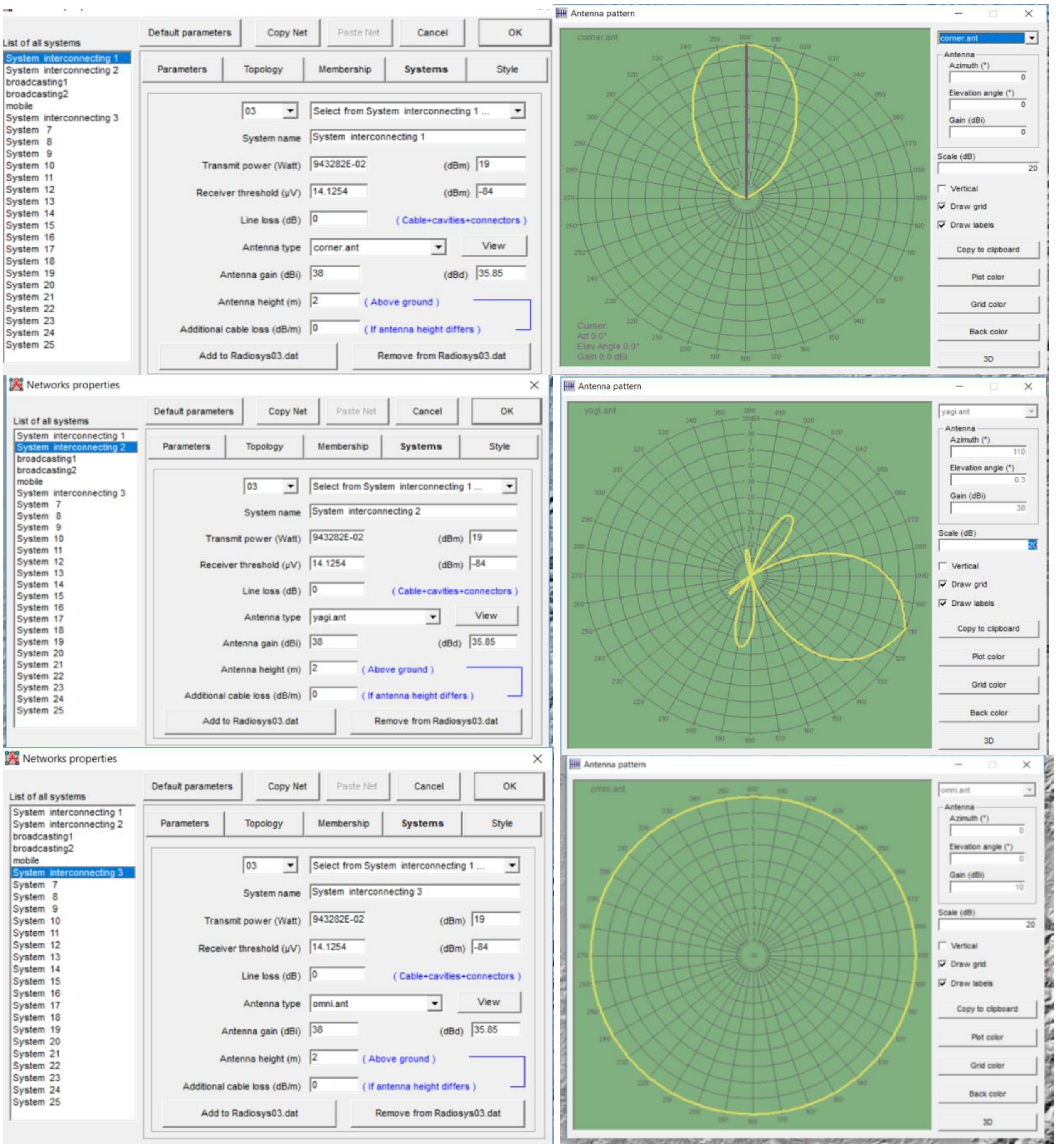

Figure 5. Specification of the systems interconnecting from top to bottom: system interconnecting 1, system interconnecting 2, system interconnecting 3 (left hand pictures) and their antenna patterns (right hand pictures).

The definition of the system specifications for the ***interconnecting*** network for which we set the names to "*system interconnecting 1*", "*system interconnecting 2*", "*system interconnecting 3*", is as stated in the [Figure 5].

We defined 3 systems with 3 different antennae types. Our motivation behind this decision is that first, according to the lectures we should choose antennas with very narrow radiation pattern to stablish point to point microwave-link so, we chose our first type of antenna in Corner mode [Figure 5 top picture]. Second type is Yagi pattern [Figure 5 middle picture] with fixed angles and the third pattern is Omni [Figure 5 bottom picture].

Since we should make sure that each of the two pairs of antennas can see each other we proceeded with two different scenarios:

- First scenario: We assigned to unit 4, Yagi pattern with azimuthal angle $100°$ (So, it will be between unit 1 and unit 2. We gave unit 2 and unit 1 the corner pattern both faced to unit 4. But we need to insert another based station namely unit 5 and assign to Omni pattern. this way all the antennas can see at least 2 other antennas but the problem is that the **gain is not consistent** because in one direction we have high gain and in the another we may have lower gains (for Corner and Yagi). [Figure 6]

- Second scenario: We assign Omni directional pattern to all the unit 1, 2, 4 this way we don't need to add another extra station and all the **gains are consistent** for all the antennas and also, we made sure that all the antennas can see each other. This approach is better since we use less antennas and the gains are constant, but the waste of the power is much more than the first scenario so, from now on we consider this topology for our interconnecting network. [Figure 7]

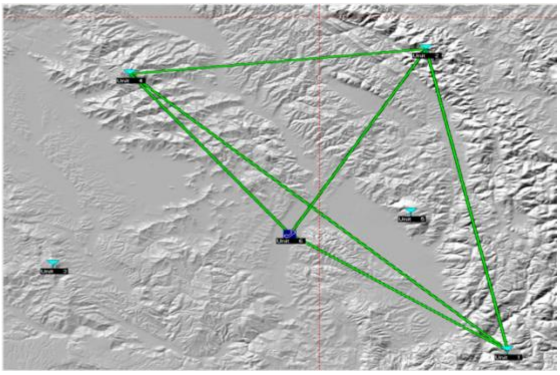

Figure 7. Scenario 2 with Omni directional antennas

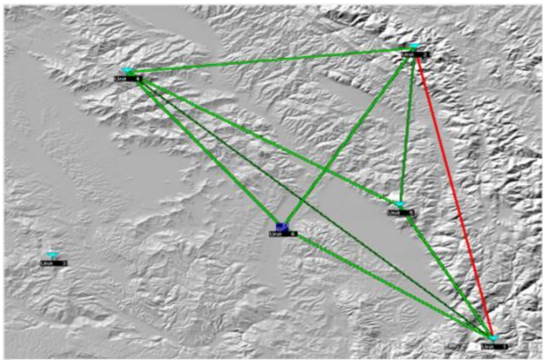

Figure 6. Scenario 1 with multi-pattern antennas

2- Specifications for ***broadcasting*** network according to the datasheet of SLR5100 (repeater):

The second network is connecting our base stations to the vehicular terminal, Motorola EM200, we named this network “broadcasting”.

RECEIVER

Frequency Range	136-174 MHz	400-470 MHz	450-512 MHz	300-360 MHz / 350-400 MHz
Channel Spacing	12,5 kHz / 20 kHz / 25 kHz			
Frequency Stability	0,5 ppm			
Sensitivity (typical)	0,22 uV			
Intermodulation (typical)	82 dB			
Selectivity (TIA603D), 25 / 12.5 kHz 83	83/55 dB	83/55 dB	80/55 dB	55 / 80 / 80 dB
Selectivity (TIA603), 25 / 12.5 kHz 83	83/68 dB	80/63 dB	80/68 dB	68 / 80 / 80 dB
Selectivity (ETSI) 25/12.5 KHz	70/63 dB			
Intermodulation Rejection (TIA603D/ETSI)	82/73 dB			
Spurious Rejection (TIA603D/ETSI)	95/90 dB			
Audio Distortion	<1%			
Hum and Noise (12.5 kHz/25 kHz)	-45 / 50 dB			

TRANSMITTER

Frequency Range	136-174 MHz	400-470 MHz	450-512 MHz	300-360 MHz / 350-400 MHz
RF Output Power	1-50 W			
Max Duty Cycle	100%			
Channel Spacing	12.5 kHz / 25 kHz**			

Figure 8. Repeaters Station Motorola SLR 5100.

TRANSMITTER	Low Power	High Power
RF Power Output	1 - 25W	25 - 45W (VHF) 25 - 40W (UHF)
Modulation Limiting	±2.5 @ 12.5 kHz / ±4.0 @ 20 kHz / ±5 @ 25 kHz	
Hum & Noise	-40dB (VHF) @ 12.5 kHz -35dB (UHF) (UHF) @ 12.5 kHz	-45dB (VHF) @ 25 kHz -40dB (UHF) (UHF) @ 25 kHz
Conducted/Radiated Emissions	-36 dBm < 1 GHz / -30 dBm > 1 GHz	
Audio Response (0.3 - 3 kHz)	+1, 3dB	
Audio Distortion	3%	
Receiver	**@ 12.5 KHz**	**@ 25 kHz**
Sensitivity (12 dB SINAD) EIA (typical)	0.35 µV	
Intermodulation	-65dB (VHF) / -60dB (UHF)	-75dB (VHF) / -70dB (UHF)
Adjacent Channel Selectivity	-65dB (VHF) / -60dB (UHF)	-75dB (VHF) / -70dB (UHF)
Spurious Rejection	75dB (VHF), 70dB (UHF)	
Rated Audio Internal Speaker External Speaker	4W 13W	

Figure 9. Vehicular Terminal Motorola EM 200

According to the data sheet of the Mobile antenna [Figure 9] we can see that the frequency range is between (136MHz, 162 MHz) [figure 9] and, for repeaters (136 MHz, 174 MHz) [Figure 8], as we want the network to work on 158MHz we decided to define our network in the interval of (136 MHz, 162 MHz).

We define 2 systems with Omni [Figure 6] and Cardio [Figure 7] antennas, Omni for the antennas that are more located at the center and Cardio for the corner ones.

The system specifications for repeaters are given in the data sheet of SLR5100 repeater [Figure 8].

Transmit power is between 1-50 W, we decided to put the max power 50 W and get the EIRP = 500 W since the gain is 10dBi

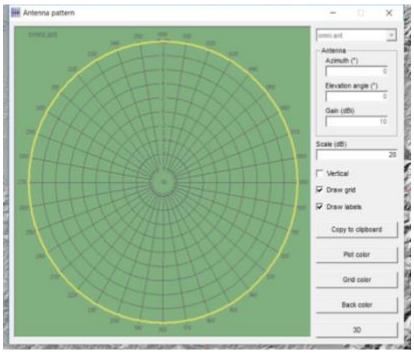

Figure 10. Omni directional

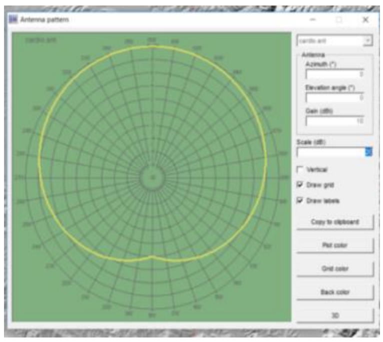

Figure 11. Cardio

The sensitivity is 0.22 μv with a margin of 6dB, we got 0.44 μv for the repeater. Line loss is 2dB.

The system specification for the **vehicular** system according to the data sheet of Motorola EM 200 [Figure 9] is stated below:

- **Power** = 10 W,
- **Gain** = 0 dBi,
- **Sensitivity** = 0.75 μv,
- **Line loss** = 2 dB

4. Network analysis

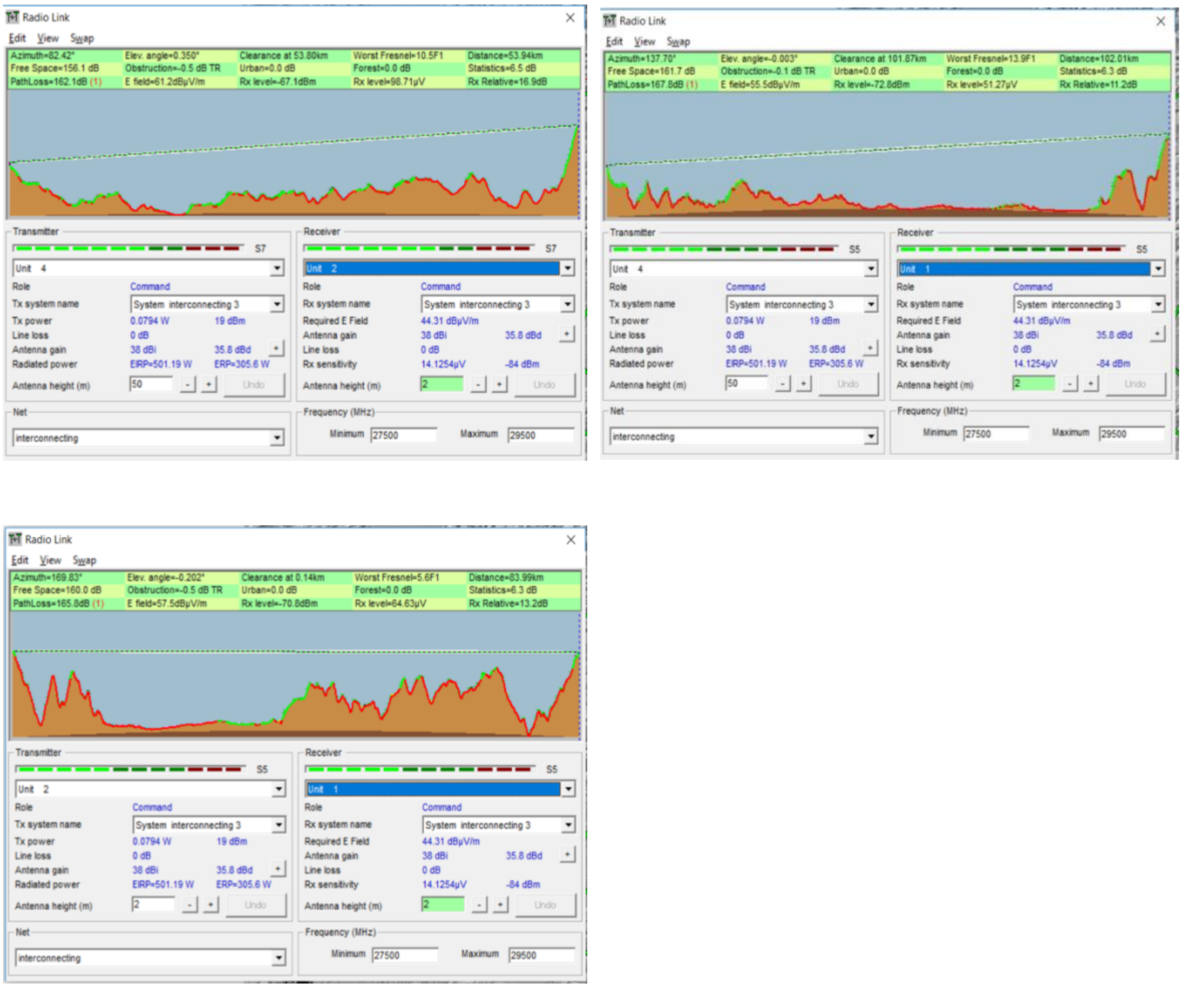

Figure 12. Point to point visibility of two antennas with consideration of first Fresnel ellipsoid.

1- Interconnecting Network

Now it’s time to implant our antenna, we put first antenna (unit 1) at the highest point which we found with peak elevation button, and then we put the second antenna to the second highest point (unit 2). Now we should free the first Fresnel-zone ellipsoid. In the [Figure 12 bottom left] we can see that it is free, and they can see each other.

After that we must put third antenna (unit 4). We put it on the peak of 1107 meter. We can check and see that unit 1 and unit 4 are in range [Figure 12 top right] and the first Fresnel-zone ellipsoid is empty. Now we are sure that unit 1 at least can see 2 other units (unit 4 and unit 2). We put (unit 4) at the height of 1058m. We set all units to “system interconnecting 3”. Now unit 4 can see unit 1 and unit 2. We used the performance report tool to make sure our observations are true. The result is obvious in the [Figure 13] for interconnecting network among those 3 units.

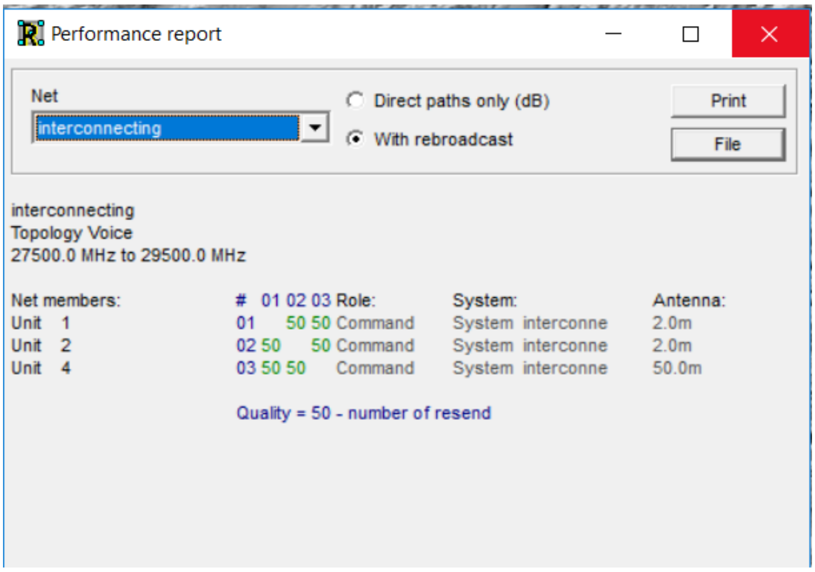

Figure 13. Performance report tool

2- Broadcasting Network

For the broadcasting network first, we tried with 5 base station plus one mobile (used with vehicular network specification)[Figure 9], which we named it unit 6 as it obvious in the [Figure 13] and [Figure 14].

We can understand from [Figure 13] that 5 base stations are too much, so we decided to reduce them to three. We got the coverage of units 1,2,4 and we have them, two by two line of sighted, as it mentioned in previous section (section 4).

The resulting combined coverage is shown. [Figure 14]

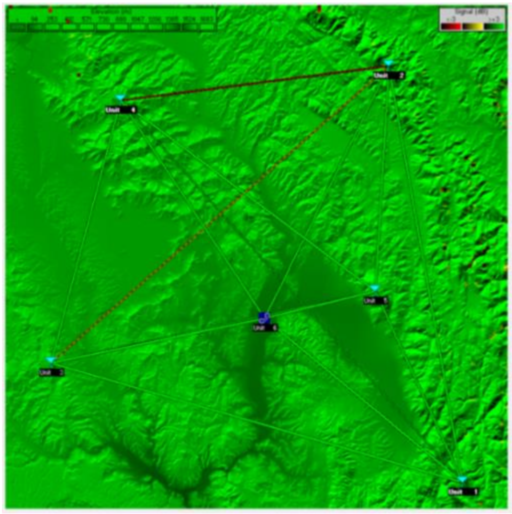

Figure 13. First scenario combined coverage

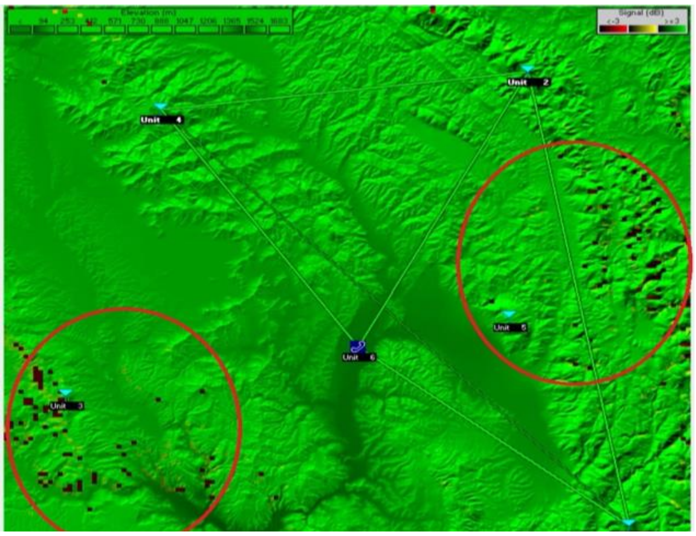

Figure 14. Second scenario combined coverage

As we can see at [Figure14], the red areas are increasing in comparison to the first scenario but, these areas are around mountains and the system performance is not damaged too much.

Below you can find the unit by unit radio coverage.

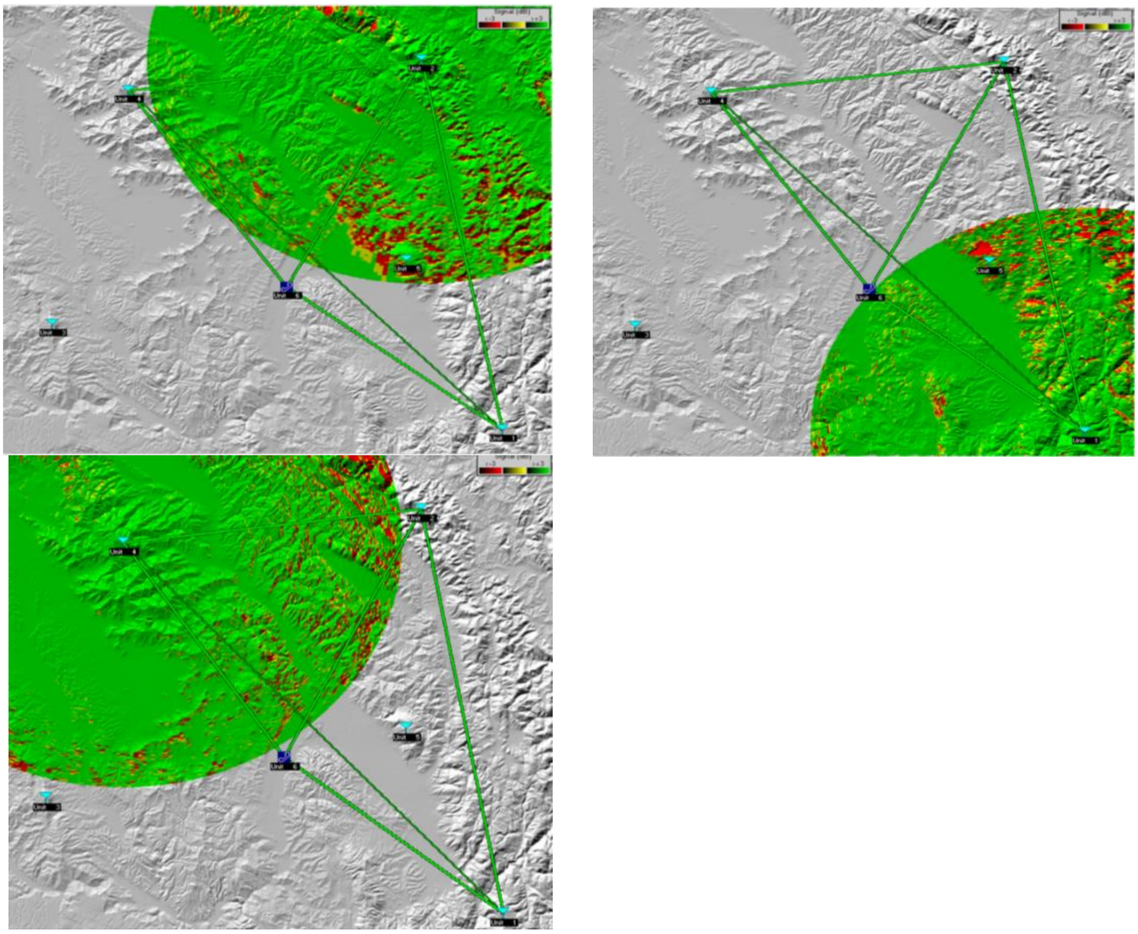

Figure 15. Unit by unit radio coverage. (top left unit 2, top right unit1, bottom unit 4)

Below we visualized visual coverage for each unit.

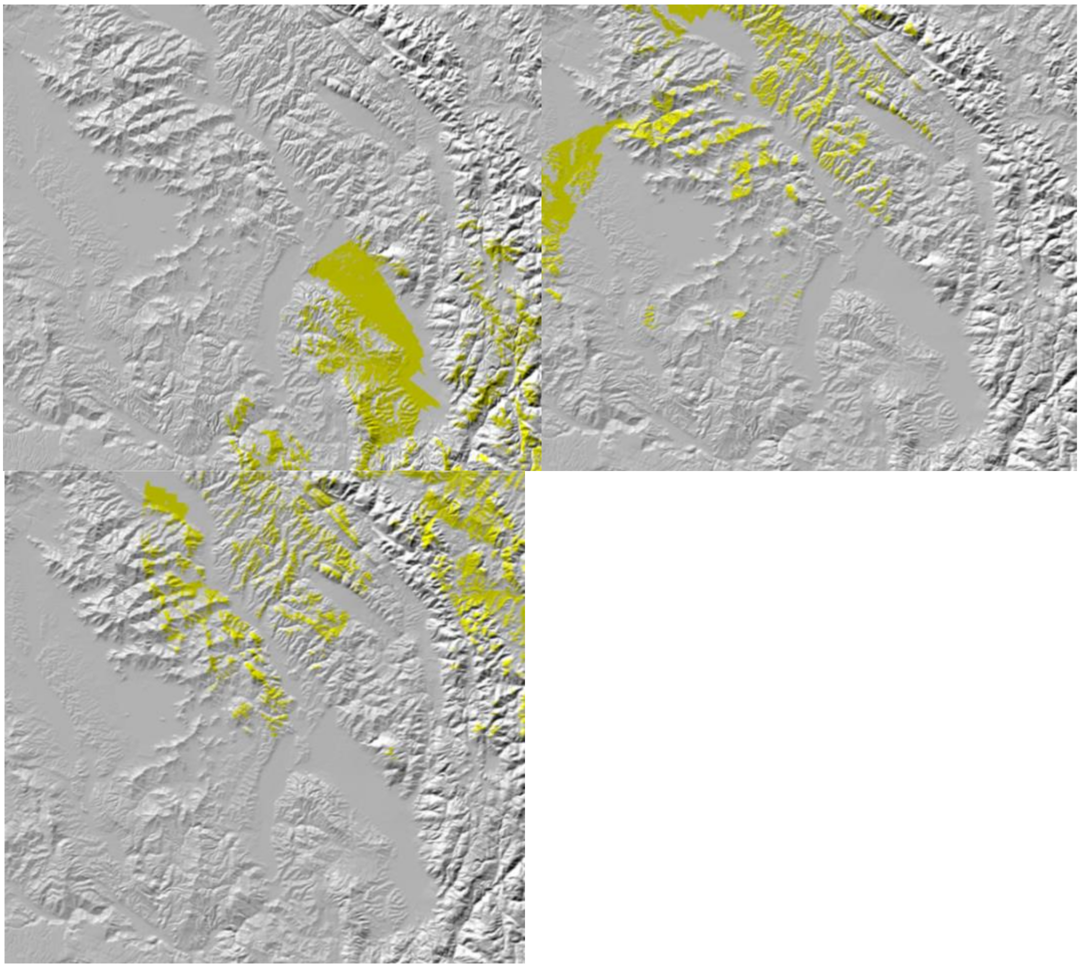

Figure 16. Visual coverage for each unit. (top right unit 1, top left unit 4, bottom unit 2)

5. Geometry analysis

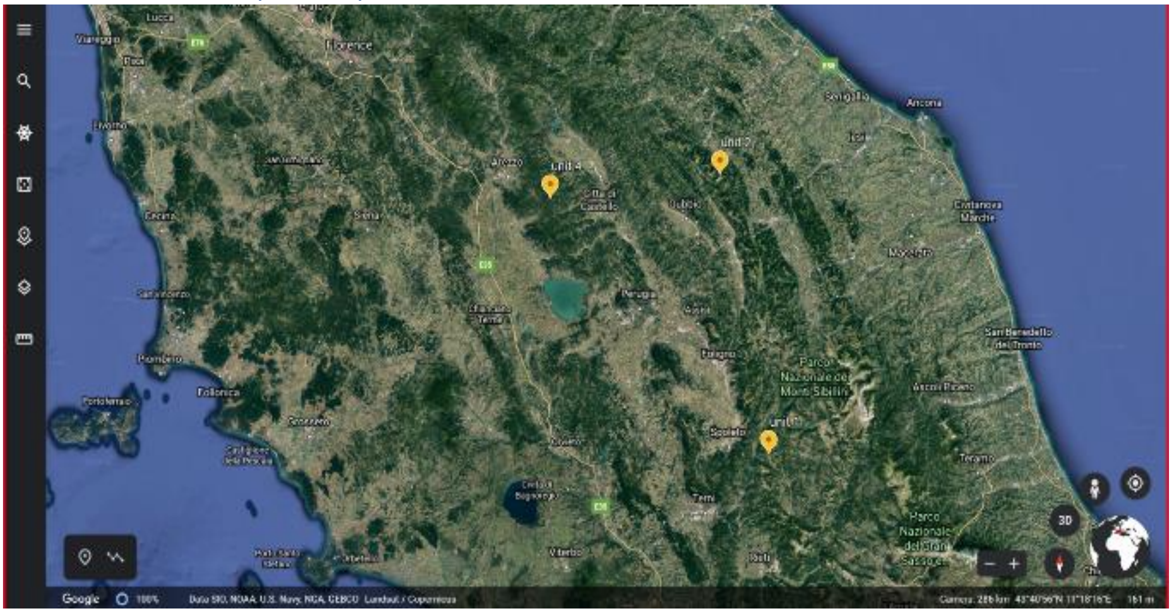

Figure 17. overview on Perugia and Units

For better visualization of our geometry we decided to use Google earth. After putting our units in the google earth application we get our geometry like in [Figure 17]. We divided the geometry to three different areas: Mountain area, Lake area and City area.

1- Unit by unit analysis:

- Unit 2: (Mountain area)
  This unit is located at the highest point in the area we can observe that [Figure 18] our antenna is not surrounded by trees, mountains, etc. So, we decided to keep the default height (2m). This area is a very efficient point to put our antennas we can see that after the mountains it is almost valleys which it can help to propagating signal better.

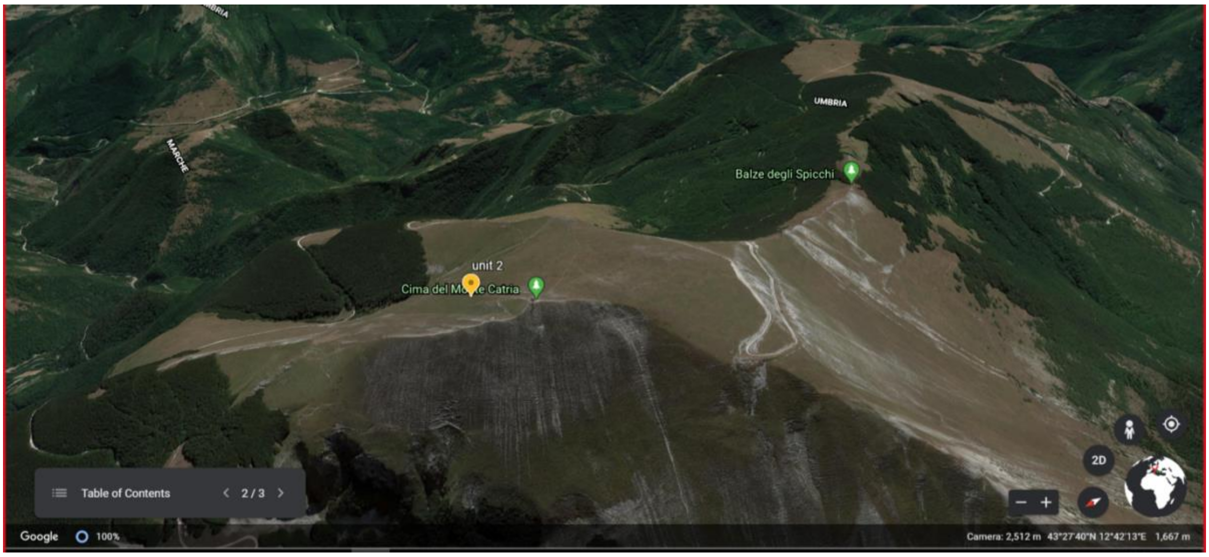

Figure 18.Geometry of Unit 2

- Unit 4: (lake area)
  By analyzing the area [Figure 19], it is one of the highest points on the left part of map, we realized that there are a lot of trees, and obstacles around are variant so, we are facing a rough area. we decided to increase the height of unit 4 to 50m (it must be taller than the trees which are surrounding the unit).

Figure 19.geometry of unit4

We can see that unit 4 is near a lake [Figure 20]. While it can be a touristic place, implementing a base station which can support this area is important. The height of both antennas 4 and 2 are higher than their intermediate obstacles and they can see each other as also mentioned previously, and their first Fresnel ellipsoid is free in the interconnecting system.

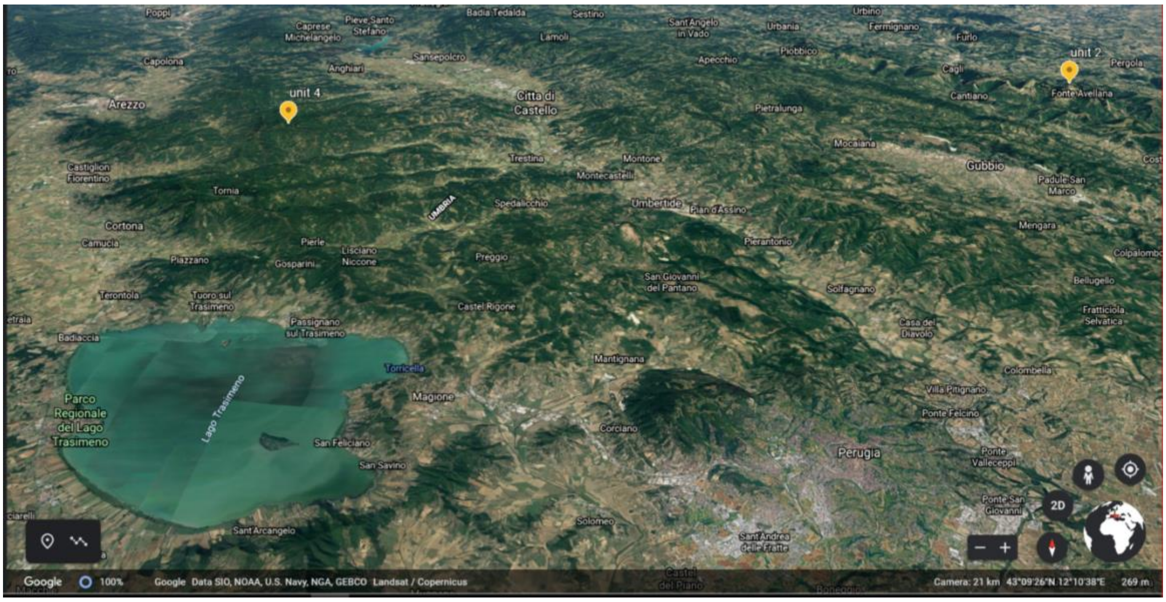

Figure 20. lake geometry

- Unit 1: (city area)
  We can see that unit 1 is near the city area [Figure 21]. We can put base station on a top area (like a backhauling base station) which can provide a good coverage on the city. Again, for dense streets we can implant microcells and femtocells. They also must be connected to the interconnecting network.

Figure 10. geometry of unit 1

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