Link Budget Calculation

Training materials for wireless trainers

The Abdus Salam
International Centre
for Theoretical Physics

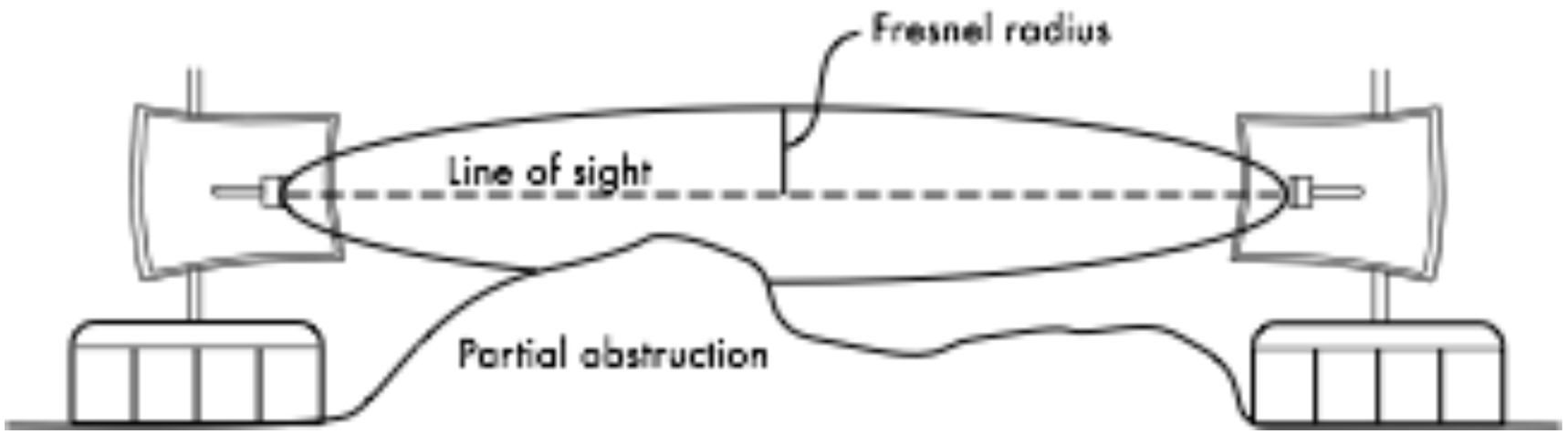
Goals

- To be able to calculate how far we can go with the equipment we have.
- To understand why we need high masts for long links.
- To determine what kind of antennas you should use.

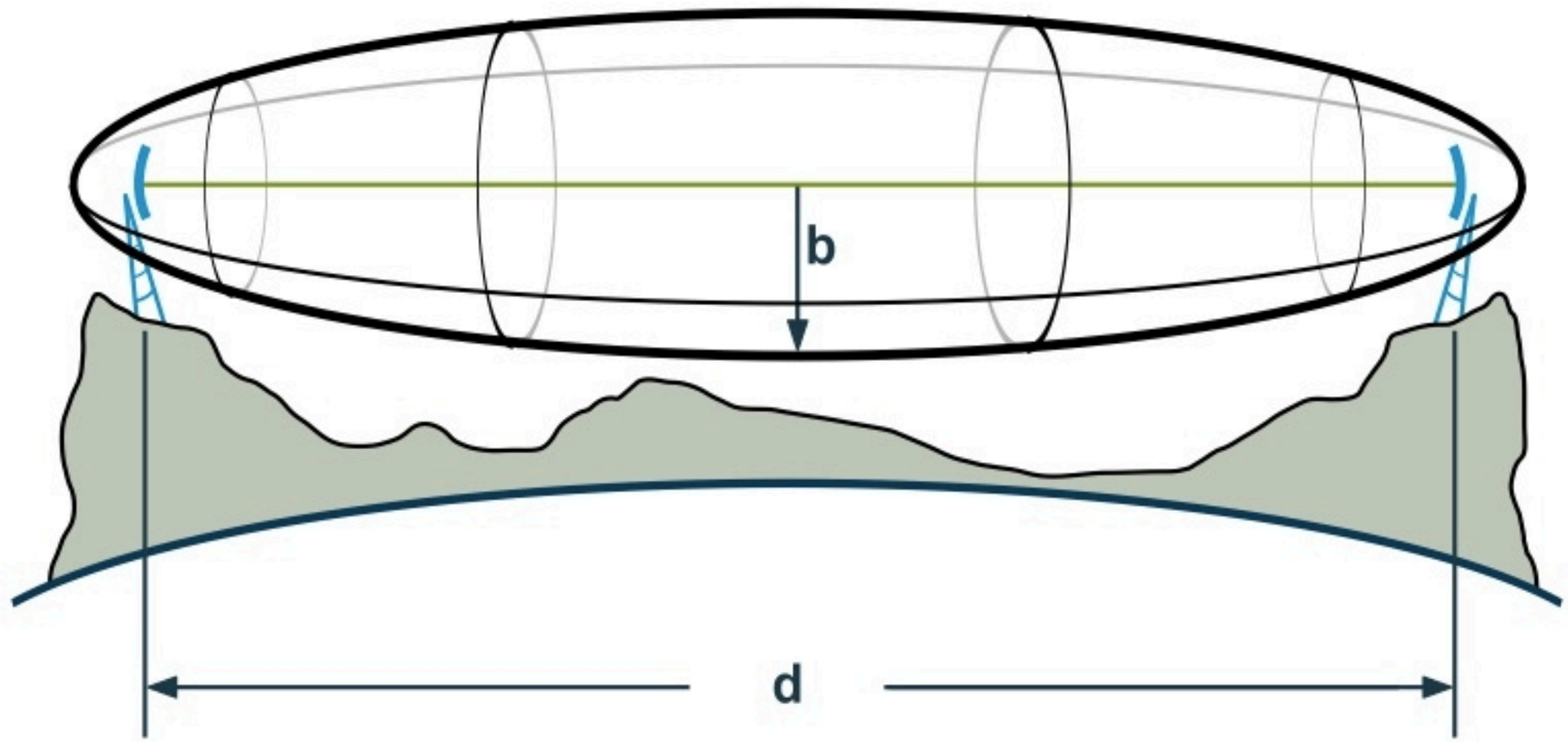
Fresnel Zone

- The Fresnel Zone occupies a series of concentric ellipsoid-shaped areas around the Line-of-Sight path.
- The Fresnel Zone is important to the integrity of the RF link because it defines an area around the LOS that can introduce RF signal interference if blocked.
- Objects in the Fresnel Zone as trees, hilltops and buildings can block the main signal away from the receiver.

Fresnel Zone



Fresnel Zone



Fresnel Zone

- The radius of the Fresnel Zone at its widest point can be calculated as:

$$r=72.6 \times \sqrt{d/4f}$$

- ...where ***d*** is the link distance in miles, ***f*** is the frequency in GHz and the answer ***r*** is in feet. Or:

$$r=17.32 \times \sqrt{d/4f}$$

- ...where ***d*** is the link distance in km, ***f*** is the frequency in GHz and the answer ***r*** is in meters.

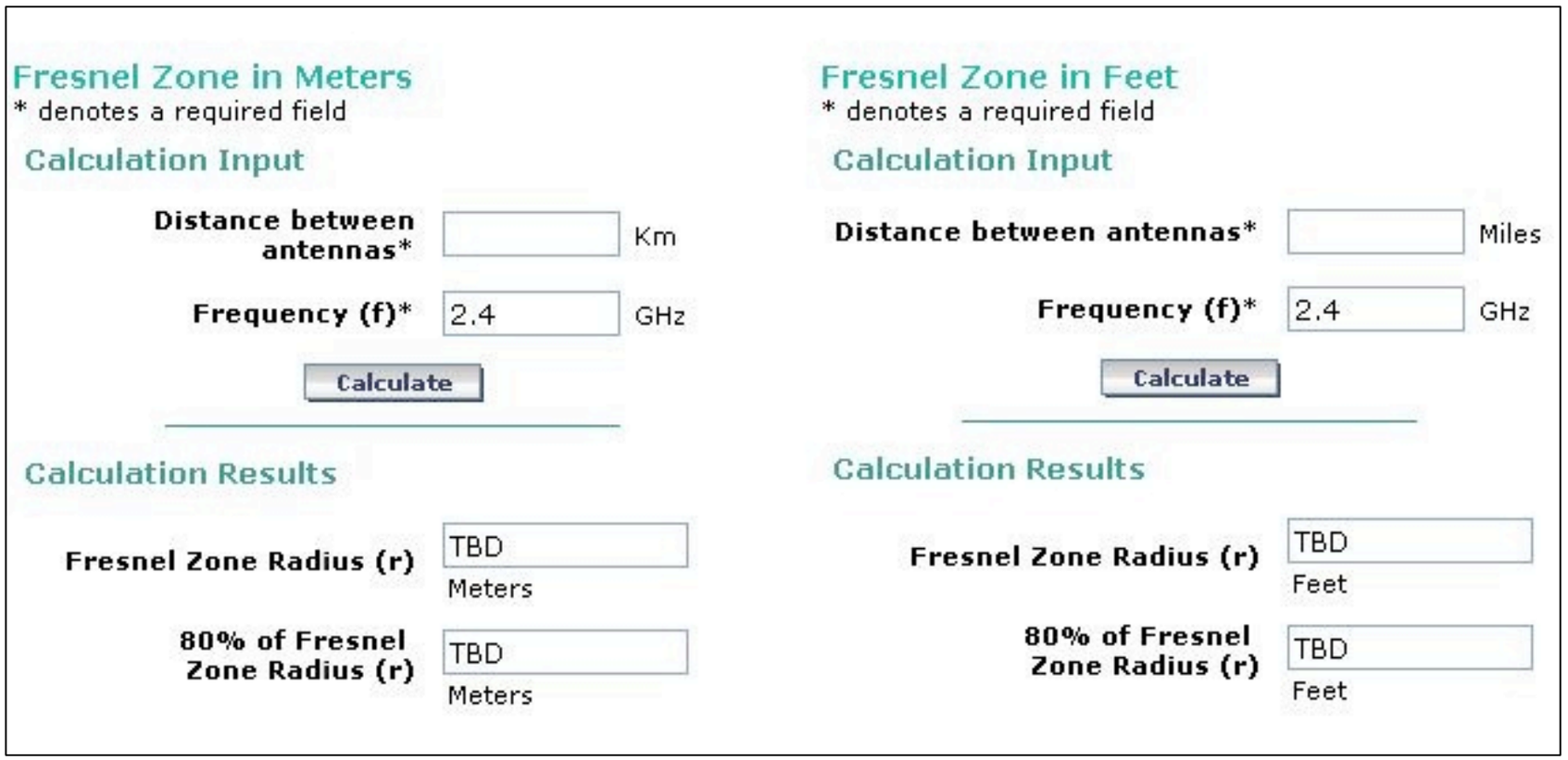
Fresnel Zone

Km	1st (m)	70% (m)	Earth curvature (m)	Total (m)
1	5.5	3.9	0.0	3.9
2	7.8	5.5	0.2	5.6
3	9.6	6.7	0.4	7.1
4	11.1	7.7	0.7	8.4
5	12.4	8.7	1.0	9.7
6	13.6	9.5	1.5	11.0
7	14.6	10.2	2.0	12.3
8	15.6	11.0	2.7	13.6
9	16.6	11.6	3.4	15.0
10	17.5	12.2	4.2	16.4
11	18.4	12.8	5.0	17.9
12	19.2	13.4	6.0	19.4
13	19.9	14.0	7.0	21.0
14	20.7	14.5	8.2	22.7
15	21.4	15.0	9.4	24.4
16	22.1	15.5	10.7	26.2
17	22.8	16.0	12.0	28.0
18	23.5	16.4	13.5	29.9
19	24.1	16.9	15.0	31.9
20	24.7	17.3	16.7	34.0
25	27.7	19.4	26.0	45.4
30	30.3	21.2	37.5	58.7

Fresnel Zone

- Considering the importance of the Fresnel Zone, it is important to quantify the degree to which it can be blocked.
- Typically, 20% - 40% Fresnel Zone blockage introduces little to no interference into the link.
- It is better to err to the conservative side allowing no more than 20% blockage of the Fresnel Zone.

Fresnel Zone: website



- *http://www.terabeam.com/support/calculations/fresnel-zone.php*

Link margin

- The performance of any communication link depends on the quality of the equipment being used.
- ***Link margin*** is a way of quantifying equipment performance.
- An 802.11 link has an available link margin that is determined by four factors: ***transmit power***, ***transmitting antenna gain***, ***receiving antenna gain***, and ***minimum received signal strength***
- Link margin is computed as:

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TX(power) + TX(ant gain) + RX(ant gain) - RSL
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Link margin

- The link factors are usually listed in the manufacturer's data sheets for the equipment being used.
- Note that the minimum RSL is dependent upon rate, and the 1 Mbps rate is used for maximum range.
- TX power can also be rate dependent but manufacturers rarely indicate this.

UBIQUITI NETWORKS

BULLET2

UBIQUITI NETWORKS

Zero Variable Outdoor Wireless Deployment

SYSTEM INFORMATION	
Processor Specs	Atheros MIPS 4KC, 180MHz
Memory Information	16MB SDRAM, 4MB Flash
Networking Interface	1 X 10/100 BASE-TX (Cat. 5, RJ-45) Ethernet Interface

REGULATORY / COMPLIANCE INFORMATION	
Wireless Approvals	FCC Part 15.247, IC RS210, CE
RoHS Compliance	YES

RADIO OPERATING FREQUENCY 2412-2462 MHz

TX SPECIFICATIONS

	DataRate	TX Power	Tolerance
802.11b	1Mbps	20 dBm	+/-1dB
	2Mbps	20 dBm	+/-1dB
	5.5Mbps	20 dBm	+/-1dB
	11Mbps	20 dBm	+/-1dB
802.11g OFDM	6Mbps	20 dBm	+/-1dB
	9Mbps	20 dBm	+/-1dB
	12Mbps	20 dBm	+/-1dB
	18Mbps	20 dBm	+/-1dB
	24Mbps	20 dBm	+/-1dB
	36Mbps	18 dBm	+/-1dB
	48Mbps	16 dBm	+/-1dB
	54Mbps	15 dBm	+/-1dB

RX SPECIFICATIONS

	DataRate	Sensitivity	Tolerance
802.11b	1Mbps	-95 dBm	+/-1dB
	2Mbps	-94 dBm	+/-1dB
	5.5Mbps	-93 dBm	+/-1dB
	11Mbps	-90 dBm	+/-1dB
802.11g OFDM	6Mbps	-92 dBm	+/-1dB
	9Mbps	-91 dBm	+/-1dB
	12Mbps	-89 dBm	+/-1dB
	18Mbps	-88 dBm	+/-1dB
	24Mbps	-84 dBm	+/-1dB
	36Mbps	-81 dBm	+/-1dB
	48Mbps	-75 dBm	+/-1dB
	54Mbps	-72 dBm	+/-1dB

ADJUSTABLE CHANNEL SIZE SUPPORT		
5MHz	10MHZ	20MHz

Maximum range

- Using the link margin, we can calculate how far our link can go.
- ***Maximum range*** is achieved when the signal loss is less than the link margin.
- To calculate the maximum range, we must know the equipment parameters, calculate the free space loss and estimate the allowed loss.
- Equipment parameters can usually be found on the manufacturer's data sheets.

Free space loss

- ***Geometric spreading*** happens because the wavefront radiated signal energy expands as a function of the distance from the transmitter.

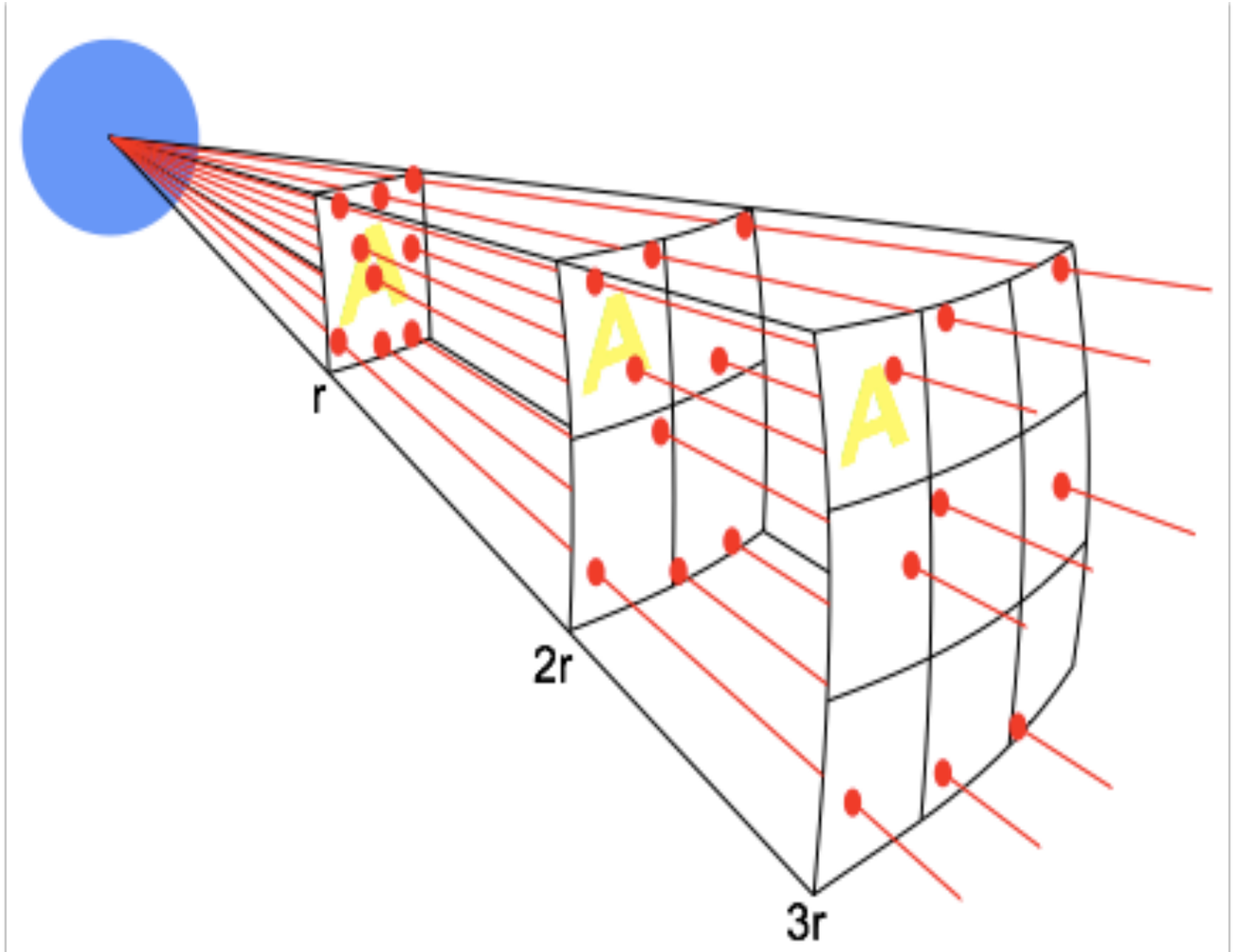


Figure from *http://en.wikipedia.org/wiki/Inverse_square*

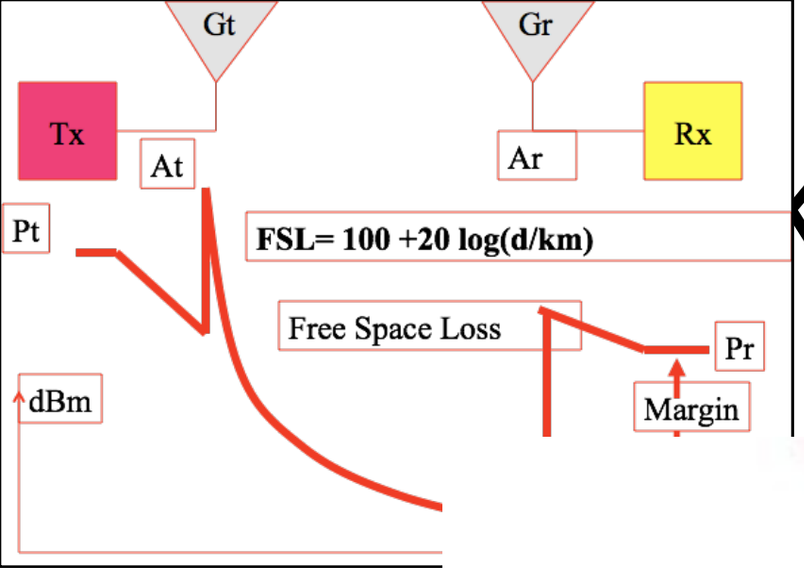
Free space loss

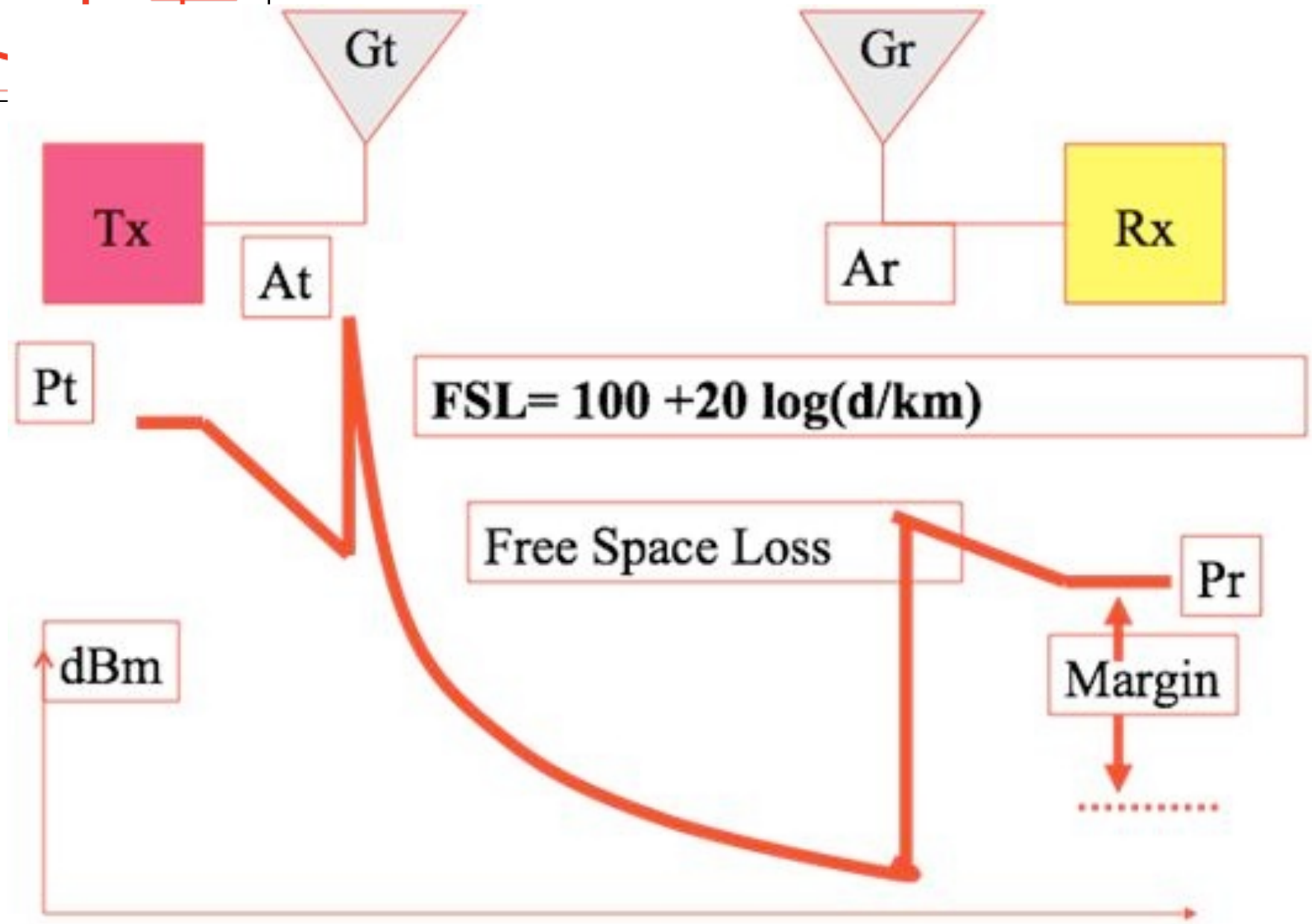
- Using decibels to express loss and using 2.45 GHz as the signal frequency, the equation for the Free Space Loss is:

$$L_{fsl} = 100 + 20*\log(r)$$

- ...where ***L_{fsl}*** is expressed in dB and ***r*** is in kilometers.

k budget calculation





Radio Mobile: intro

- It is a tool for the design and simulation of wireless systems.
- Predicts the power budget of a radio link.
- Uses digital maps and GIS (Geographical Information Systems) as well as any other digital map, even the ones digitized by yourself.

- It is public domain software.
- Runs on Windows 95, 98, ME, NT, 2000 and XP.

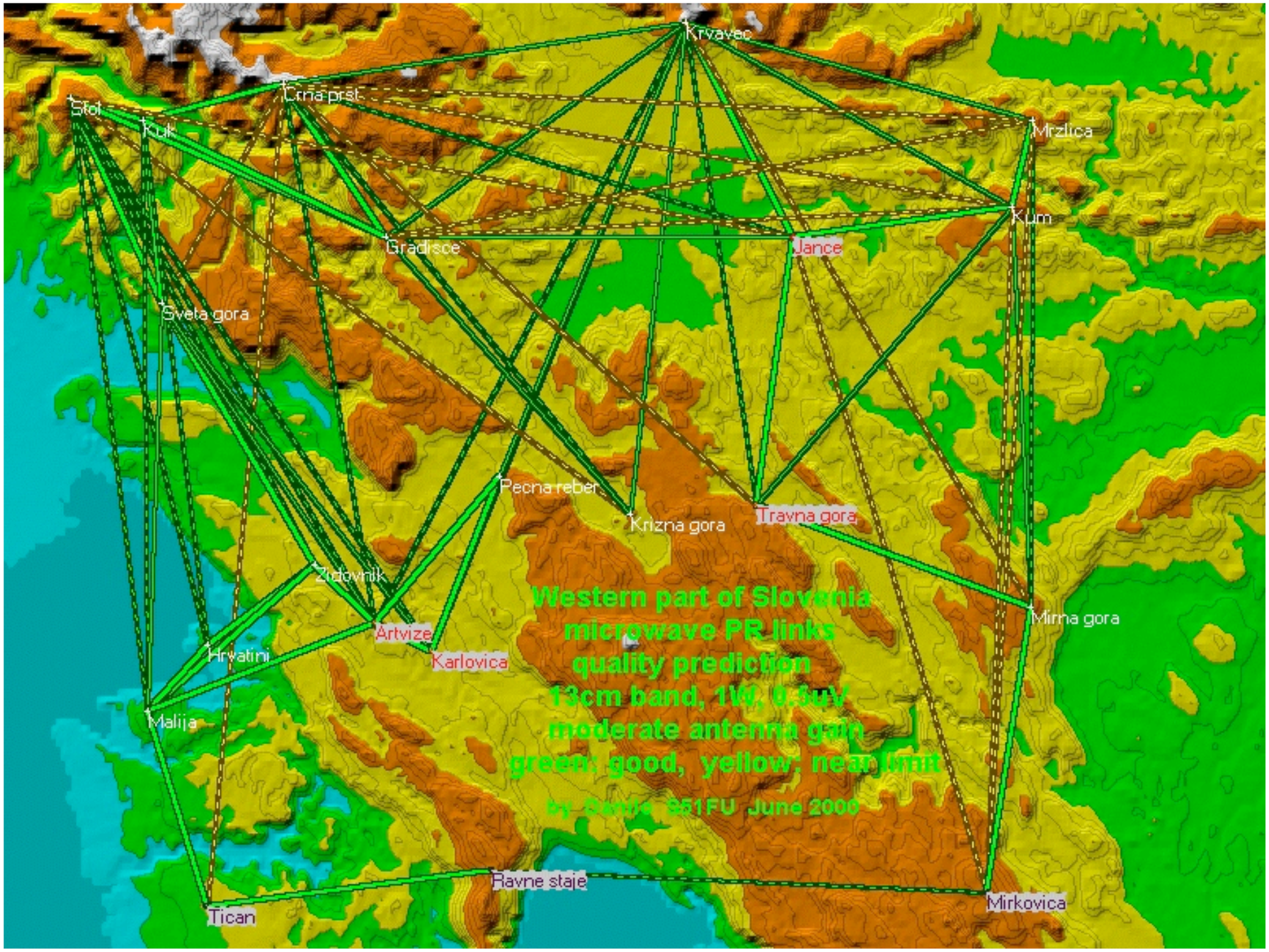
Radio Mobile

- Uses Digital terrain Elevation Model for the calculation of coverage, indicating received signal strength at various point along the path.
- Radio Mobile automatically builds a profile between two points in the digital map showing the coverage area and 1st Fresnel zone.
- Digital elevation maps (DEM) are available from several sources.
- Different antenna heights can be tried to achieve optimum performance.

Radio Mobile

- Works from 20 kHz to 200 GHz.
- Checks for line of sight.
- Calculates path loss, including losses due to obstacles.
- Creates networks of different topologies (net master/slave, PTP and PMP).
- Calculates coverage area from the base

Radio Mobile



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