Wireless and Mobile Propagation Project
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1. Introduction

This project was a part of wireless and mobile propagation course held by Prof. Michele D'Amico. By doing this activity we learn how to work with Radio mobile software. Using this software, we can predict radio coverage and propagation condition. Combining with everything we learn from lectures now we can design a private network and see different scenarios. After setting up all base stations, we used an Image processing code in Matlab to measure radio coverage precisely.

2. Radio network characteristic

The project is about designing a radio mobile network in UHF band. Our network includes mobile terminals which they communicate to each other using repeaters (base stations). Base stations are connected to each other via PTP microwave link. Characteristics of radio network are as follows:

- Covered region: a 100 km x 100 km square area centered around the city of Redmond, Oregon, USA
- Requested coverage: equal or larger than 98% of the territory
- Frequency of operation: 453 MHz
- Modulation type: Analog FM (F3E)
- Repeaters' interconnection: point-to-point microwave links at 28 GHz

- Repeater stations (PMR): Motorola SLR5100
- Vehicular terminals (PMR): Motorola EM200

Fig. 1. This is hybrid (aerial and roads) image of interested area.

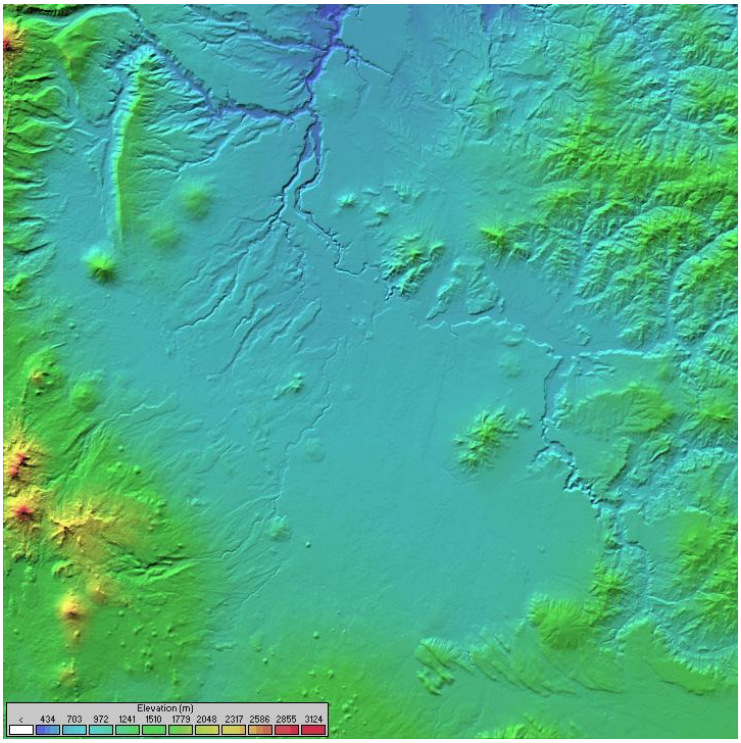


Fig.2.This image shows elevation. Warmer color means higher altitude

PRODUCT DATA SHEET
MOTOTRBO SLR5100 REPEATER

GENERAL SPECIFICATIONS

	VHF	UHF BAND 1	UHF BAND 2	300 MHz
Frequency Range	136-174 MHz	400-470 MHz	450-512 MHz	300-360 MHz / 350-400 MHz
Channel Capacity	64			
RF Output Power	1-50 W			

TRANSMITTER

Frequency Range	136-174 MHz	400-470 MHz	450-512 MHz	300-360 MHz / 350-400 MHz
RF Output Power	1-50 W			

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			

PRODUCT SPEC SHEET
EM200 INDUSTRIAL MOBILE RADIO

Receiver	**@ 12.5 KHz**	**@ 25 kHz**
Sensitivity (12 dB SINAD) EIA (typical)	0.35 µV	

TRANSMITTER	**Low Power**	**High Power**
RF Power Output	1 - 25W	25 - 45W (VHF) 25 - 40W (UHF)

Fig.3. Spec sheets of Network 2

.

Technical data

DUAL POLARIZATION

ANTENNA 28 GHz 03M

HIGH PERFORMANCE

Type: HAE2803DPB320, HAE2803DUB320

LEAX
ARKIVATOR TELECOM

Electrical data

Frequency range	27.5 – 29.5 GHz
Gain, low-band	37.0 dBi
Gain, mid-band	37.6 dBi
Gain, high-band	37.8 dBi

Fig.4. Spec sheet of Network 1 associated antenna.

Specifications PTP 820S SPECIFICATION SHEET

	Frequency (GHZ)								
Transmit Power (dBm)	6	7	8	10-11	13-15	18	23	26	28-38
QPSK	29	28	28	27	24	22	20	21	18

MODULATION	6	7	8	11	13	15	18	23	26	28	31	32	36	38
QPSK	-93.0	-91.5	-91.0	-92.5	-92.0	-91.0	-92.0	-90.5	-90.0	-90.5	-90.5	-91.5	-89.0	-88.5

Fig.5. Spec sheet of Network 1 microwave link

3. Network parameters

We are using two networks. Network 1 is working at 28 GHz which connects repeaters to each other using PTP microwave links. Network 2 works at 453 MHz and connects repeaters with vehicular terminals. For Network 1 all repeaters can see each other. This means first Fresnel ellipsoid must be free to have radio visibility. Since all repeaters can see each other, we have a perfect routing. For network 2 we used Omnidirectional pattern to reach maximum coverage. Omni pattern is shown in figure below:

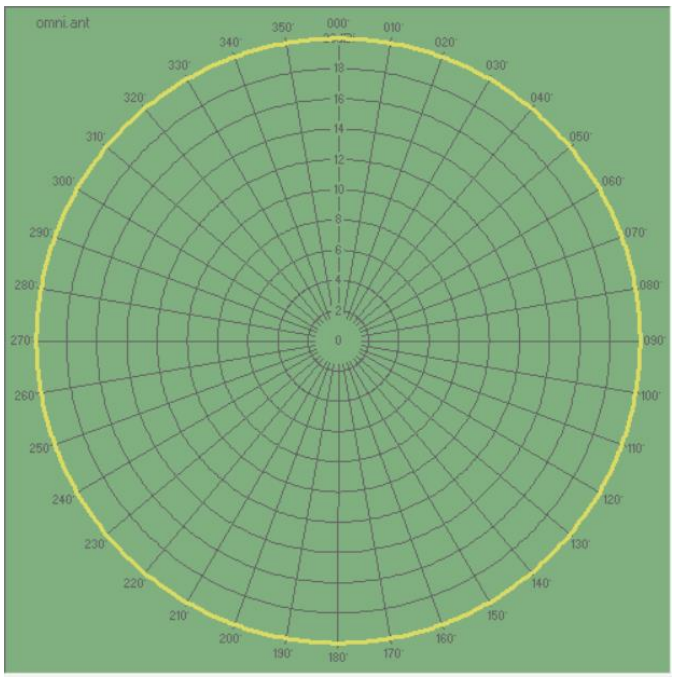


Fig.6. Omnidirectional pattern

We need to define systems for our networks. For Network 2, from repeater specification sheet we assign 50W as transmitted power and antenna gain of 10 dBi so our EIRP is 500 W. For

Network 2 we need a mobile terminal with Omnidirectional antenna and gain of 0 dBi. Also, we assign 10 W for transmitted power according to specification sheet. For sensitivity we add 6 dB as margin to consider worst case scenario. So, for repeater and mobile terminal sensitivity is 2 x 0.22 uv and 2 x 0.35 uv, respectively.

For network1 which is a point to point microwave link working at 28 GHz from specification sheet we assign 63 mW (18 dBm) as transmitted power, antenna gain of 37 dBi and sensitivity of 17.78 uv (-82 dBm). Here we also consider 8 dB margin for worst case scenario. In this case ERIP is 316 W.

4. Base station location

To achieve maximum coverage, it is better to place repeaters on top of hills and mountains. To do this we select each area and then by clicking on "Find peak elevation" tool we can find highest point in selected area. After finding best spots we select best possible points to reduce number of base stations without losing coverage, this is how we design our topology. Since our selected locations are on top of mountains, we are able to reach maximum covered area with only 8 base station. Figure below shows best possible scenario to have coverage more than 98% of area.

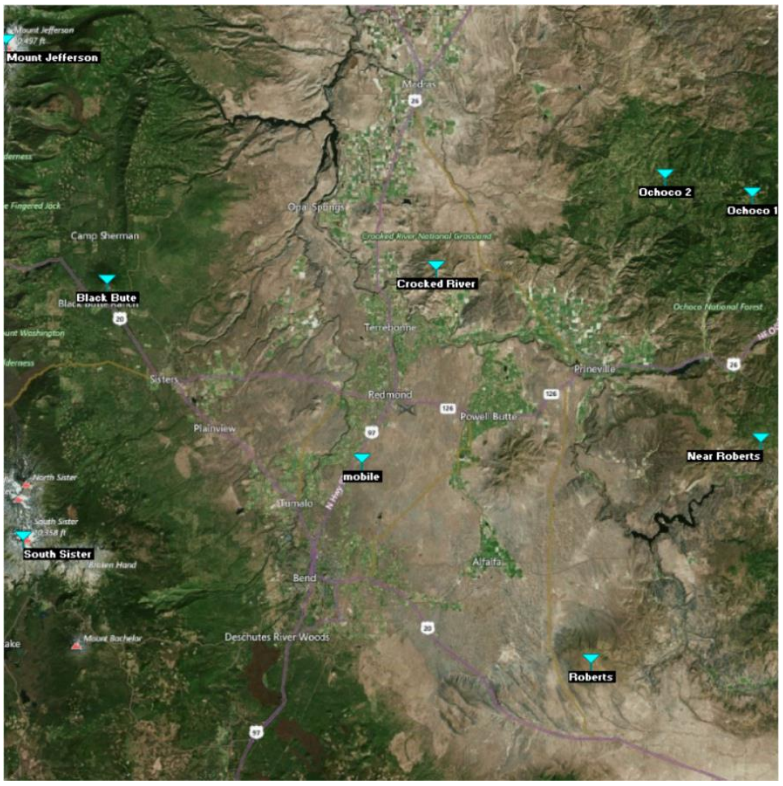


Fig.7. Location of Base station and mobile unit

5. Link dimensioning

To check if PTP microwave link is working fine and we have radio visibility, Network report tool and Radio link tool were used, respectively. By using Radio link tool, we can check state of first Fresnel ellipsoid between two repeaters. Using Network report tool, we can see state of our network through a matrix. Since our topology was designed cautiously all links between repeaters are green in matrix which means our network works perfectly. Following figures are results of using these tools:

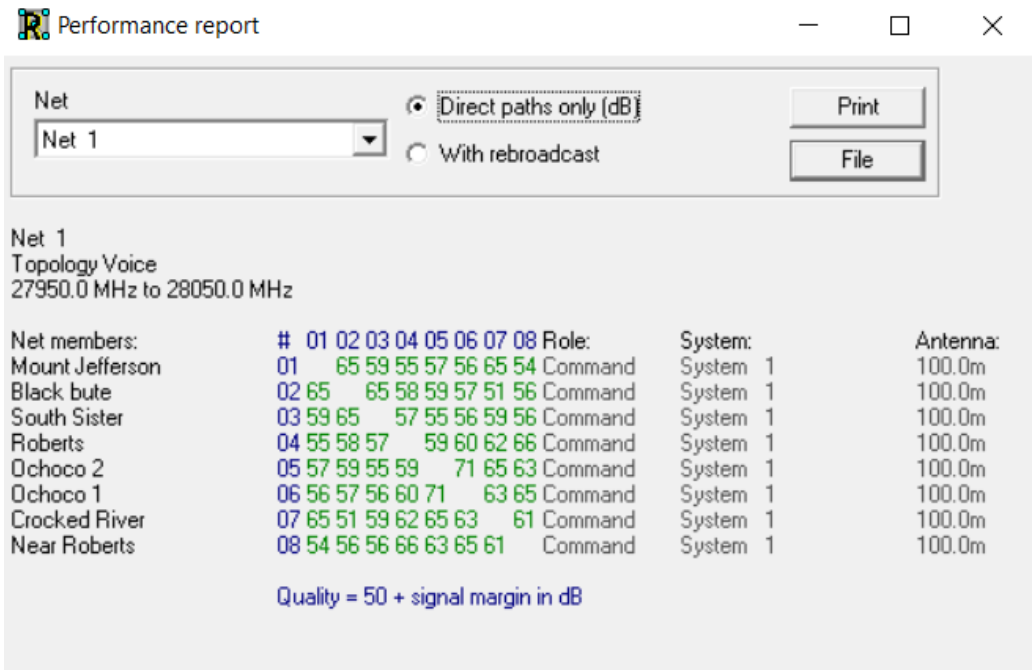


Fig.9. Network report tool and height of antenna.

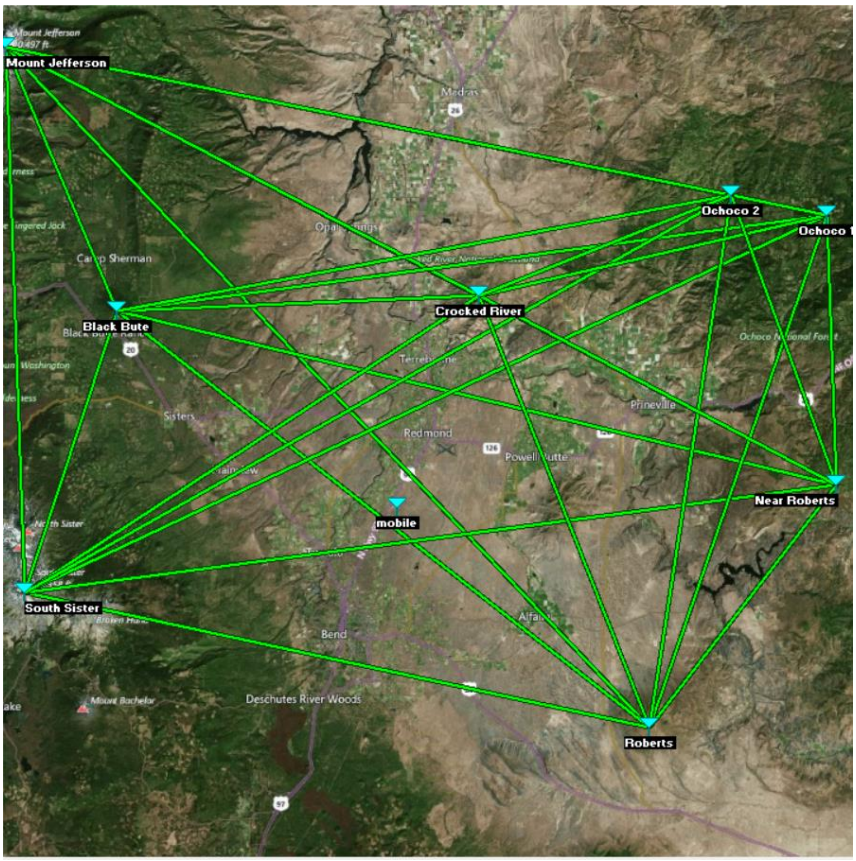


Fig.10. Network 1 topology

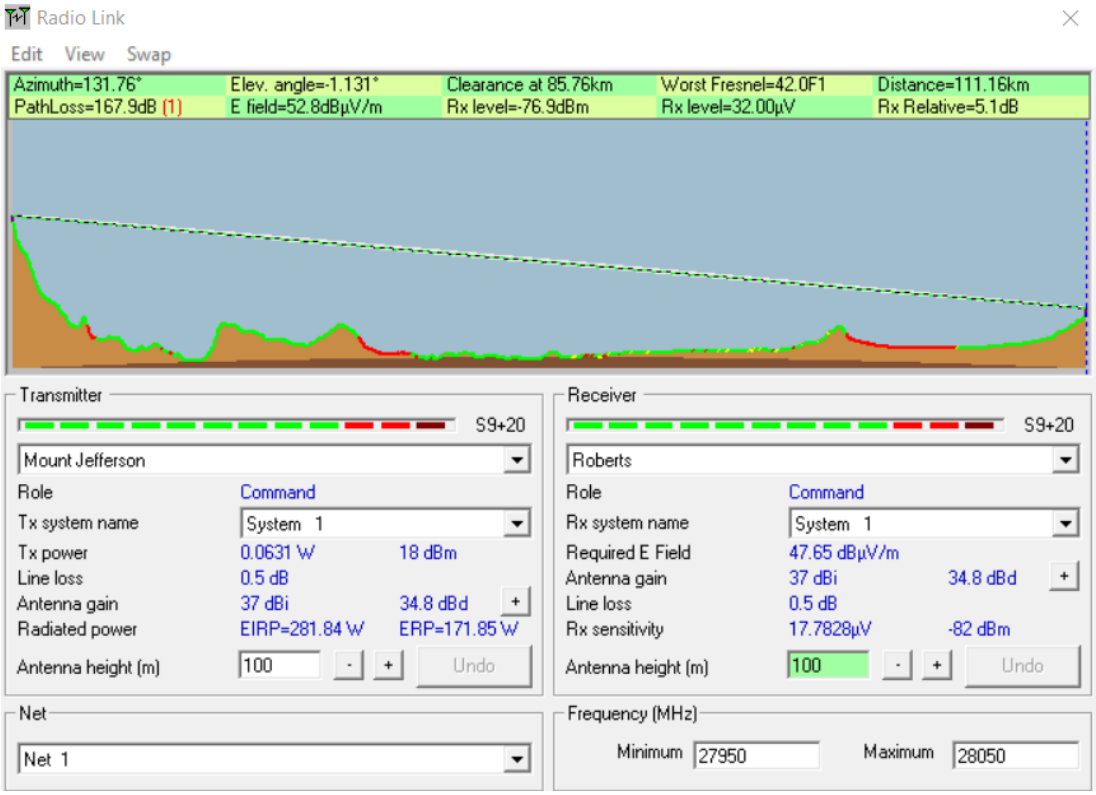
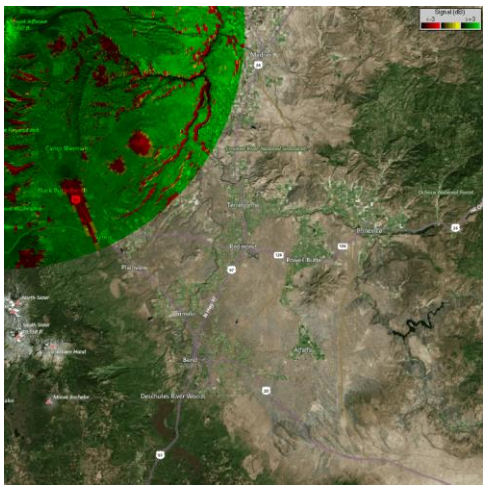
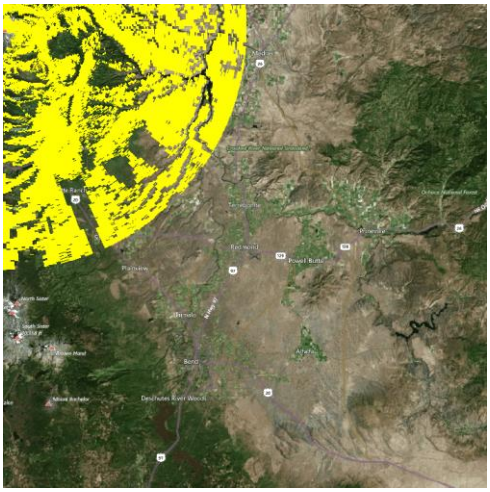


Fig.11 Radio link tool. longest distance between two repeaters

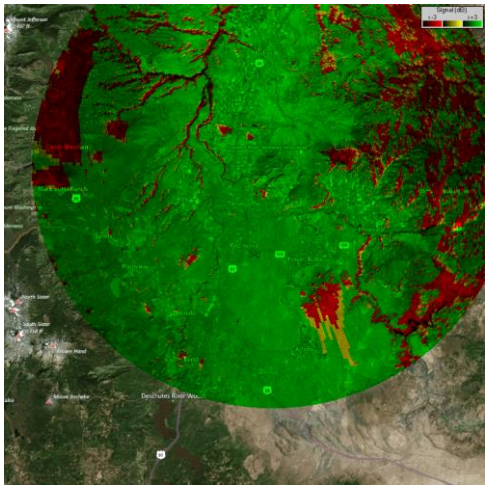
6. Unit by unit analysis and final coverage

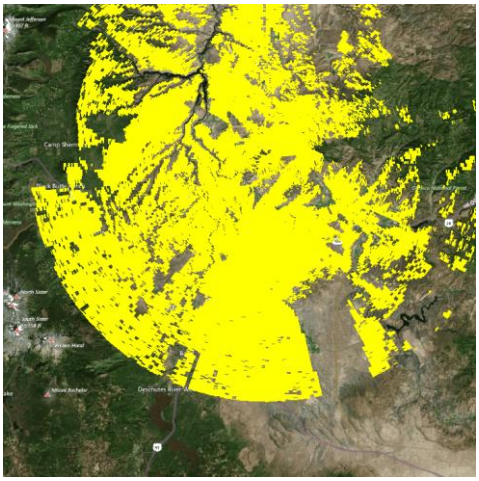
In this section we will see radio coverage and visual coverage for each base station for network 2. Height of all towers is 100 meters. After that we will see whole radio coverage of area by base stations. We use Polar radio coverage tool to simulate covered area for each base station. Also, to simulate whole covered area by network, Cartesian radio coverage tool were used. Figures bellow are results of simulation using Radio mobile software. Left ones are radio coverage and right ones are visual coverage.



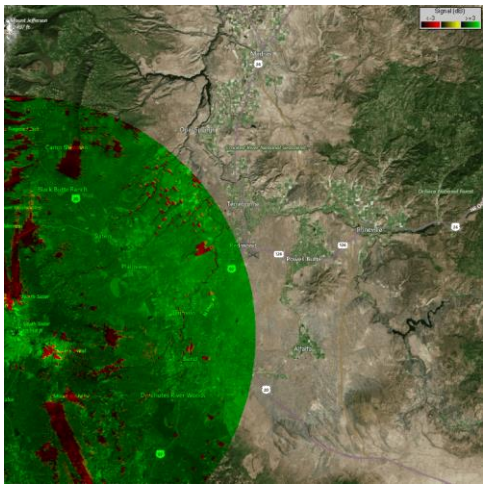


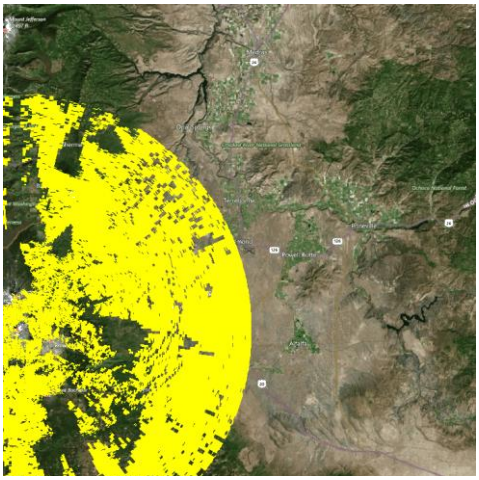
Mount Jefferson Coordinates: 44.6792 , -121.8011 Elevation: 3142.8 m



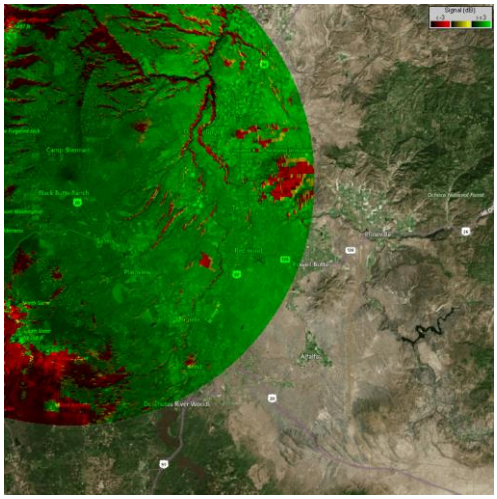


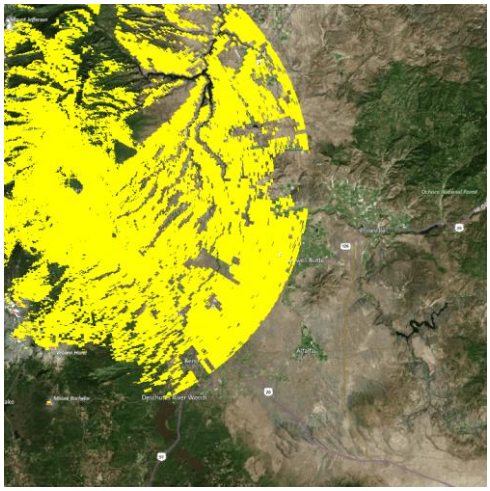
Crocked River Coordinates: 44.41685 ,-121.1019 Elevation: 1531.9 m



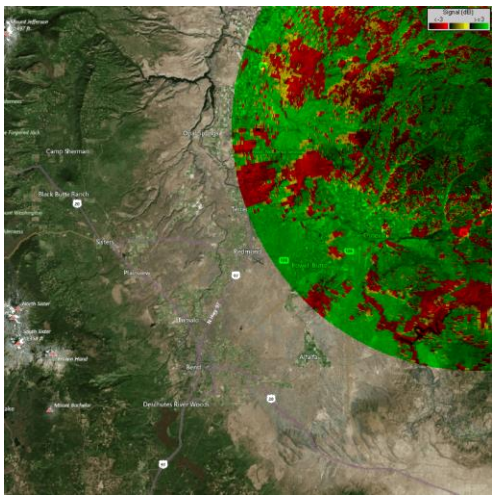


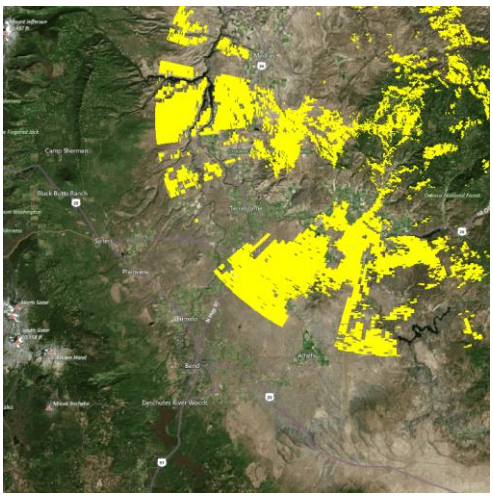
South Sister Coordinates: 44.10215 , -121.7732 Elevation: 3115 m



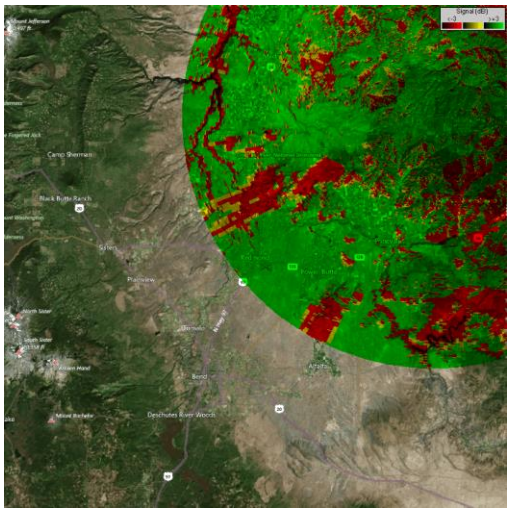


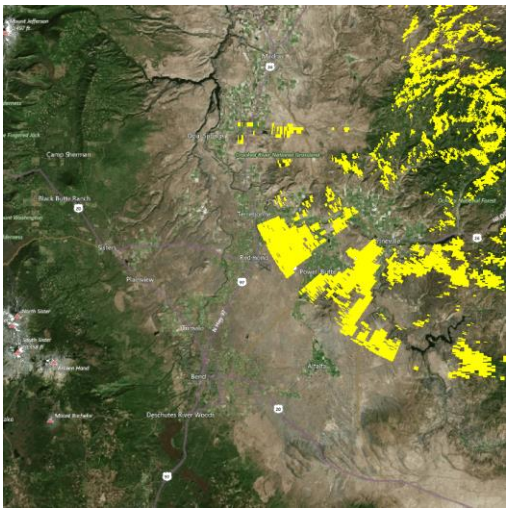
Black bute Coordinates: 44.40073 ,-121.6369 Elevation: 1937 m



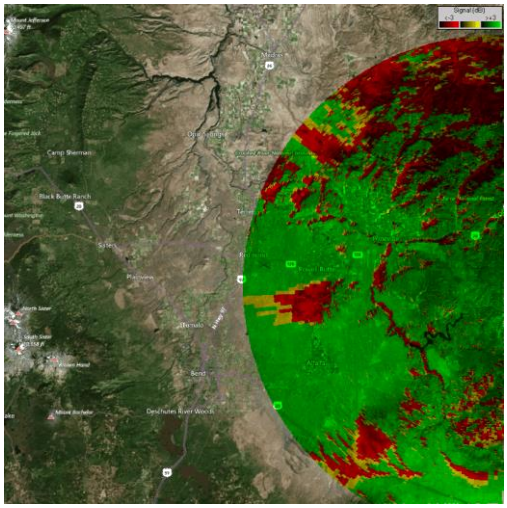


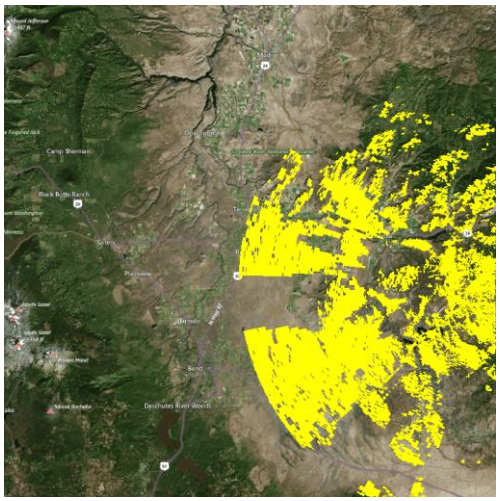
Ochoco 2 Coordinates: 44.52531,-120.7817 Elevation: 1606.9 m



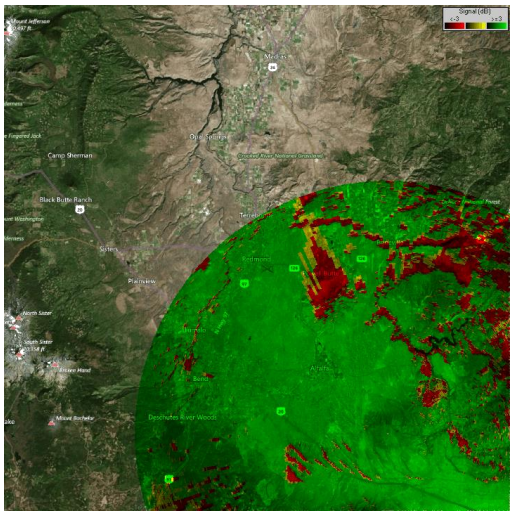


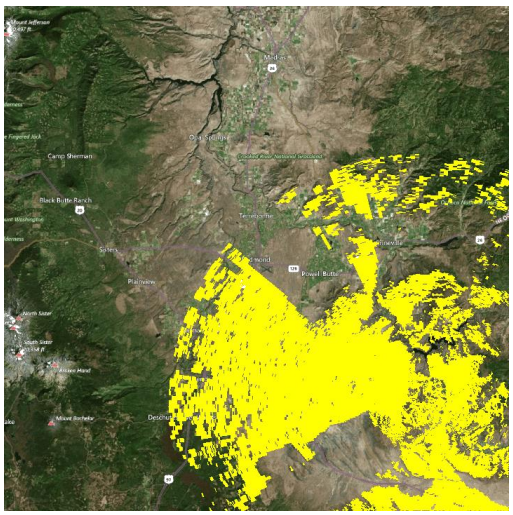
Ochoco 1 Coordinates: 44.50195,-120.588 Elevation: 1809 m





Near Roberts Coordinates: 44.21659,-120.574 Elevation: 1731.9 m





Roberts Coordinates: 44.00874,-120.7645 Elevation: 1669 m

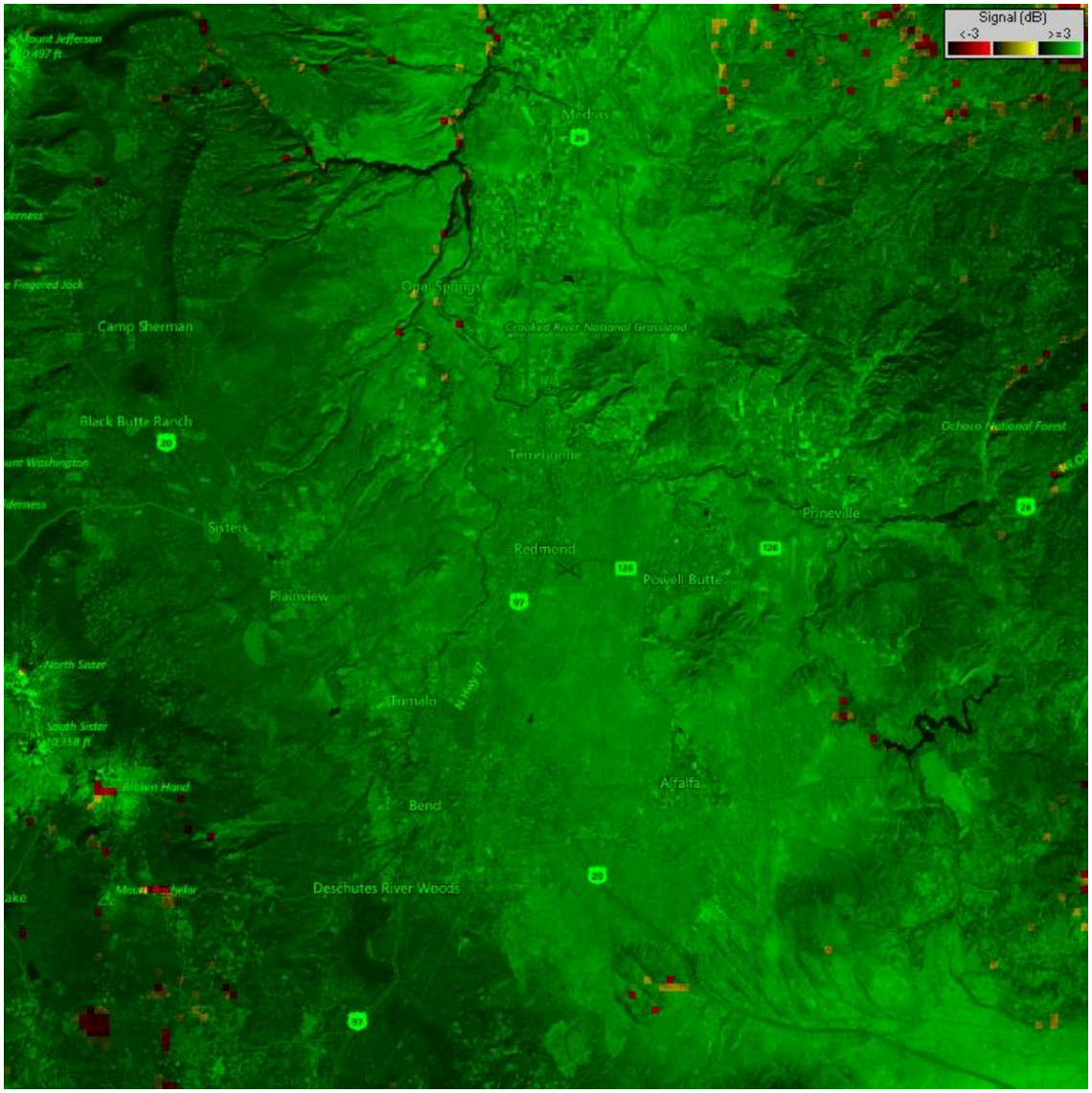


Fig.12. Combined radio coverage of all repeaters

7. Measuring precise coverage using Matlab

This software cannot measure percentage of covered area. To measure precise percentage of covered area we use a very simple image processing Matlab code. The picture used in Matlab is covered area without background map. This image can be extracted easily from Radio mobile software by selecting “save coverage pictures in frames directory” in combined Cartesian Radio coverage tool. The coverage is 98.45 percent.

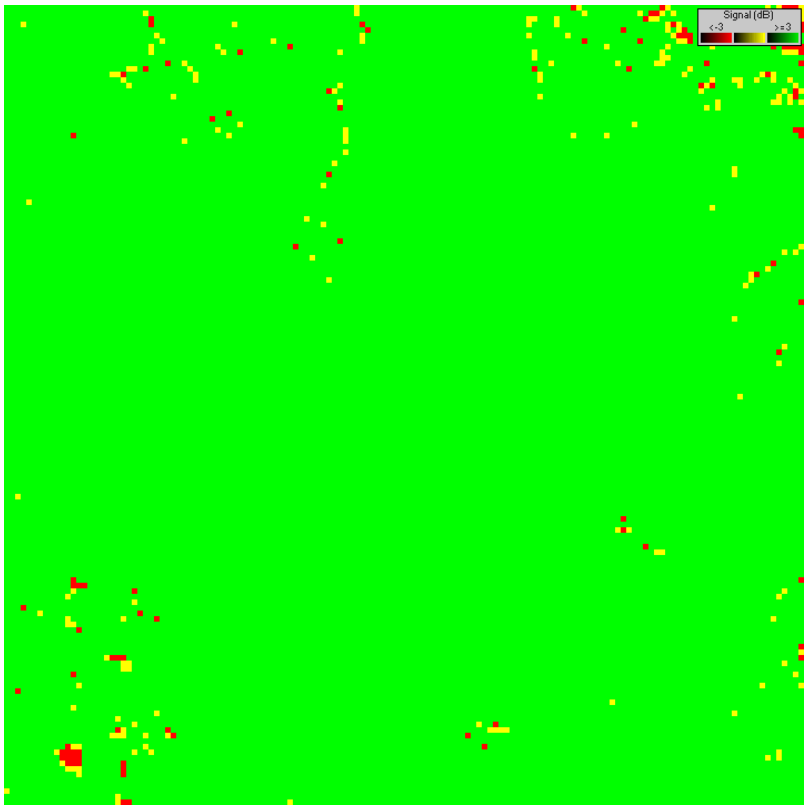


Fig.13. picture used in Matlab without background map

```
img = imread ( '106.png' );
imshow (img);
th = 10;
totalPixelNumber = numel (img);
pixels = find (img<th);
length (pixels) / totalPixelNumber * 100
```

This code measures percentage of brighter pixels. Since green is brighter than yellow and red, we can calculate number of green pixels. To tune this code always check the “img” matrix in Matlab and then adjust Th parameter.

8. Conclusion

The interested area contains mountain in the west and east. Redmond and other cities are between mountains in a valley. By placing base stations on top of mountains we can achieve a perfect coverage. This was a great experience for us to challenge our knowledge from lectures with real scenarios. These types of exercises were complementary to things that we have learnt from lectures and gave us point of view in real world applications.