Radio Mobile

Training materials for wireless trainers



The Abdus Salam International Centre for Theoretical Physics



Educational, Scientific and Cultural Organization

Goals

- To learn how to use Radio Mobile, a free software that provides a detailed propagation model for radio. It allows to simulate a radio link and perform "what if?" scenarios, by changing the link parameters. It can also show the area coverage from a given site.
- There are two versions of the program: an on-line application and a downloadable version that runs on Windows.
- We will also describe the use of Google Earth for building elevation profiles.

Software for radio link simulation

There are many programs that can be used to simulate radio links and base station coverage, some of which cost thousands of dollars.

By using a link simulator, you can save considerable time during link planning and analysis. For example, if a link is proven to be impossible in simulation, there is little need to perform a site survey, and other options have to be considered (such as the use of repeater sites).

Radio Mobile is a free program developed for radio amateurs by Roger Coudé that is based on the well known Longley-Rice Irregular Terrain Model and predicts radio propagation, making use of several sets of freely available Digital Elevation Maps.

Windows Vs Web Radio Mobile:

On-line version (web)

Pros: runs on any machine (Linux, Mac, Tablet); does not require big downloads; saves sessions; user friendly, will fetch the elevation data automatically

Cons: requires connectivity; only certain frequencies

Windows version

Pros: runs offline; can use the GPS

Cons: runs on Windows only; requires big downloads; user must select digital elevation maps; hard to learn

It is advisable to start using the on-line version to get acquainted with the capabilities of the software and then move to the downloadable version for extra features.

Radio Mobile On-Line

Point your web browser to

http://www.cplus.org/rmw/rmonline.html

- Register in the site (no cost) and create your account, you will receive your password in your email account.
- You can then start using the program.

Web Radio Mobile

Radio M	lobile On	line - Chromium		🐱 💷 🕴 奈 🜒	8:16 AM	👤 mz
	Goo 🚼	ogle ×	M Account creation confirm: X 👫 Radio Mobile Online 🛛 X 🦲			
	← →	C www.cplus.or	g/rmw/rmonline.html		\$	e
	Ra	<u>dio Mobile</u>	Par/By Roger Coudé VE2DBE			Info
		Welcome mz				
	\$	My Settings	Create a site (location)			
120	*	New Site				
	Å	My Sites				
	¥	New Link				
	ቸላቸ	My Links				
	শ	Multiple links				
	•	New Coverage				
Ĺ	•	My Coverages				
•	٥	Multiple coverages				
	H	New antenna type				
	# #	My antenna types				
	⇒	Log Out				
?						
2						

Radio Mobile On-Line



Radio Mobile							
* New Site							
-							
Loca	te						
Latitude	4 53535638						
Longitude	-73.66607666						
Zoom	9						
Name	New Site 16						
Elevation (m)	2927.1						
Description							
Group							
Add to M	y Sites						
Cancel							

If you happen to know the coordinates, you can modify the values on the screen. Check that the elevation provided by the program is reasonable. Assign a name to the site and click "Add to my sites" Repeat the procedure for the second site.

W New Link

Cancel

Radio Mobile

From	Sitio 1 🛊
Antenna height (m)	2
То	sitio 2 🛊
Antenna height (m)	2
Description	Radio link study 10
Frequency (MHz)	2300
Tx power (Watts)	0.1
Tx line loss (dB)	1
Tx antenna gain (dBi)	24
Rx antenna gain (dBi)	19
Rx line loss (dB)	0.5
Rx threshold (µV)	10
Required reliability (%)	70
Use land cover	
Use two rays	

Submit

Input 2300 MHz as frequency when working at 2.4 GHz and 5825 MHz when working at 5 GHz, since in the on-line version they are the closest allowed frequencies. This will affect the propagation loss by a small amount.

"Rx Threshold" is the minimum received signal in microvolts, also called "Receiver sensitivity" Click "Submit".

A word on power

Electrical power in watts is $P = v^2/R$ Telecommunication antennas have normally R = 50 ohm In that case, $P = v^2/50$, v = SQRT(50P)The received power level RP is frequently expressed in dBm: $RP = 10Log_{10} (P/10^{-3})$, therefore $P = 10^{-3}10^{RP/10}$ So, the received voltage corresponding to RP dBm is:

$v = SQRT(0.05 \times 10^{RP/10})$

Example: for RP -90 dBm, $v = SQRT(0.05 \times 10^{-9}) = 0.00000707$

That is v = 7.07 microvolts, this the RF voltage one would measure at the antenna terminals

Radio Mobile	Par/By Rog	ger Coudé VE2DBE	Information
	Radio lii	1k study 10	
Sitio 1 (1)			(2) <u>sitio 2</u>
Latitude	4.535356	Latitude	4.653080 °
Longitude	-73.666077 °	Longitude	-73.355713 °
Ground elevation	2927.1 m	Ground elevation	1082.5 m
Antenna height	2.0 m	Antenna height	2.0 m
Azimuth	69.15 °	Azimuth	249.18 °
Tilt	-3.03 °	Tilt	2.70 °
Radio system			Propagation
TX power	20.00 dBm	Free space loss	130.96 dB
TX line loss	1.00 dB	Obstuction loss	117.51 dB

This link is not feasible because of the blocked line of sight

Let's see another link:

Radio Mobile	Par/By Roger	r Coudé VE2DBE	Information		
Return to my links Return to main menu					
	Aguila-	Platillon			
Aguila2012 (1)			(2) <u>Platillon</u>		
Latitude	8.829425 °	Latitude	9.859167 °		
Longitude	-70.834667 °	Longitude	-67.521770 °		
Ground elevation	4165.4 m	Ground elevation	1519.7 m		
Antenna height	2.0 m	Antenna height	2.0 m		
Azimuth	72.25 °	Azimuth	252.79 °		
Tilt	-2.11 °	Tilt	-1.32 °		

Radio Mobile	Par/By Ro	ger Coudé VE2DBE	Information
Radio system			Propagation
TX power	20.00 dBm	Free space loss	151.26 dB
TX line loss	0.00 dB	Obstuction loss	16.58 dB
TX antenna gain	34.00 dBi	Forest loss	1.00 dB
RX antenna gain	34.00 dBi	Urban loss	0.00 dB
RX line loss	0.00 dB	Statistical loss	2.83 dB
RX sensitivity	-97.46 dBm	Total path loss	171.67 dB
Performance			
Distance			381.091 km
Precision			190.6 m
Frequency			2300.000 MHz
Equivalent Isotropically Radiated Power			251.189 W
System gain			185.46 dB
Required reliability			70.000 %
Received Signal			-83.67 dBm
Received Signal			14.68 µV
Fade Margin			13.79 dB



Radio Mobile on-line Example of area coverage from another site



Elevation profiles with Google Earth

- I) In the upper menu, click "Add path"
- 2) Click to establish the first point and then the second
- 3) Assign a name to the link (for instance "Longest") and click OK in the pop-up window
- 4) The link will show up in the menu on the left.
- 5) Right click in the link name ("Longest" in our example)
- 6) Select "Show elevation profile"
- 7) The elevation profile will be shown on the bottom of the screen
- 8) Moving along the profile, a red arrow will show the position on the map.

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Exercise

We want to establish a link between GGH-ICTP and ISMAR (a research institution in Trieste downtown), with WiFi and with TVWS equipment.

I) GGH-ICTP 2) ISMAR

Latitude	45.70348900	Latitude 45.64337000
Longitude	13.72081800	Longitude 13.75378700
Latitude	045° 42' 12.56"N	Latitude 045° 38' 36.13"N
Longitude	13° 43' 14.94"E	Longitude 13° 45' 13.63''E

Is the link feasible? What equipment would you use? What antenna gain do you need? What antenna height?

Why use downloadable Radio Mobile?

Radio Mobile runs in Windows but it can be used in Linux or Mac OS by means of emulators.



It provides all sort of details for point to point links, including expected signal level at any point along the path, including diffraction losses due to obstacles.

Radio Mobile automatically builds a profile between two points on the digital map, showing Fresnel zone and earth curvature clearance, as well as required antenna heights. It is a wonderful tool for exploring "what if?" scenarios.

Download Radio Mobile

Download Radio Mobile here:

http://www.cplus.org/rmw/english1.html

Instructions are provided for how to download the digital elevations maps for your area of interest.

- Digital elevation maps come in one degree longitude, X degree latitude tiles so you might need to download a few tiles for your application. Resolution of 30 and 3 arc seconds (or better!) are available for all regions of the world.
- Once you have downloaded the maps, you no longer need Internet access (unlike using Google Earth).

Using Radio Mobile

- Let's assume Radio Mobile is already correctly installed on your computer (installation instructions are provided in the download page). We will now review the procedure to simulate a simple wireless network composed of a few nodes
- We will then use Radio Mobile to perform some simple link budget calculations, coverage analysis and "what if?" simulations



Using Radio Mobile: example

We will use Radio Mobile to simulate a few radio links around the city of Trieste (Italy).Coordinates of some locations are (approx.):

The Miramare Campus: N 45°42'15" E 13°43'13"

The Church (Muggia): N 45°36'10" E 13°45'10" The Castle (San Giusto): N 45°38'51" E 13°46'21"

The Hotel (Grado): N 45°40'32" E 13°23'17"

Using Radio Mobile: DEMs

 Before you start working with Radio Mobile, you may want to download the Digital Elevation Maps of your area of interest. Radio Mobile can use a number of formats including SRTM.

Elevation data so	Elevation data source						
SRTM -	inistrator\desktop\srtm	Browse					
DTED -	C	Browse					
GTOPO30 💌	c	Browse					
GLOBE 💌	c	Browse					
BIL	c	Browse					
🔲 Ignore missing	Ignore missing files Bottom layer						
Initialize matrix with elevation (m)							

Radio Mobile screenshot



http://eros.usgs.gov/#/Find_Data/Products_and_Data_Available/gtopo30_info

Using Radio Mobile: DEMs

 The simplest way to get elevation data is to let Radio Mobile download it automatically when needed. It will also store the data locally for future use.

Proxy Web update	Cancel OK
SRTM Landsat	SRTM
OpenStreetMap Terraserver Toporama	C Download from Internet if a file is not found on local path
	Ownload from Internet if a file is not found on local path and keep a local copy
	C Use local files only
	Local files path
	C:\Documents and Settings\Administrator\Desktop\SRTM Browse
	Internet ftp directory
	USGS Eurasia - 3 arcsecond
	http://dds.cr.usgs.gov/sttp:/version2_1/SBTM3/Eurasia/

Radio Mobile screenshot

Using Radio Mobile: create map

- Menu "File", select item "Map properties"
- Insert coordinates (center of map) and dimensions of the map
- We use:

N 45.6 - E 13.5 640x480 pixels 64x48 km

"Extract"

Radio Mobile screenshot

👰 Properties of\venice-wimax-map.map 🛛 🛛 🔀					
Centre 45°36'00.0''N 013°30'00.0''E JN65S0	Size (pixel) Width(pixels) 640 480	ght (pixels) D	Extract		
Latitude Longitude 45.6 13.5	- Size (km)	-1.1.0	Cancel		
Use cursor position	64.00 48.	gnt (Km) .00	Top Left 45°48'57''N 013°05'18''E		
World map Select a citu name	Elevation data source Drive or path	Top layer Browse	Top Right 45°48'57''N 013°54'42''E		
Enter LAT LON or QRA	None C	Browse	Bottom Left 45°23'02''N 013°05'18''E		
Select a unit	None 💌 C	Browse	Bottom Right		
	None 💌 C	Browse	45"23"02"N 013*54'42"E		
Adjust units elevation	None 💌 c	Browse	Resolution 100.0 m/pixel		
Merge pictures	Ignore missing files	Bottom layer	3.24 arcsecond		
Force gray scale	midalize madix with elevado	n (m) 19			

Using Radio Mobile: the map



Using Radio Mobile: add map

- We can add road details using this procedure: menu "Edit" select item "Merge pictures..."
- Then select

OpenStreetMap

with Zoom=10

Operation:Add

- click on "Draw"
- "Keep in picture"



Using Radio Mobile: new map



Using Radio Mobile: terminology

- Radio Mobile has its own special terminology. In order to create radio links we need to learn a few new terms:
 - a system: a particular choice of radio and antenna (TX power, gain, radiation pattern, ...)
 - a unit: a system installed in a particular location (coordinates, height of antenna, ...)
 - a network: a set of units, part of the same radio network (all at the same frequency)

Using Radio Mobile: systems

- Let's create two different systems (WiFi@2.4GHz):
- SmallRadio:
 P_{TX}=16dBm
 S_{RX}=-90dBm
 omni 8dBi
- BigRadio: P_{TX}=20dBm S_{RX}=-96dBm dish 24dBi
- other: default

🔀 Networks properties		
List of all systems	Default parameters Copy Ne	et Paste Net Cancel OK
System 1 System 2 System 3	Parameters Topology	Membership Systems Style
System 4 System 5 System 6 System 7	00 -	Select from VHF UHF
System 8 System 9 System 10	System name	System 1
System 10 System 11 System 12	Transmit power (Watt)	10 (dBm) 40
System 13 System 14 System 15	Receiver threshold (μV)	(dBm) -107
System 16 System 17 System 18	Line loss (dB)	omni ant
System 19 System 20 System 21	Antenna gain (dBi)	2 (dBd) -0.15
System 22 System 23 Sustem 24	Antenna height (m)	2 (Above ground)
System 25	Additional cable loss (dB/m)	0 (If antenna height differs)
	Add to Radiosys.dat	Remove from Radiosys.dat

Using Radio Mobile: units

- Let's create 5 new units, located in the 4 sites:
- Miramare I
- Miramare 2
- Church
- Castle
- Hotel



Using Radio Mobile: units

- After creation, you should assign the proper system to each unit:
- Miramare I
- Church
- Castle are all "SmallRadio"
- Miramare 2
- Hotel are both "BigRadio"

🔀 Networks properties					
List of all nets	Default parameter:	s Copy Ne	et Paste No	et Cancel	ОК
List of all nets Net 1 Net 2 Net 3 Net 4 Net 5 Net 6 Net 7 Net 8 Net 9 Net 10 Net 11 Net 12 Net 13 Net 14 Net 15 Net 16 Net 17 Net 18 Net 19 Net 20 Net 21 Net 23 Net 24 Net 25	Parameters List of all units Miramare 1 Miramare 2 Church Castle Hotel Unit 6 Unit 6 Unit 7 Unit 8 Unit 9 Unit 10 Unit 10 Unit 11 Unit 12 Unit 13 Unit 13 Unit 14 Unit 15 Unit 15 Unit 16 Unit 17 Unit 18 Unit 18 Unit 18 Unit 19 Unit 19 Unit 19 Unit 10 Unit 10 Unit 11 Unit 11 Unit 12 Unit 13 Unit 14 Unit 15 Unit 16 Unit 17 Unit 18 Unit 19 Unit 1	Topology	Membership Membership Membership Membership Role Cor Syst Sm Ar C Ar	Systems Systems Systems System Sitenna height (m) System Connection System Connectio	Style

Using Radio Mobile: network

To view your network on the map, just select "View" → "Show networks" → "All"



Using Radio Mobile: network

- To be able to correctly calculate the loss due to propagation, you should set the correct
 frequency.
- We are using the 2.4GHz band, so let's set the range 2400-2485.

Xetworks properties			1					
List of all nets	Default parameters	Copy Net	Past	e Net	Cancel	ОК		
WirelessTrainingKit Net 2 Net 3 Net 4	Parameters	Topology	Members	hip	Systems	Style		
Net 5 Net 6 Net 7 Net 8	Net name WirelessTrainingKit			Surfa Gro	ace refractivity (N ound conductivity	-Units) 301		
Net 9 Net 10 Net 11 Net 12 Net 12	Minimum frequency (MHz) 2400 Maximum frequency (MHz) 2485				Relative ground permittivity			
Net 14 Net 15 Net 16 Net 17	Vertical Mode of variability:	C Horizo	 Equatorial Continental sub-tropical 					
Net 17 Net 18 Net 19 Net 20 Net 21	 Spot Accidental 	% of ti	ne 50		faritime sub-tropic)esert	al		
Net 22 Net 23 Net 24 Net 25	C Mobile	% of situatio	ns 70	 Continental temperate Maritime temperate over land 				
	Additional loss	Forest	% 0	C M	faritime temperate	e over sea		

Using Radio Mobile: results

Now that we have set our scenario, let's calculate the link budget for our links: "Tools" \rightarrow "Radio link"

🕅 Radio Link					X
Edit View Swap					
Azimuth=147.2° PathLoss=123.1dB	Elev. angle=0.180* C E field=45.4dBμV/m F	Clearance at 0.10km Rx level=-92.1dBm	Worst Fresnel=1 Rx level=5.58µ∖	1.6F1 Distance / Rx Rela	e=7.49km tive=-2.1dB
<u></u>					
Terrenilter		Baaa			
Transmitter		S0	iver		S0
Miramare 1		Cast	e		•
Role	Command	Role		Subordinate	
Tix system name	SmallRadio	▼ Rx sy	stem name	SmallRadio	•
Tx power	0.0398 W 16 dBm	n Requ	ired E Field	47.47 dBµV/m	
Line loss	0.5 dB	Anter	na gain	8 dBi	5.85 dBd +
Antenna gain	8 dBi 5.85 dB	3d + Line k	280	0.5 dB	
Radiated power	EIRP=0.22 W ERP=0	.14 W Rx se	nsitivity	7.0795µV	-90 dBm
Antenna height (m)	2 · +	Undo Anter	na height (m)	2 +	Undo
Net		Frequ	ency (MHz)		
WirelessTrainingKit		•	Minimum 2400	Maximum	2485
		34	_	_	

Using Radio Mobile: results

 You can switch to the detailed view, that gives you a textual description of the output of the simulation

<mark>۳۳</mark> R	adio Link					D				
Edit	View Swap									
Azim	🗸 Profile	Elev. and	🕅 Radio Link							
Fair	Details	E neid=4;	Edit View Swap							
	Range Distribution	==	Distance between Mir True North Azimuth = Terrain elevation varia	amare 1 and Castle i: 147.2°, Magnetic No ation is 64.5 m	s 7.5 km (4.7 miles) rth Azimuth = 144.7°, B	Elevation angle = 0.1800°				
	Large window		Propagation mode is line-of-sight, minimum clearance 1.6F1 at 0.1km Average frequency is 2442.500 MHz							
	Observe 🕨		Free Space = 117.6 d Total propagation loss	B, Obstruction = -1.2 is 123.1 dB	dB, Urban = 0.0 dB, F	forest = 0.0 dB, Statistics = 6.6	; dB			
			System gain from Miramare 1 to Castle is 121.0 dB System gain from Castle to Miramare 1 is 121.0 dB Worst reception is 2.1 dB below the required signal to meet 70.000% of situations							
_ Trai	nsmitter									
Mir	amare 1		Transmitter			Receiver				
Role	e	Commar	/		 \$0			 \$0		
Txs	system name	SmallR	Miramare 1		•	Castle		•		
Тхр	ower	0.03981	Role	Command		Role	Subordinate			
Line	loss .	0.5 dB	Tix system name	SmallRadio	-	Rx system name	SmallRadio	-		
Ante Rod	enna gain liated power	S dBI	Tx power	0.0398 W	16 dBm	Required E Field	47.47 dBµV/m			
nau	ilateu powei	Einr=0	Line loss	0.5 dB		Antenna gain	8 dBi	5.85 dBd 🔶 🛨		
Ante	enna height (m)	2	Antenna gain	8 dBi	5.85 dBd +	Line loss	0.5 dB			
⊢ ⊢Net			Radiated power	EIRP=0.22 W	ERP=0.14 W	Rx sensitivity	7.0795μV	-90 dBm		
			Antenna height (m)	2 .	+ Undo	Antenna height (m)	2 ·	+ Undo		
JWir	reiess i rainingKit	_	Net			Frequency (MHz)				
-			WirelessTrainingKit		35 🔹	Minimum 2400	Maximum	2485		

Using Radio Mobile: coverage

- "Tools" \rightarrow "Radio coverage" \rightarrow "Single polar"
- This will start the calculation of the coverage area of a selected station in
 - your net.

Centre unit	Castle		•	Draw		2
Mobile unit	Church		•	Cancel		
Network	WirelessT	rainingKit	•		and the second	Cena -
Link Direction			Radial range (km)			+1+
 Centre Tx - M Centre Rx - M Worst case 	lobile Rx lobile Tx		Minimum 0.01	Maximum 50		
Plot			Azimuth range (*)			and the
Contour line		Color	Minimum Maximum	Step	1	1233
✓ Fill area		SMA	0 360	1	-	Ha Cours
Network style		803				and the set
🔽 Rainbow		MAN	Antenna pattern		1305	39
Blur		Color	Use network antenna s	ettings	1000	the state
Complete.wav			anni ant		E Stat	Martin Land

Using Radio Mobile: "what if?"

 With the help of Radio Mobile is very easy to simulate different scenarios, or just different values of the antenna height and/or gain,TX power, etc...

ाँभें Radio Link						\mathbf{X}
Edit View Swap						
Azimuth=263.1*	Elev. angle=-0.171*	Clearance at	23.04km W	/orst Fresnel=0.9F1	Distan	ce=26.03km
PathLoss=129.4dB	E field=39.1dBµV/m	Rx level=-82.	4dBm R	x level=17.07µV	Rx Rel	ative=13.6dB
Transmitter			Receiver			
J		— \$5	J		_	 \$6
Miramare 1		•	Hotel			_
Role	Command		Role	Sub	ordinate	
Tx system name	SmallRadio	•	Rx system nam	ne Bigl	Radio	•
Tx power	0.0398 W 10	6 dBm	Required E Fie	ld 25.4	7 dBµV/m	
Line loss	0.5 dB		Antenna gain	24 d	Bi	21.85 dBd 🔶
Antenna gain Dadiatad assure	8 dBi 5.	.85 dBd _+	Line loss	0.5 c	1B 01-37	00.40-4
Hadiated power	EIRP=0.22 W E	HF=0.14 W	HX sensitivity	3.54	-81μν	-96 GBM
Antenna height (m)	2 · +	Undo	Antenna heigh	t (m) 20	·	+ Undo

Azimuth=21.5° PathLoss=152.2dB	Elev. angle=0.396° E field=63.2dBµV/r	Clearance a m Rx level=-65	t 13.98km .2dBm	Worst Fresh Rx level=123	el=9.3F1 Dista 3.03μV Rx F	ance=54.81km Relative=41.8dB	O ()	ther exam 1alawi)	ples	
Transmitter Mpimgwe Hill		\$9+20 ▼	Receiver-	^v eak						
Role Tx system name Tx power Line loss Antenna gain Radiated power Antenna height (m) Net Mpimgwe - Zomba	Master System 1 10 W 4 0.5 dB 24 dBi 2 EIRP=2.24 kW E 10	0 dBm 1.85 dBd + RP=1.37 kW Apply	Azimuth= PathLoss	325.4° =177.5dB	Elev. angle=-0 E field=31.0dE	0.508* Obstruct βμV/m Rx level	ion at 1.83k =-90.5dBm	m Worst Fr Rx level:	esnel=-1.3F1 =6.71μV	Distance=56.50km Rx Relative=16.5dB
			Transmit Mtaja Role Tx syst Tx pow Line los Antenn Radiato Antenn	ter em name ver ss a gain ed power na height (m) - Mangochi	Master System 1 10 W 0.5 dB 24 dBi EIRP=2.24 kW 10	40 dBm 21.85 dBd + ERP=1.37 kW Apply	Reco Ma Ro Ro Rx Re Ant Lin Rx Ant Lin Rx Mir 24	eiver angochi repeate system name quired E Field enna gain e loss sensitivity enna height (m) uency (MHz) imum	r Slave System 1 14.49 dEμV/m 24 dBi 0.5 dB 1 μV 10 Maximum 2500	 S7 21.85 dBd + -107 dBm Apply

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Links

http://radiomobile.pe1mew.nl/?About_Radio_Mobile



http://www.pizon.org/radio-mobile-tutorial/point-to-point-link.html

Files

Articles

Useful Links

Conclusions

- Radio Mobile makes it possible to simulate one or more radio links and perform "what if?" simulations, changing various link parameters
- While it cannot prove that a link is 100% possible, Radio Mobile can prove that a link is not possible (or would be very difficult).
- By combining DEM data and free overlay maps, it is possible to make very informative reports about coverage, link quality, and other radio parameters.

Thank you for your attention

For more details about the topics presented in this lecture, please see the book **Wireless Networking in the Developing World**,

available as free download in many languages at:

http://wndw.net/

