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# Instruction for Laboratory classes on Wireless Communications

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## Exercise 5. Microwave data link design

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The aim of this exercise is to:

- learn the fundamentals of microwave data link design,
- learn how to design microwave data link in Radio Mobile software.

### 1. References:

1. Gordon L. Stüber, “Principles of Mobile Communication”, Second Edition, Kluwer Academic Publishers, 2002

### 2. The scope of the exercise.

In this exercise you will learn the basics of point to point wireless transmitting systems that are used in the transport network.

A microwave link is a communications system that uses a high frequency electromagnetic waves to transmit data with high rates between two points (fig.1). Microwave links are commonly used to transmit data between base stations or for fast point to point connection when no fiber is available (e.g. mountain sides).

Because of the high frequencies used, a line-of-sight transmission path between the stations is required (fig.2). Additionally, in order to avoid attenuation of the beam, an area around the beam called the first Fresnel zone must be free from obstacles. Obstacles in the signal field cause unwanted attenuation. That is why the antennas are located on high mountain peaks or on the high buildings.

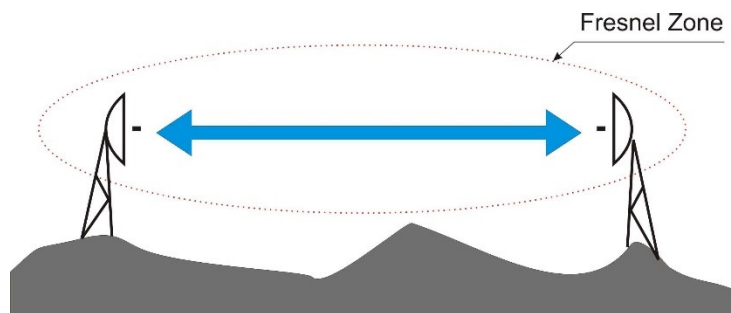
A Fresnel zone, is an ellipsoidal region of space between and around a transmitter and a receiver. If there are obstructions or reflecting objects between the transmitter and receiver,

the wave can follow slightly different paths. As the result, the waves can arrive at different times and will be out of phase due to the different path lengths. Depending on the magnitude of the phase shift, the waves can interfere constructively or destructively. The size of the calculated Fresnel zone at any particular distance from the transmitter and receiver can help to predict whether obstructions or discontinuities along the path will cause significant interference. For more information see:

[http://radiomobile.pe1mew.nl/?Calculations:Propagation\\_calculation:Fresnel\\_zones](http://radiomobile.pe1mew.nl/?Calculations:Propagation_calculation:Fresnel_zones)



*Fig.1. Antennas for microwave links located on the top of the mountain*



*Fig.2. Line-of-sight transmission*

### **3. The course of the exercise**

You are free to use any region of terrain map that has 50 km of height. Configure the radio link network that consist of two units.

The frequency of operation (in “Networks properties” window) should be set up in the range from 10 GHz to 11 GHz. Antenna gain should be more than 20 dBi (you will check for different values), transmit power 50 W and the sensitivity of the receiver should be -105 dBm. Use the following parameters:

Networks properties

Default parameters Copy Net Paste Net Cancel OK

List of all systems

- Radio Link
- System 2
- 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

Parameters Topology Membership Systems Style

01 Select from FM ...

System name Radio Link

Transmit power (Watt) 50 (dBm) 47

Receiver threshold ( $\mu$ V) 1,2589 (dBm) -105

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

Antenna type omni.ant View

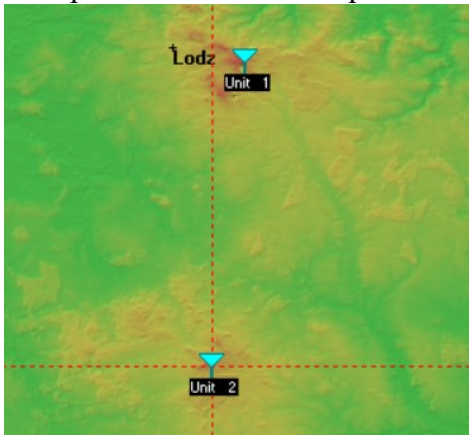
Antenna gain (dBi) 20 (dBd) 17,85

Antenna height (m) 10 (Above ground)

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

Add to Radiosys01.dat Remove from Radiosys01.dat

First place the Units at the points on the map that has the highest elevations:



Then Use “Radio link” button:



The “Radio Link” window presents the terrain profile along the line that connects two units and the Fresnel zones. The parameters of the transmission calculated for given link configuration are presented above the terrain profile. Beneath the profile of the terrain, unit parameters are displayed. In this field antenna heights can be changed as well as frequency.

Radio Link

Edit View Swap

Azimuth=186,25°	Elev. angle=0,040°	Clearance at 25,48km	Worst Fresnel=1,6F1	Distance=27,77km
Free Space=141,7 dB	Obstruction=-0,2 dB TR	Urban=0,0 dB	Forest=0,0 dB	Statistics=6,3 dB
PathLoss=147,8dB (1)	E field=76,3dB $\mu$ V/m	Rx level=-61,8dBm	Rx level=182,20 $\mu$ V	Rx Relative=43,2dB

Transmitter
 

S9+20

Unit 1

Role

Command

Tx system name

Radio Link

Tx power

50 W

46,99 dBm

Line loss

0,5 dB

Antenna gain

20 dBi

17,8 dBd

Radiated power

EIRP=4,46 kW

ERP=2,72 kW

Antenna height (m)

10

-

+

Undo

Receiver
 

S9+20

Unit 2

Role

Command

Rx system name

Radio Link

Required E Field

33,13 dB $\mu$ V/m

Antenna gain

20 dBi

17,8 dBd

Line loss

0,5 dB

Rx sensitivity

1,2589 $\mu$ V

-105 dBm

Antenna height (m)

10

-

+

Undo

Net

link

Frequency (MHz)

Minimum

10000

Maximum

11000

While designing microwave link, it is important to use line-of-sight configuration. To predict, where this condition can be fulfilled the “Visual Coverage” can be calculated. From menu: Tools > Visual coverage you can open the window that configures visual coverage calculations:

Visual coverage

Observer
 

Unit 1

Sensor height above ground (m)

2

Plot
 

☐ Contour line
 

Color

☒ Fill area
 

Color

☐ Solid
 

Color

Draw

Cancel

Azimuth range
 

Minimum (°)

0

Maximum (°)

360

Step (°)

1

Elevation angle range
 

Minimum (°)

-89

Maximum (°)

89

Target
 

☒ Nap-of-the-earth
 ☐ Fixed altitude

Target height above ground (m)

2

Radial range
 

Min. (km)

0,01

Max. (km)

50

#### **4. Analysis of factors influencing the radio link parameters (tasks for self-study)**

Analyse how different factors influence the operation of radio link.

##### **a. Fresnel zone clearance**

Make simulations of two systems that operate at approximately the same distance. First system should have first Fresnel zone cleared from obstacles. In second system terrain should be inside first Fresnel zone. Use visual coverage tool to identify the localization of units that will fulfil these two requirements. Antenna height parameter has influence on the localization of Fresnel zone. Adjust this parameter to have Fresnel zone cleared or not. Compare the path loss and Rx level for each system.

##### **b. Antenna gain**

Make simulations of one system with different antenna gain (from 20 dBi to 60 dBi). Compare the path loss and Rx level for each case.

##### **c. Frequency**

Analyze the system that operates with different frequencies: 450 MHz, 890 MHz, 2450 MHz, 10 GHz, 60 GHz. You can change it in “Radio Link” window. Note how Fresnel Zone shape changes for different frequencies. Compare the path loss and Rx level for each case.

The report should include the necessary simulation results, on the basis of which it should be determined how the factors described in points a-c affect the radio link performance.