Politecnico Di Milano

School of Industrial and Information Engineering

Wireless and Mobile Propagation Project

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Chapter 1

Introduction

In this project, we designed a private mobile radio in Shahr-e Bābak City, Iran. Our goal is digital communications over a 100 km × 100 km (a square area centered around the city) of the network's design. This project focuses on creating a strong and reliable communication system.

We used radio mobile software to plan and analyze the network during the design process. System parameters such as frequency and antenna gain are given by datasheets to ensure high availability and performance. In the following, we explain the design of microwave links, PMR network structure, and the coverage area.

The Shahr-e Bābak city that we want to design the PMR network for is shown in Figure 1.1.

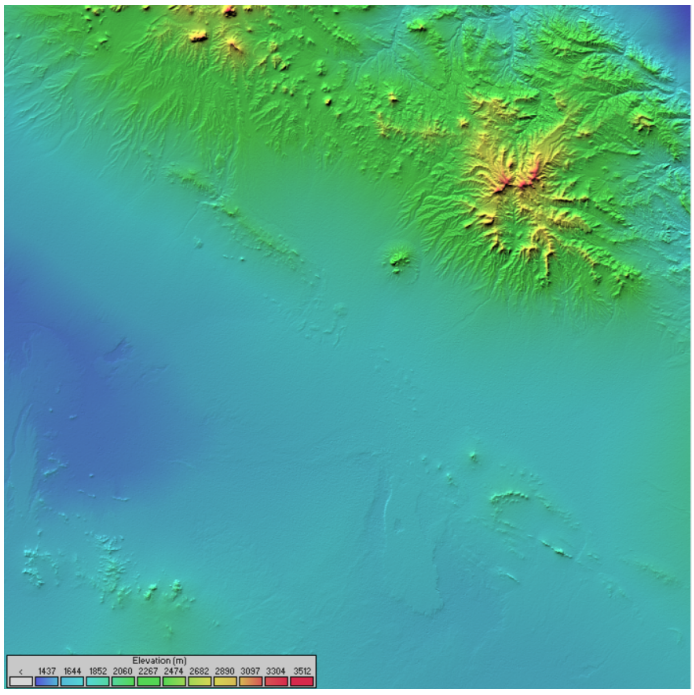


Figure 1.1: Center of the area of interest

We should minimize the number of repeaters and consider tall buildings or mountains as a good place to locate repeaters. There are some specifications that we should consider.

- **Radio Network Specifications:**
  - Operating frequency: 166 MHz.
  - Modulation type: ETSI Digital Mobile Radio (DMR).
  - Repeater stations (DMR): Motorola SLR5500
  - Vehicular terminals (DMR): Motorola DM4000e
  - Vehicular antenna gain: 0 dBi.
- **Microwave Link Specifications:**
  - The repeaters must be interconnected using point-to-point microwave links.
  - One repeater must see a minimum of two other repeaters to guarantee reliable routing.
  - Frequencies and antenna sizes based on link length (7–38 GHz).
  - Minimum link margin must be at least 10 dB above the modulation threshold.

Chapter 2

PMR Network Design

In this section we explain about two networks that help to reach full area coverage: the VHF Network and the Microwave Network.

2.1 VHF Network

Very High Frequency (VHF) Network works at 166 MHz. The parameters of this network are shown in Figure 2.1. Ensuring dependable, comprehensive coverage for all mobile customers across the region was the main objective.

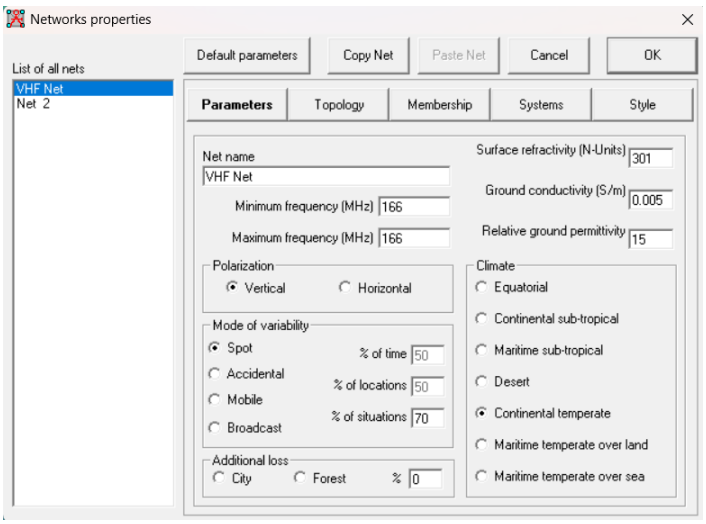


Figure 2.1: VHF network

Each mobile user can easily connect to the nearest repeater and carefully positioned locations. In the following, we will explain about mobile unit and repeater configuration.

In the mobile unit, the digital sensitivity of the mobile radio is 0.18 µV, which is better than that of the repeater (0.22 µV). We fixed the transmitter power at 40W. The mobile units were configured to operate at 166 MHz using DMR digital. As cars move around,

the mobile radios seamlessly communicate by automatically connecting to the area's strongest repeater signal. Assuming 0 dBi antenna gain for mobile devices was necessary for the project. The properties of the mobile unit are shown in Figure 2.2.

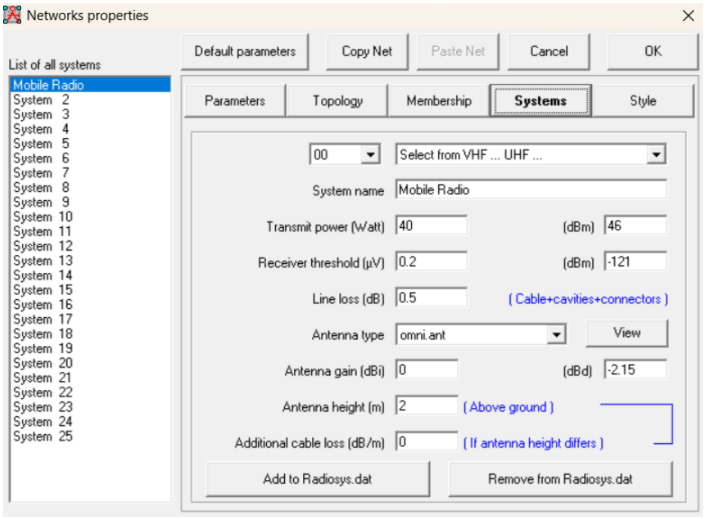


Figure 2.2: Mobile unit configuration

The project specifications included the Motorola SLR5500 repeater. The properties of the repeater are shown in Figure 2.3. The transmit power is 50 W, the receiver sensitivity is 0.25 uV, the antenna gain is 5 dB, the antenna height is 10 m. We choose RT 50/20 coaxial cable. This coaxial cable is low-loss and utilized for VHF applications, because of its attenuation characteristics around 166 MHz. The RT 50/20 coaxial cable datasheet states that the attenuation is 6.0 dB per 100 meters at 200 MHz, which is the nearest frequency to 166 MHz. So, we put the line loss is 1 dB.

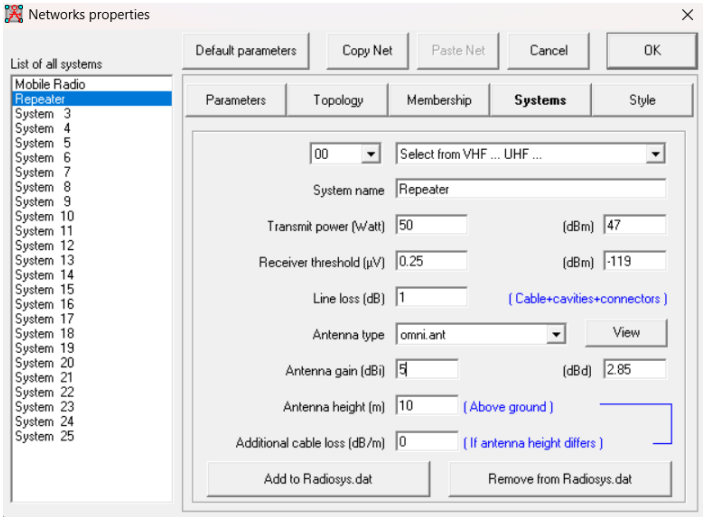


Figure 2.3: Repeater configuration

2.2 Microwave Network

Point-to-point microwave links that operate at a higher frequency than the VHF network are used in the backbone network design. The goal is to dependably connect all repeater locations and guarantee that signals are distributed quickly and uniformly throughout the coverage region. The microwave network configuration is shown in Figure 2.4.

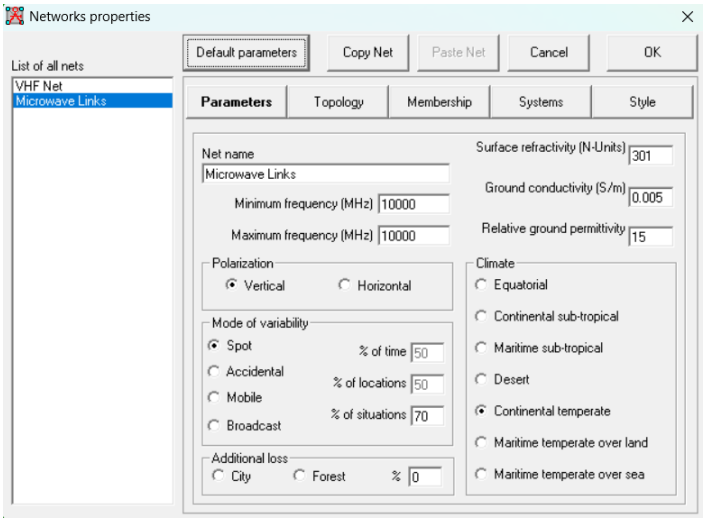


Figure 2.4: Microwave network configuration

According to the project specifications, the microwave backbone had to operate in the 10 GHz frequency spectrum because of the distance between the repeater sites. The 10 GHz band is widely utilized and well-supported by commercial microwave equipment. We also configured the microwave radio unit. Figure 2.5 shows the microwave radio configuration.

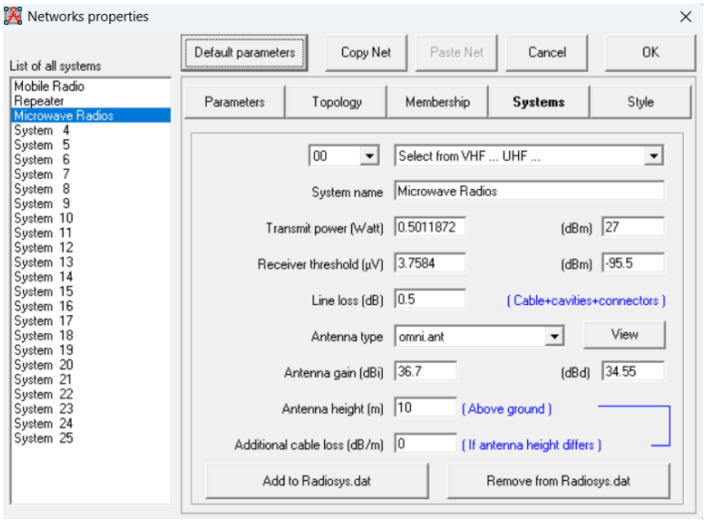


Figure 2.5: Microwave radio configuration

Based on our requirement, we decided to use the PTP 820S microwave radio. This microwave radio works from 6 to 38 GHz. The transmitter power is 27 dB, and the receiver

sensitivity is -95.5 dB. For optimal performance and fade protection, smart modulation (QPSK to 2048 QAM with adaptive adjustment) is used. For point-to-point microwave communications between repeater sites, the antenna must be selected. We select antenna THP 08 100 D WB. The frequency range of this antenna is 10 to 11.7 GHz. The antenna has a 0.8 diameter, 842 mm height, 814 mm width, and 434 mm depth. The gain of midband that we chose for our work is 36.7 dBi.

Chapter 3

Results

3.1 Location of Repeaters

Because higher altitudes improve radio signal propagation at VHF frequencies, the repeaters were positioned strategically on mountaintops to achieve excellent coverage using the prescribed repeater model. We use three repeaters to cover all the area of Shahr-e Babak City. In Figure 3.1, the areas that repeaters covered are shown. On the right side of the entire area, the first repeater was positioned at the highest point. The highest point in the whole area was where the second repeater was positioned. The third repeater is located in the northeast part of the area. The repeater positions are displayed in Figure 3.2

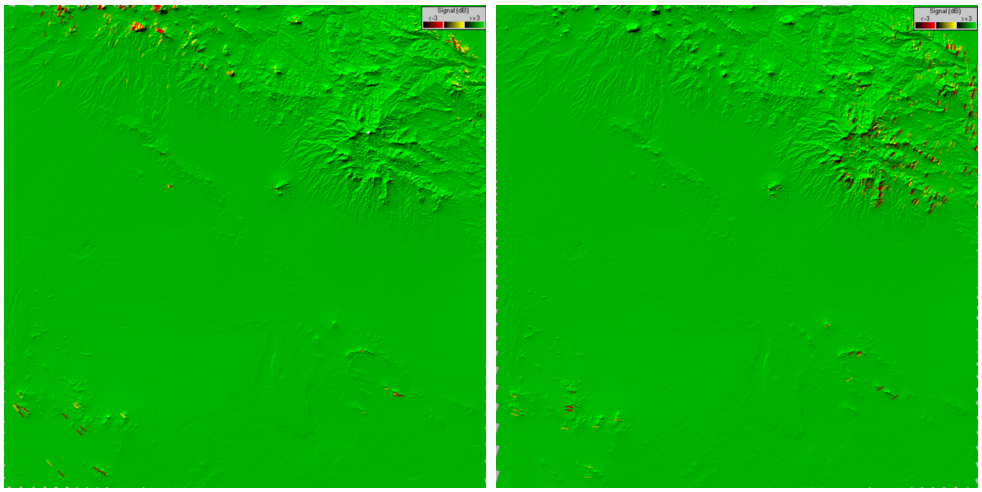
Although we could cover the entire area using two repeaters, considering that one repeater must see a minimum of two other repeaters to guarantee reliable routing. We minimize the number of repeaters, as required by the project criteria. Each repeater can establish redundant signal paths by communicating with a minimum of two other repeaters through microwave links. The network will continue to function even if a repeater fails thanks to this redundancy.

The network configuration achieves full coverage, as shown in Figure 3.3. It gives a clear representation of how coverage is distributed throughout the area.

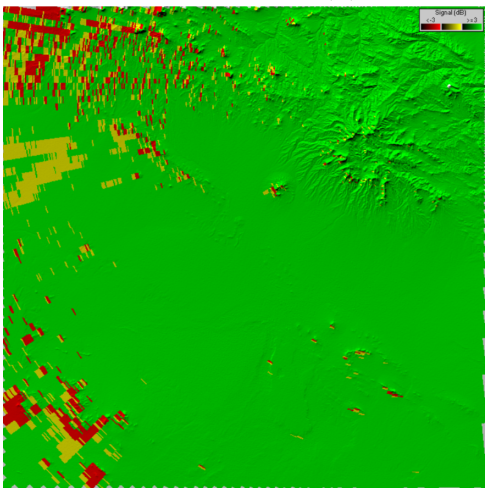
Also, we examined the connection between radio links. In Figure 3.4, you can see the connection between microwave radio 1 and microwave radio 2. The link between them is green; it means there is no blockage. The received signal is 41.3 dB higher than the threshold. The link between microwave radio 1 and microwave radio 3 is shown in Figure 3.5. The received signal is 49.6 dB higher than the threshold. Finally, the link between microwave radio 2 and microwave radio 3 is represented in Figure 3.6. The received signal is 39.8 dB higher than the threshold. As you can see, the links between microwave radios are working well.

To ensure the signal quality and analyze performance, we show the network report. For assessing coverage and link quality, these reports are crucial. The network report is shown in Figure 3.7.

Finally, we calculate the percentage of the area covered with Python code. Here is the code: Percentage of area covered (WMP) The result is shown in Figure 3.8. 99.78 percent of the whole area is covered, and that displays our good performance.



(a) Coverage of repeater 1 (b) Coverage of repeater 2



(c) Coverage of repeater 3

Figure 3.1: Individual coverage areas of the repeaters

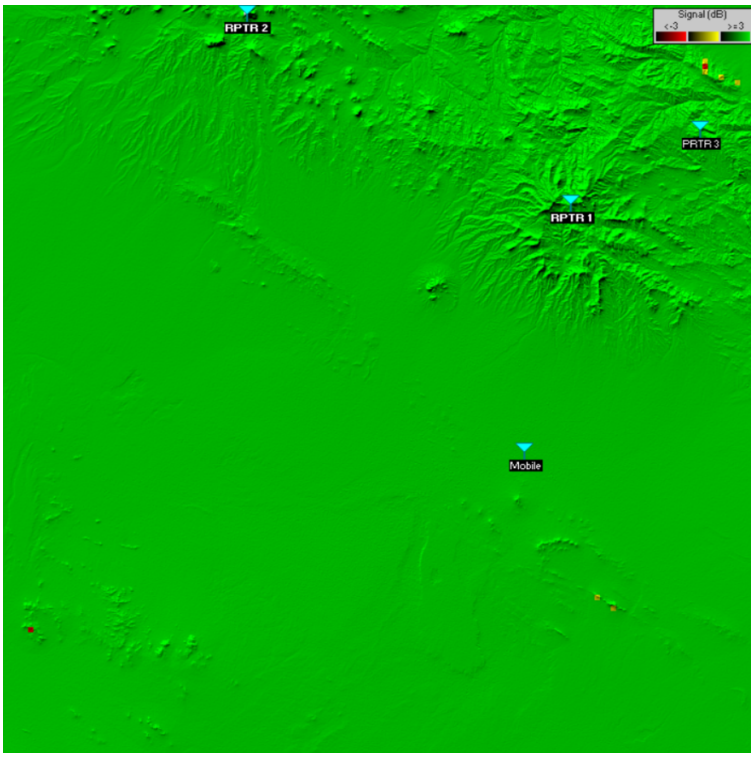


Figure 3.2: Repeater positions

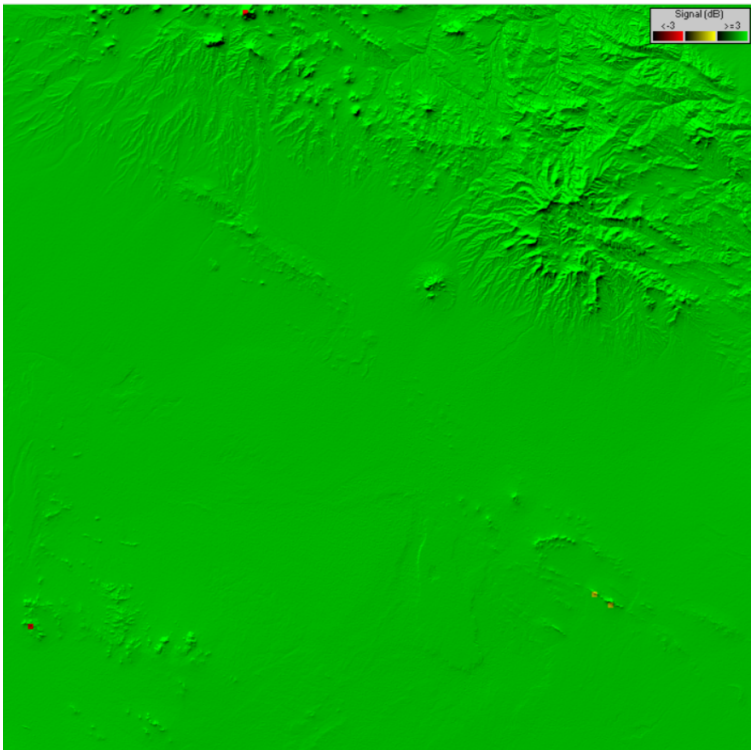


Figure 3.3: Coverage of the whole area

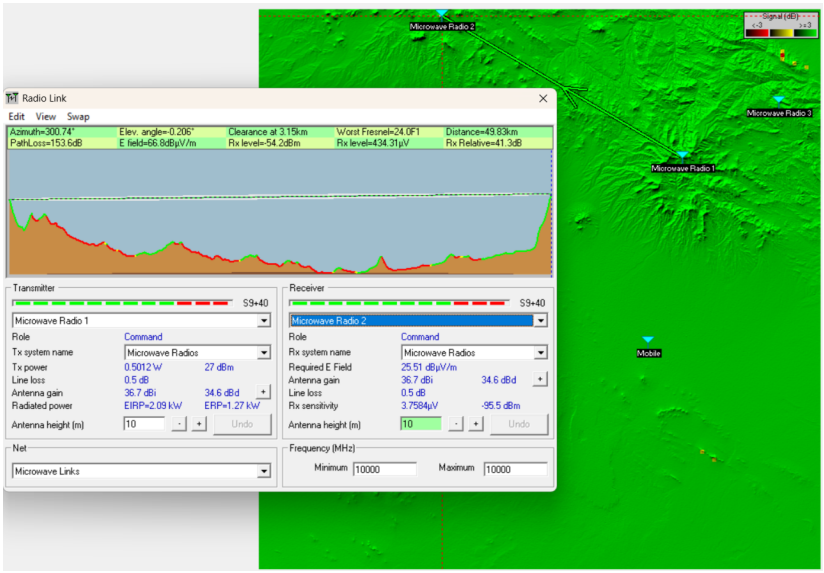


Figure 3.4: Connection between microwave radio 1 and microwave radio 2

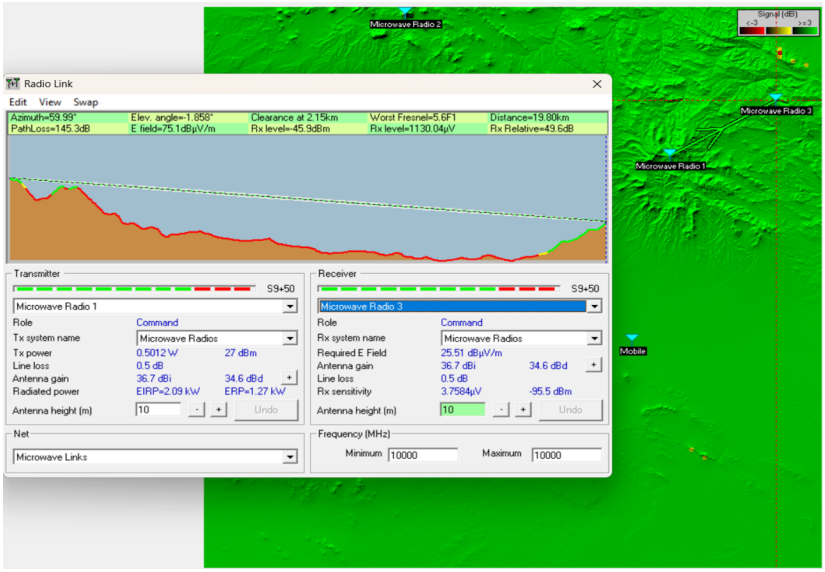


Figure 3.5: Connection between microwave radio 1 and microwave radio 3

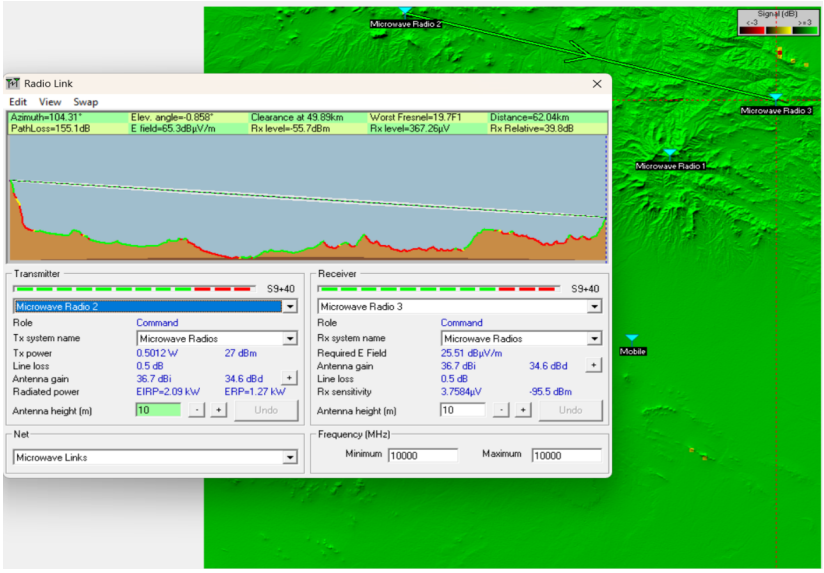


Figure 3.6: Connection between microwave radio 2 and microwave radio 3

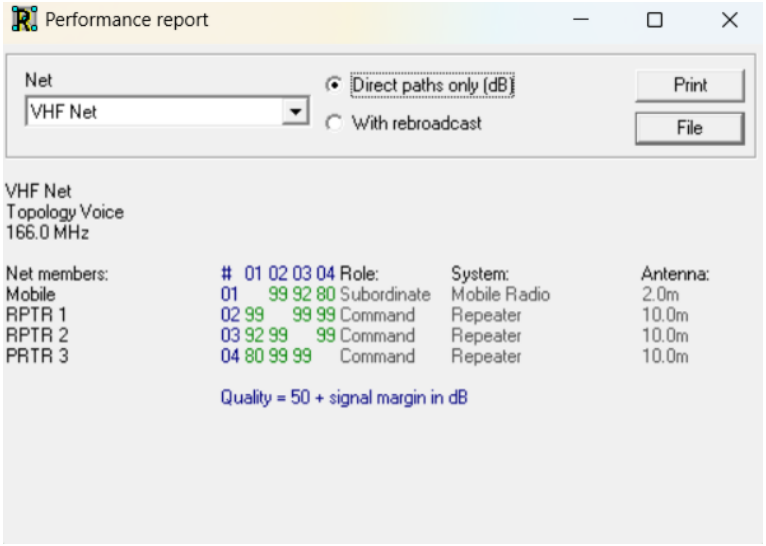


Figure 3.7: Network Report

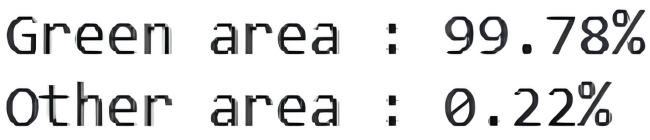


Figure 3.8: Percentage of a covered and not covered area

Chapter 4

Conclusions

For Shahr-e Bābak City, this project effectively planned and put into place a comprehensive PMR network. By positioning repeaters at higher altitudes, the final network topology was created to optimize coverage. When paired with microwave links, these well-chosen locations provide strong connectivity and offer routing redundancy to improve network dependability. In terms of user interface, mobile units use a DMR channel at 166 MHz. The nearest repeater picks up the signal from a portable radio transmission and sends it into the microwave network.

In order to ensure continuous radio coverage over the whole 100 km $\times$ 100 km service area, the planned PMR network depends on a constellation of three repeaters that are positioned strategically atop mountain peaks. In order to create a fault-tolerant ring topology that maintains network integrity even in the event of individual link failures, each site keeps two point-to-point linkages to at least two nearby stations.

Mobile units use 166 MHz for operation. The nearest repeater picks up the signal from a portable radio transmission and sends it into the microwave network, which then propagates the traffic in real time to every other repeater location. Finally, the project effectively produces a PMR network that satisfies the established requirements. This design highlights the effectiveness of strategic planning and technology selection in providing reliable communication services to professional users across the target geographic region.