WiFi Long Shots

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Elektra Wagenrad

Why?

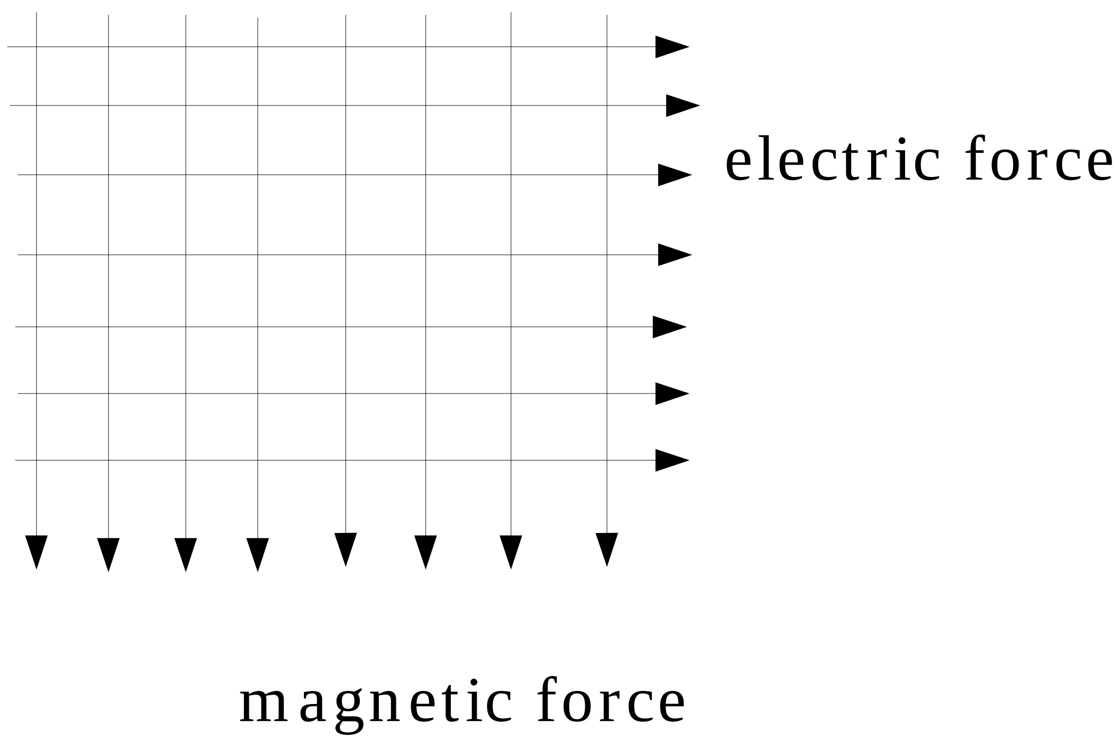
- Building cheap infrastructure wherever ISP's don't see the chance of quick return of investment.
- Community Networks
- Add your motivation here ;-)

How? Make sure you have...

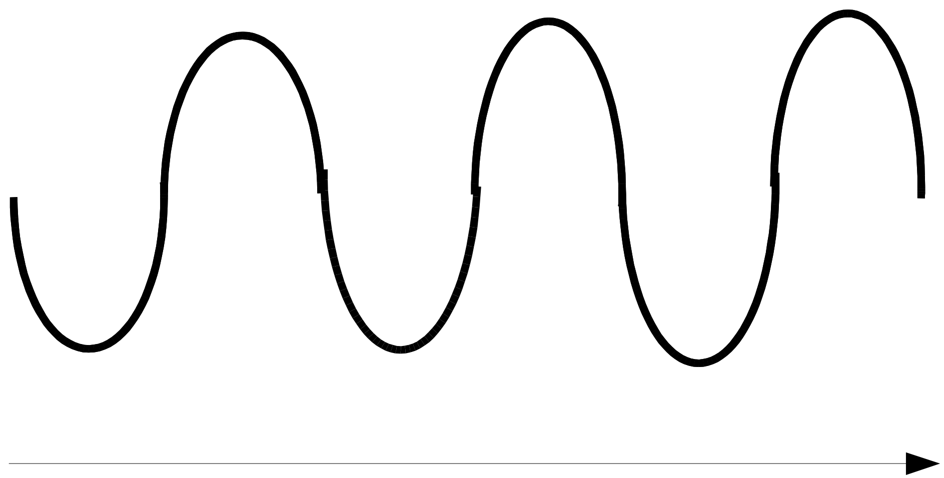
Finally, the beef...

- Free line of sight
- Clear Fresnelzone (60 % free at least)
- Good & powerful Wifi NICs that could be switched into non-standard 802.11-mode
- Antennae with a lot of gain ;-)
- Proper mounted antennae, cables and plugs
- Decent protection against rain and moisture

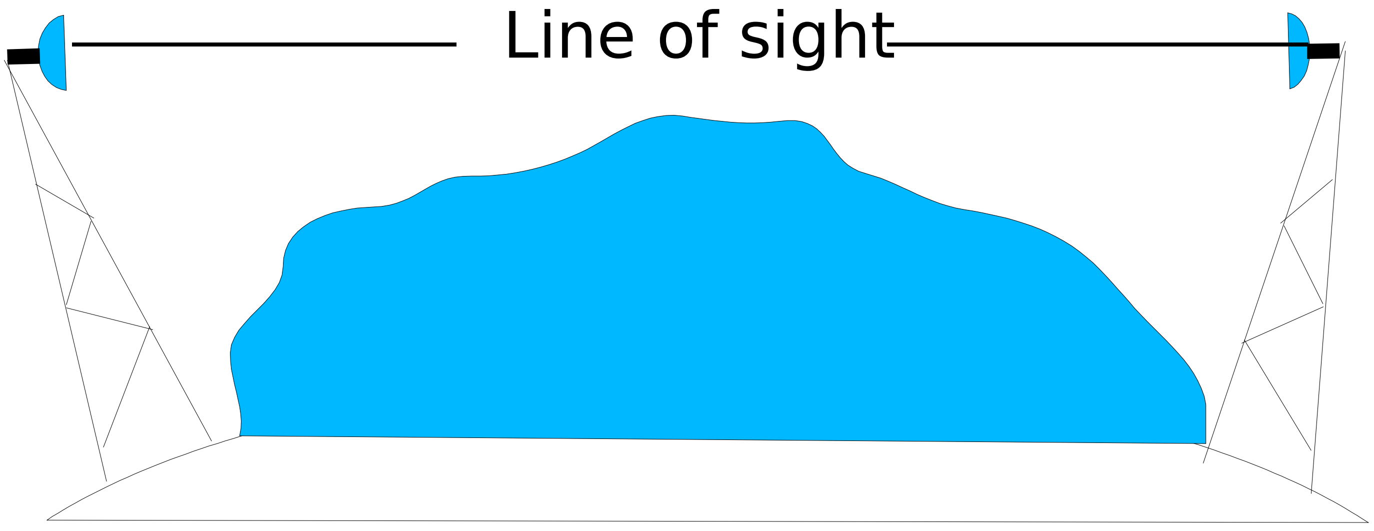
Short introduction to electromagnetic waves



Frequency and wavelength

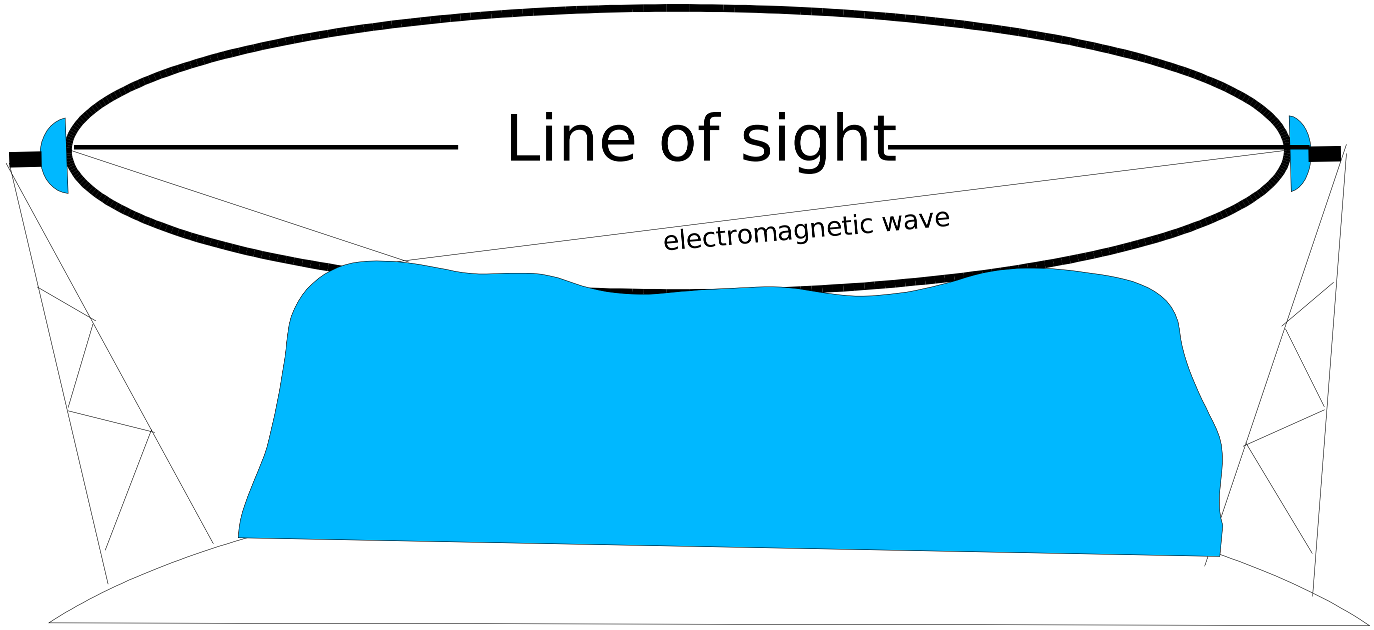


Free line of sight



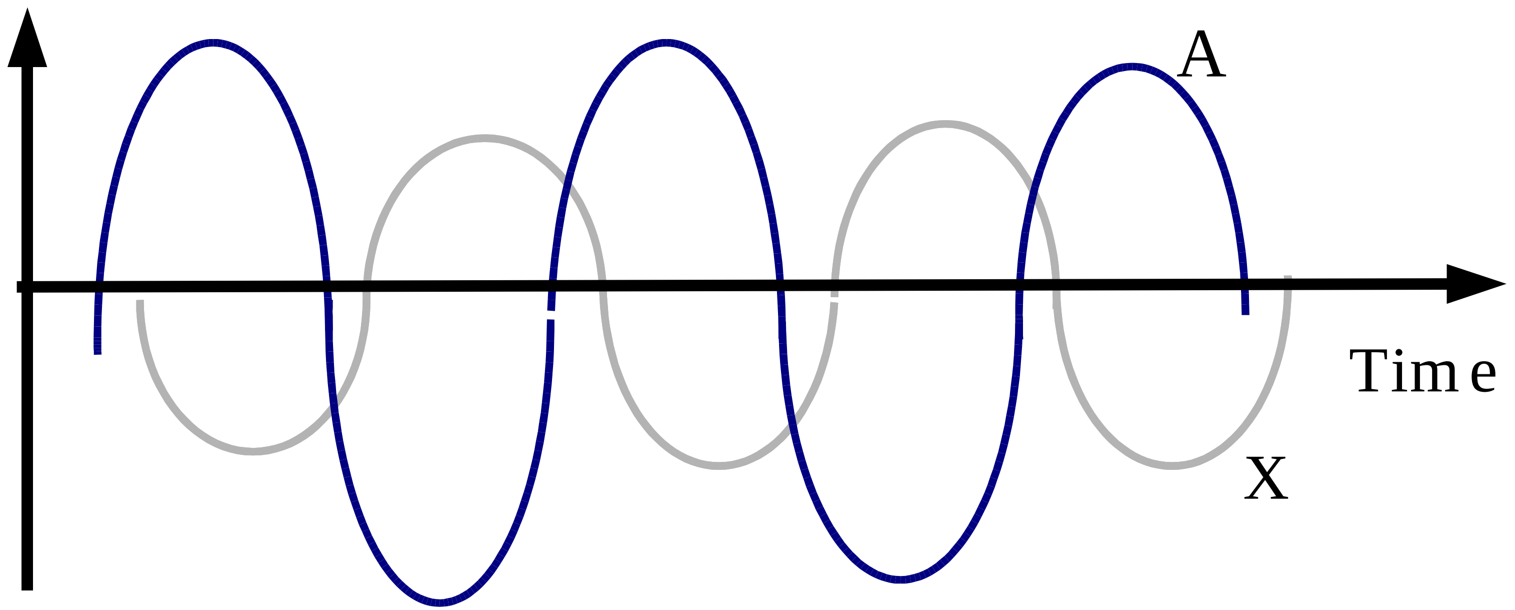
Microwaves behave like light
If the line of sight is obstructed a long shot will never work
With plenty of power you may penetrate a few objects like trees, but certainly only achieve 'short' distance (that is the way WiMAX goes)

Fresnel Zone



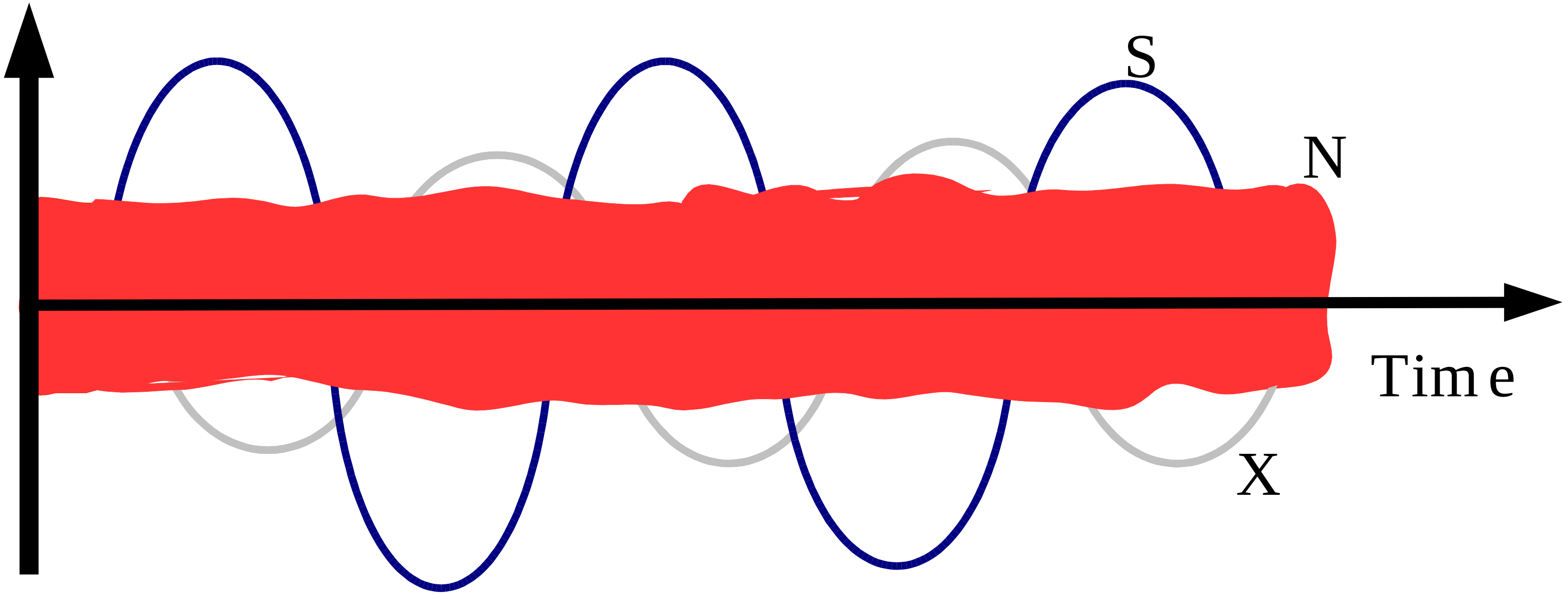
An area between the antennae that looks like a ellipsoid in 3D. If there are objects in this area, electromagnetic waves are reflected and reach the antenna on the receiving side in or out of phase. This will attenuate the signal. (In theory it can also amplify it, though.
I promise – it won't...)

Waves - in or out of Phase



Wave A is the signal we want to receive, following line of sight
Wave X is one disturbing wave reflected in the fresnel-zone
Wave X is out of phase because it arrived later travelling a longer path.

Waves - In or out of Phase



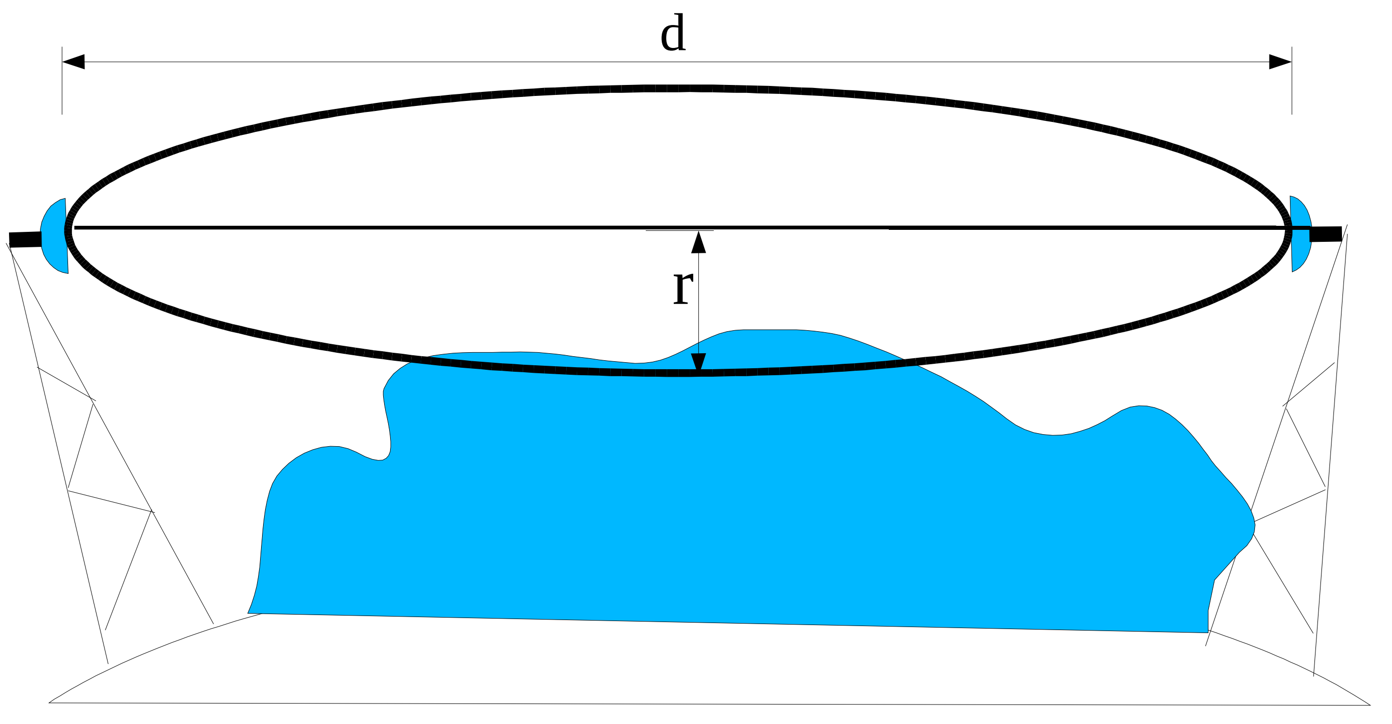
The sum of all fresnelzone-reflected waves adds up to noisefloor N, reducing our Signal-to-Noise Ratio.

Fresnel Zone

- The most difficult issue to deal with.
- 60 % of the Fresnelzone must be kept clear without obstructions at least. Otherwise the link will be unreliable, poor or may never work.
- For many links the most expensive problem – you have to keep the Fresnelzone clear by any means necessary. That could mean to erect your own towers, if you are not lucky enough to find a appropriate hill, building or the like.

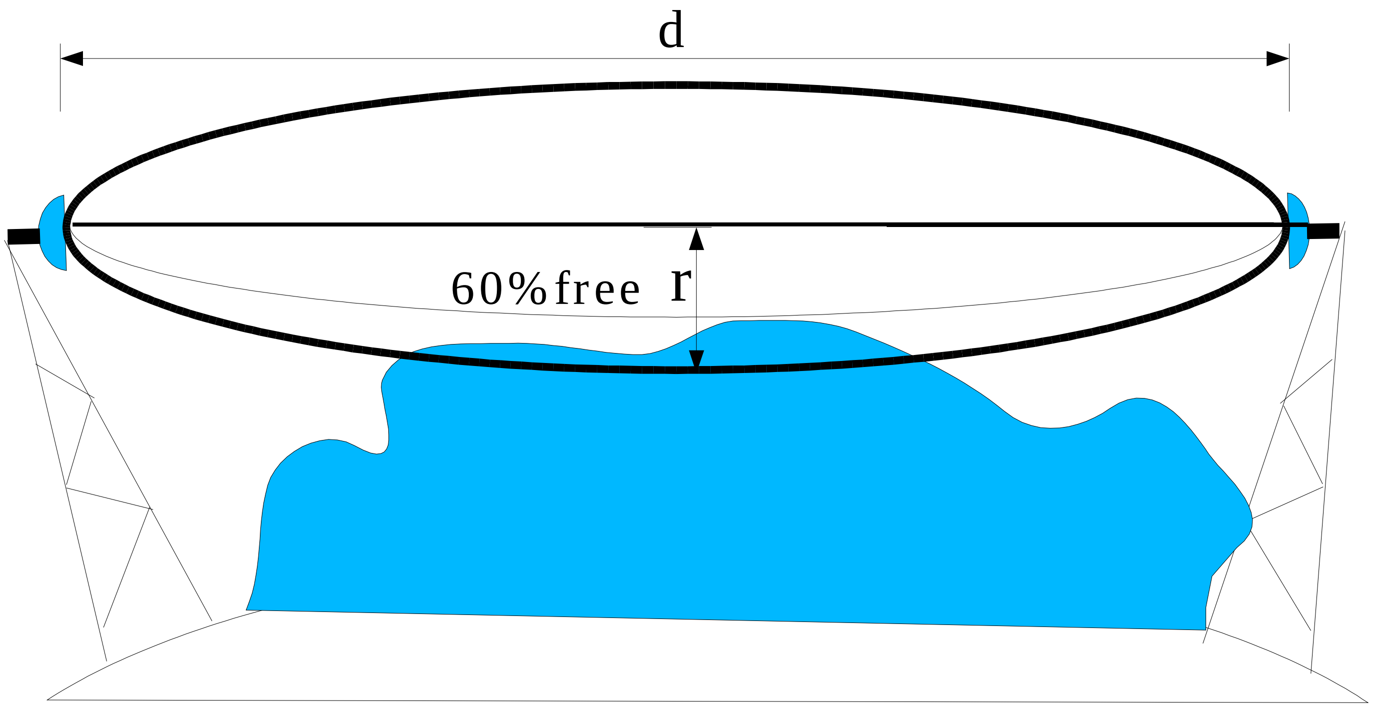
Fresnel Zone Calculation

$$r = 0.5 * \sqrt{\lambda * d}$$



Fresnel Zone Calculation

$$r = 0.5 * \sqrt{\lambda * d}$$



Ideally would be a 80%-free Fresnel Zone, no significant signal loss.
Keep at least 60 % of the Zone free – that will sacrifice some signal strength.

Fresnel Zone &Terrain Roughness

If the Fresnel Zone is 60% clear, there will be attenuation in addition to regular free space loss. A rough estimation:

- Flat surface adds 2 dB attentuation to free space attenuation
- Small houses of similar height / forest adds about 3 dB loss
- Urban area adds estimated loss of about 5 dB

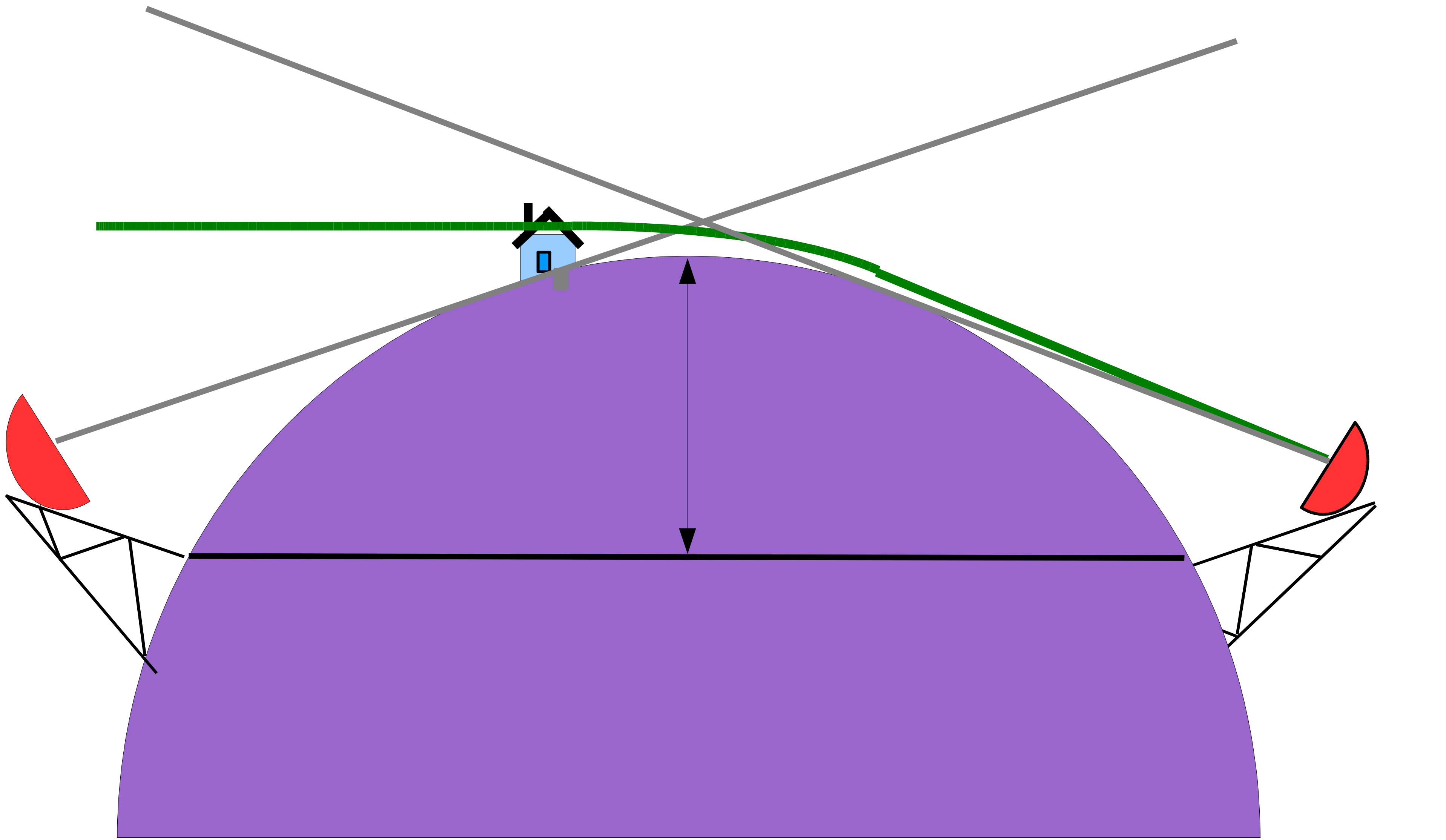
How to deal with the Fresnel Zone

The diameter of the Fresnel Zone depends on the length of the link and the wavelength λ. Keep it small by choosing the highest frequency ⇔ smallest wavelength λ you can use.

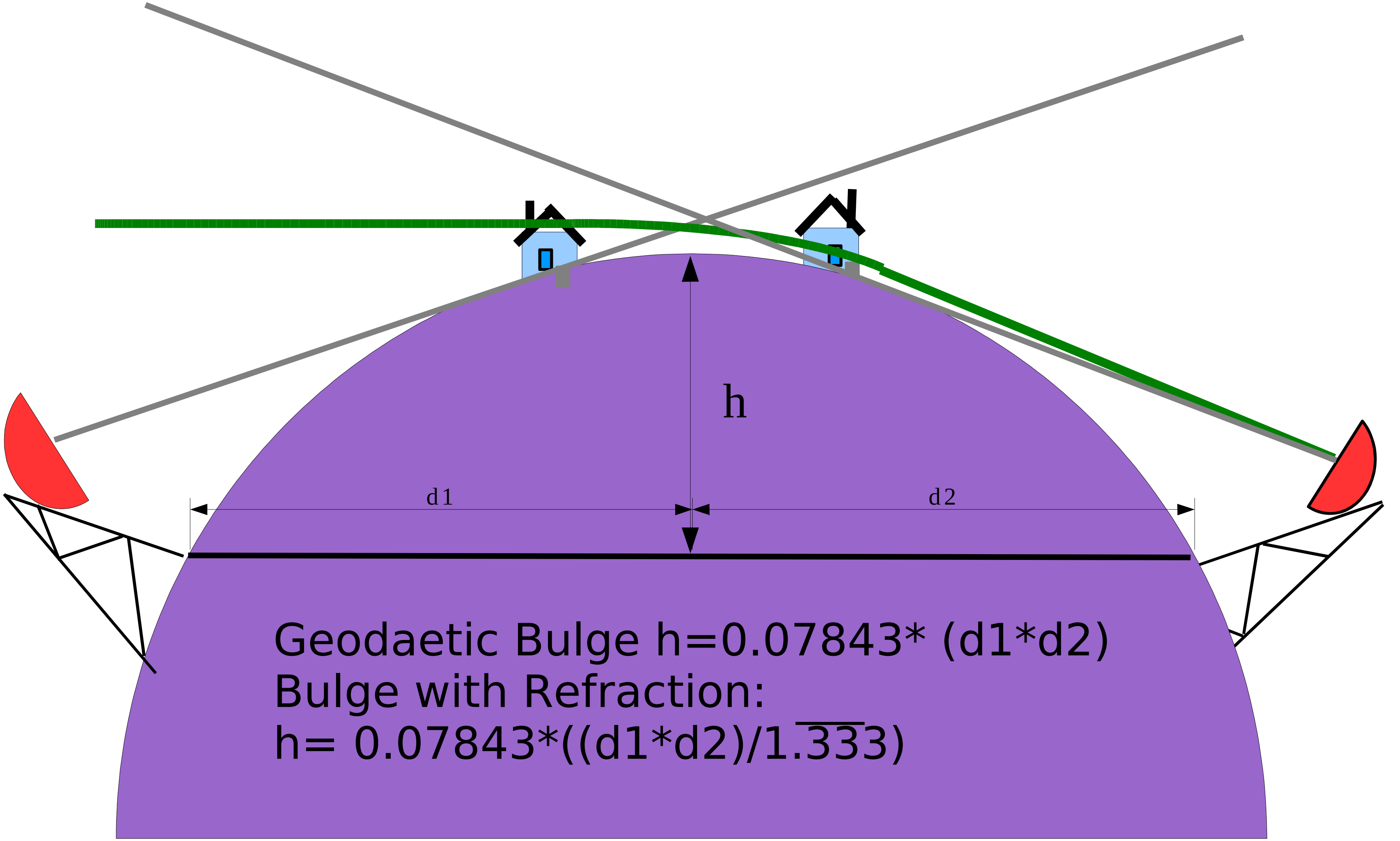
⬆Frequency = ⬇Wavelength λ = ⬇Fresnel Zone ø

A tradeoff for using 5.x Ghz instead of 2.4x is bigger free space attenuation, higher sensitivity to rain and fog. But Antennae have considerably higher gain at higher frequencies.

Earth Bulge



Earth Bulge


h
d1
d2
Geodaetic Bulge h=0.07843* (d1*d2)
Bulge with Refraction:
h= 0.07843*((d1*d2)/1.333)

Antenna height calculation

Calculate the height of the antennae (depending on Fresel Zone radius, landscape, earth bulge).

Example:
30 km distance. Frequency 5GHz

Wavelength λ = Speed of light/Frequency
λ= 299 000 000 m/sec / 5 000 000 000 Hz
λ=0.06 m

Fresnel zone radius for 5GHz :
$21.21m = 0.5 * \sqrt{30\ 000\ m * 0.06m}$

Fresnel zone radius with 40% obstructions, 60 % clear:
12.73m = 21.21m * 0.6

Antenna height calculation

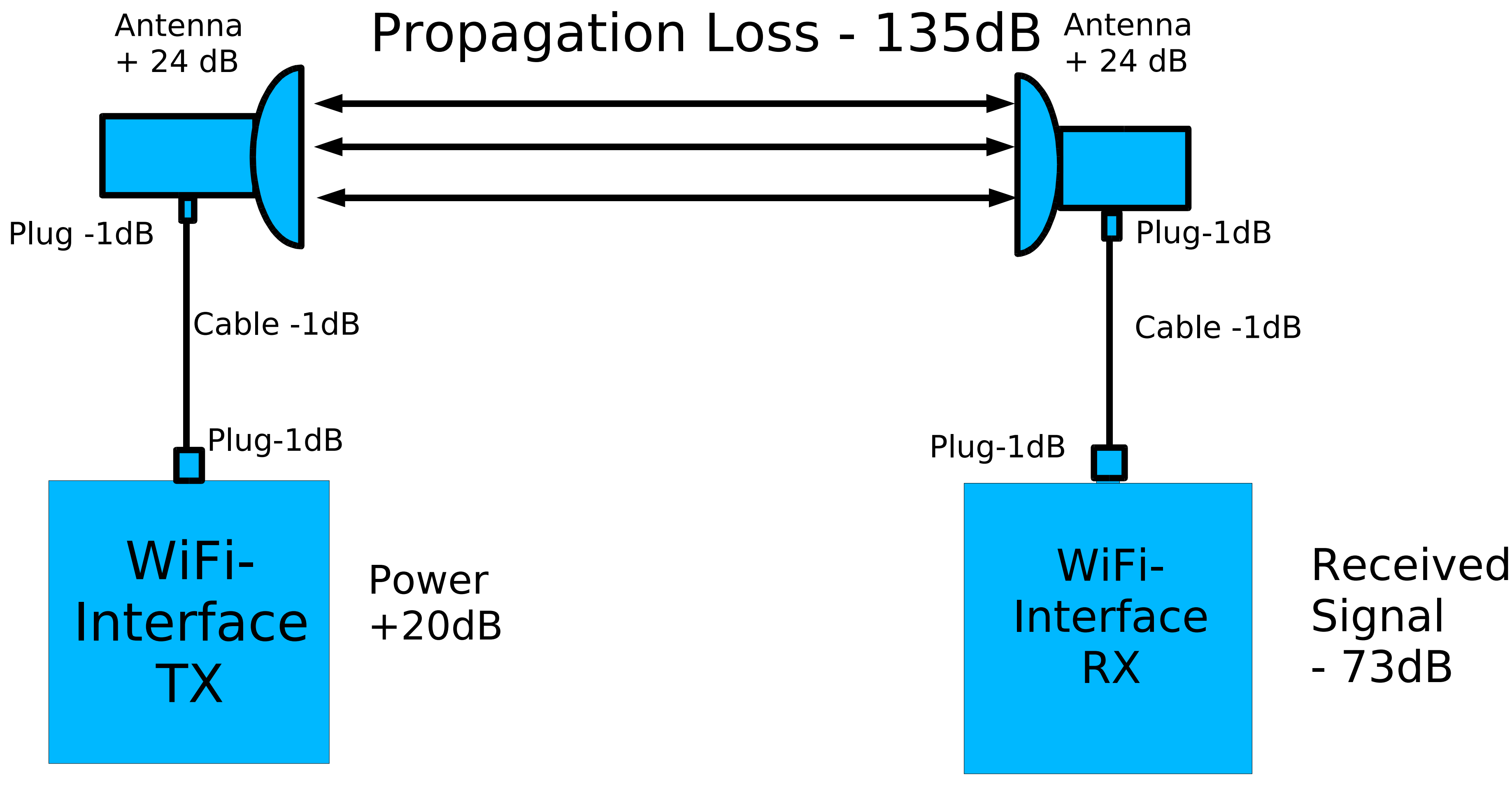
Earth bulge (in the middle between towers):

13.23m=0.07843*((15km*15km)/1.333)

Tower height:
25.96m=12.73m+13.23m

Link calculation

(Example values...)



-73dB = 20dB – 1dB – 1dB – 1dB + 24dB – 135dB + 24dB – 1dB – 1dB - 1dB

Transmitter(TX)-Power

More is more, but does not really help much if the Fresnel Zone is obstructed...

more power = more powerful disturbing reflections

Good receiver sensitivity is more important!

Measurment unit is mW or dBm.

1mW = 0 dBm	16mW = 12 dBm
2mW = 3 dBm	32mW = 15 dBm
4mW = 6 dBm	64mW = 18 dBm
8mW = 9 dBm	128mW = 21 dBm

Receiver sensitivity

Card	1	2	5.5	11 Mbps
Senao NL/SL-2511CD PLUS EXT2 (200mW, 2 MMCX connectors)	-95	-93	-91	-89
Cisco 350 Series (100mW)	-94	-91	-89	-85
Compaq MultiPort W200 (32mW)	-94	-91	-87	-85
Lucent/Agere/Proxim Orinoco Gold/Silver Card (32mW)	-94	-91	-87	-82
Netgear MA401 (PCMCIA)	-92	-88	-87	-84
Microsoft MN-520 (PCMCIA16)	-83	-83	-83	-80

http://freenetworks.org/moin/index.cgi/ReceiveSensitivity

A Uber-Wifi-Card ;-)

High Power (26dbm) Atheros 6G Mini-PCI Adapter-NMP-8602

Receive Sensitivity (Typical)
802.11a:
-90dBm @ 6Mbps,
-74dBm @ 54Mbps
802.11g:
-92dBm @ 6Mbps,
-76dBm @ 54Mbp
802.11b:
-96dBm @ 1Mbps
-92dBm @ 11Mbps

Tx-Power
2.412~2.472G(IEEE802.11g)
26 ± 2dBm @6Mbps
23 ± 2dBm @54Mbps
2.412~2.472G(IEEE802.11b)
26 ± 2dBm @1, 2, 5.5 and 11Mbps
@ 5.725 ~ 5.825GHz
20 ± 2dBm @6Mbps
17 ± 2dBm @54Mbps

Free space attenuation

Distance km	@2.5 GHz -dB	@5.9GHz -dB
0.1	80.41	87.86
0.2	86.43	93.89
0.3	89.95	97.41
0.4	92.45	99.91
0.5	94.39	101.84
0.6	95.97	103.43
0.7	97.31	104.77
0.8	98.47	105.93
0.9	99.49	106.95
1	100.41	107.86
2	106.43	113.89
3	109.95	117.41
4	112.45	119.91
5	114.39	121.84
6	115.97	123.43
7	117.31	124.77
8	118.47	125.93
9	119.49	126.95
10	120.41	127.86
15	123.93	131.39
20	126.43	133.89
30	129.95	137.41
40	132.45	139.91
50	134.39	141.84
100	140.41	147.86
150	143.93	151.39
200	146.43	153.89

Rule of thump for WiFi-frequencies:

3 dB more attentuation for 50% more distance
6 dB more attentuation for 100% more distance

Link Fade Margin

@5.8GHz= 0.5dB/km
@2.5GHz= 0.1dB/km

(worst case)

Antennae

Big grid dish
24dBi 2.4GHz
27dBi 5.8GHz

Cables and plugs

Cable

Aircom Plus
Aircell 7
LMR400
RG213

Plugs

N-Type
Don't use crimp-plugs – not waterproof

Wrap outdoor connectors with self-amalgaming tape. Don't worry too much about signal losses of different cable – just keep them as short as possible.

Example calculation @5.8GHz

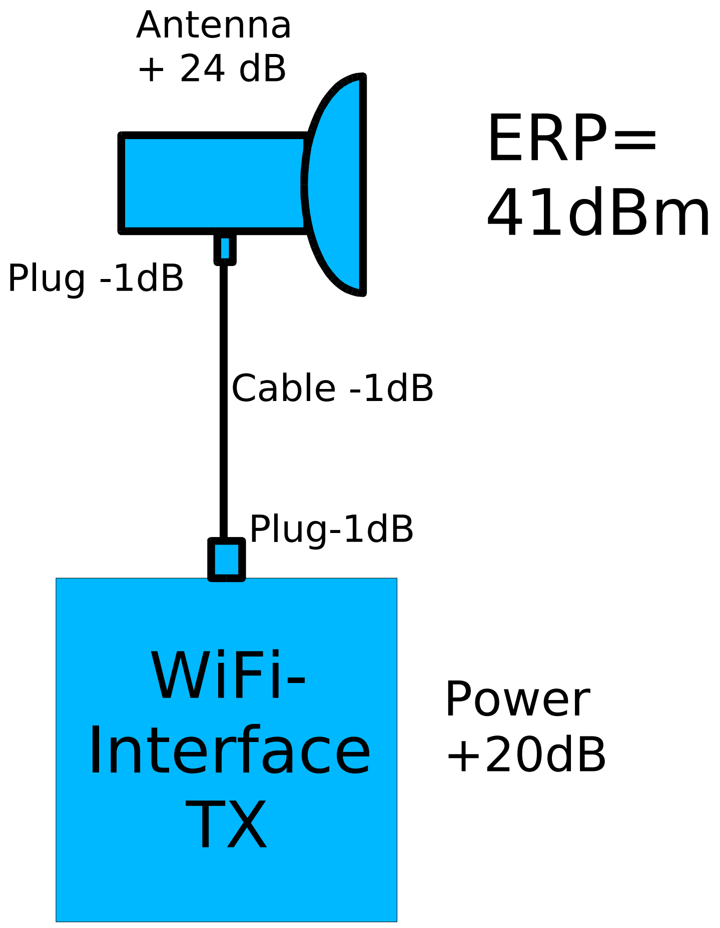
Free space loss 30 km	= -137.5dB
fade margin	= - 15dB
terrain roughness	= - 5dB
--	
total propagation loss	= -157.5dB
cable,connector loss	= - 6dB
--	
total loss	= - 163.5dB
antenna gain 2x	= + 54dB
txpower (senao)	= + 23dB
--	
signal strength at receiver input	
	= - 86.5dB

Calculation within legal limits

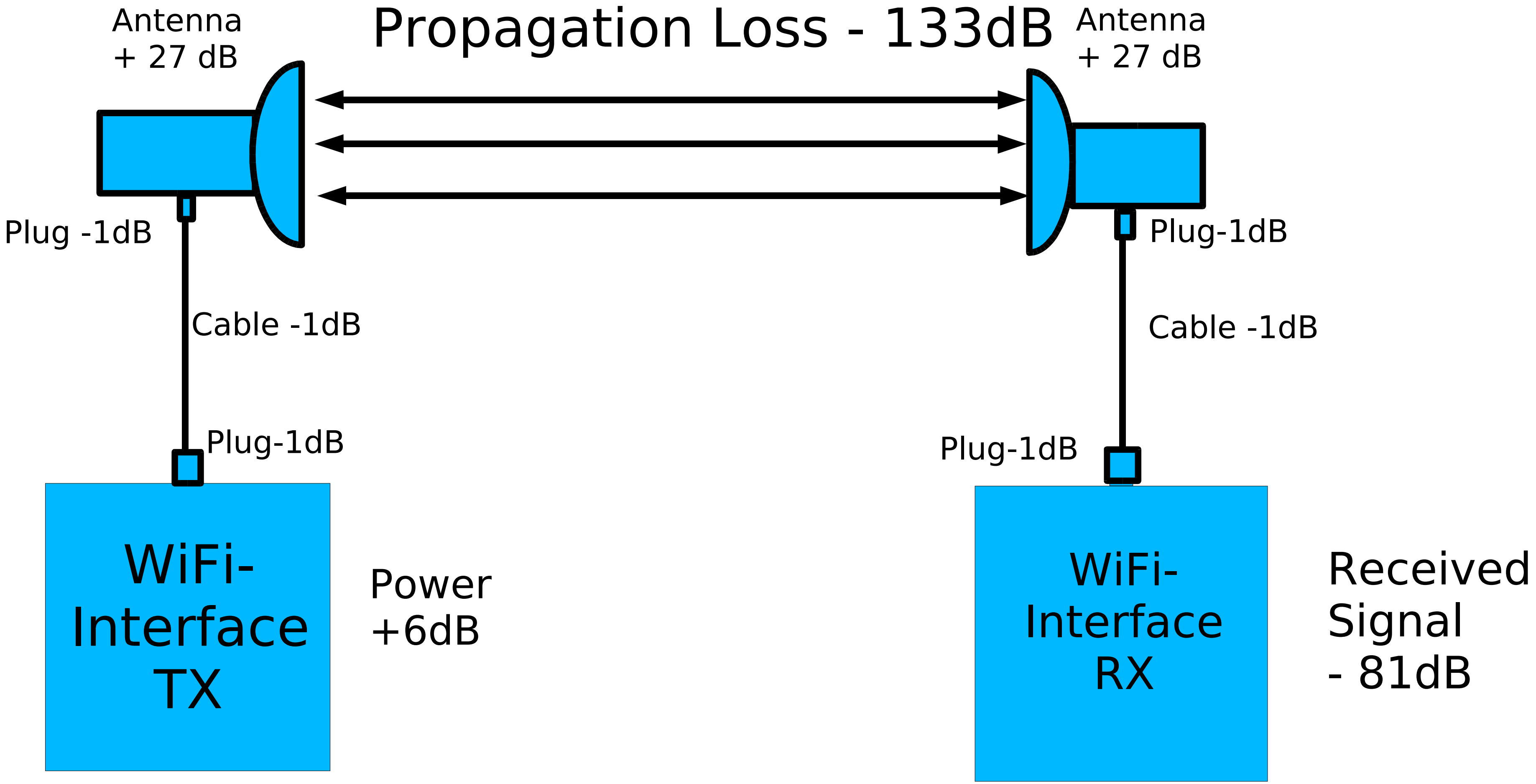
Effective radiated power ERP

The sum of all gains and losses
on the transmitter side.
2.4GHz in Germany 20dBm
5.8GHz “ “ “ 30dBm

Better to have less TX-Power and
more antenna gain.



Example: 5.8GHz @ 10km



Long distance timing issues of 802.11b

Propagation delay:

1μsec for 299 m

100μsec for 29.9km

802.11b provides very small timeslots for successful transmissions.

10 μsec Short Inter-Frame Spacing interval

50 μsec Distributed Point Coordination Function Inter-Frame Space

640 μsec Contention Window

Long distance timeing issues

Some chipsets just do the trick out of the box,
while others don't...

Working:
Prism 2, 2.5, 3
Orinoco 802.11b
Atheros a,b,g (untested, but tools are available to adjust timeslots for distance with **athctrl)**

Alternative: Adhoc-demo-mode

Available for Atheros, Prism and Orinoco
Proprietary 802.11, doesn't necessarily work between different chipsets...

Provided by drivers:
orinoco
hostap
madwifi

Doesn't send acknowledgements...

Initial alignment

Kismet

Links

This document:
www.scii.nl/~elektra

Online link calculator:
http://www.connect802.com/antenna_c_main.php