focus 2015

> Presentation of Slobodan on "Propagation equation"
> Presentation of Marshed on "Radio channels in WPAN"
> also: Shannon, Capacity
> define 2nd presentation

Repeater

Basic Internet.org
.no

- content type filtering
  only compressed text & pictures
- Kinshasa, DRC Congo

EyeSaaS
- admin

Air Ties
- mesh

GHz
5.8 mesh comm. 30dBm
5.1 } end
2.4 } devices

Multi-hop [illegible]

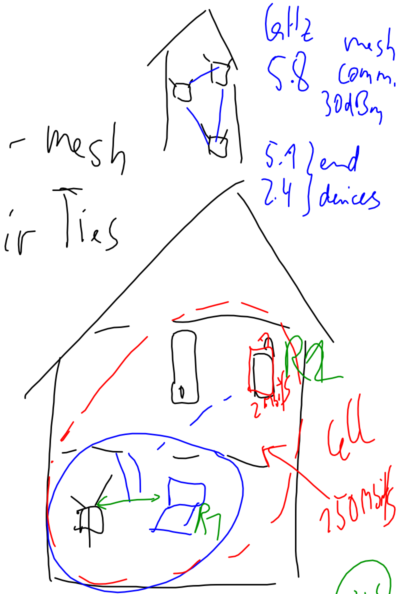
Cell breathing

hot
- timing

delay
4m → 13ns
upstairs 12m → 40ns

Cell = 600 MBit/s

$s = \frac{4m}{3E8 m/s}$ (13ns)
$t = \frac{s}{c}$
$c = \frac{s}{t}$



R2 only 2 Mbit/s
SNR
multipath fading
high power → high noise to R1

for 29Oct

- Slobodan: (I) calculation of receive power and (II) Shanon capacity values
- Marshed: short presentation of paper
- Josef to ask Pedro to present AirTies meas
- agree on 2nd topic
- (Basic Internet) presentation

Exercise:

$$P_R = P_T\, G_T\, G_R \left(\frac{\lambda}{4\pi R}\right)^2$$

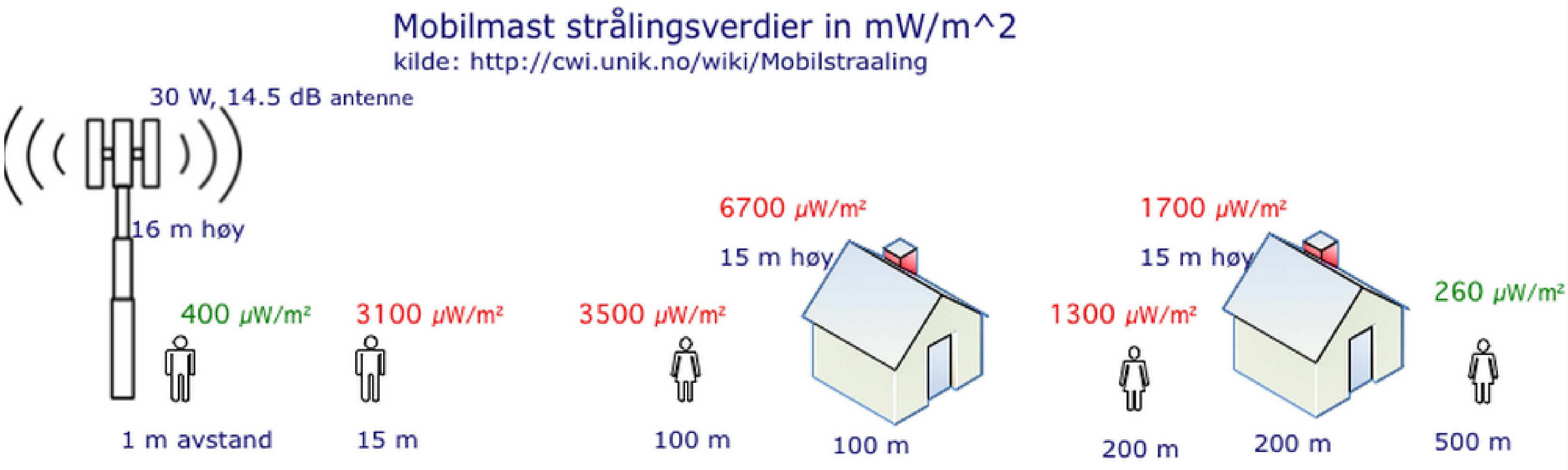
$$P_R[dB] = 10 \log (\ldots\ldots)$$ ← to do

$$= \ldots$$

L = 92.4 + 20 log(d [km]) + 20 log f [GHz]

1 GHz → 1

L =	92.4	+0	1 km
	→ 98.4	6	0.3 2 km
			4 km



Size of this preview: 800 × 244 pixels. Other resolution: 840 × 256 pixels.

Original file (840 × 256 pixels, file size: 56 KB, MIME type: image/png)

File history

Free Space Propagation

develop propagation equation, see (http://www.antenna-theory.com/basics/friis.php)

Power received in an area in a distance R from transmitter:

- area of a sphere is $A_s = 4 * \pi * R^2$
- power transmitted from isotropic antenna is P_t
- antenna area of receiver is $A_r =^2 /4\pi$
- power received in A_r = P_r

$P_r = P_t * A_r/A_s = P_r = P_t * A_r/(4 * \pi * R^2)$

thus

$$P_r = P_t\, G_t\, G_r\, \left(\frac{\lambda}{4\pi r}\right)^2.$$

- convert into dB
- provide examples for f = 10 MHz, 1 GHz, 100 GHz
- discuss influences on radiation pattern

How much is 0 dB_m and 10 dB_m?

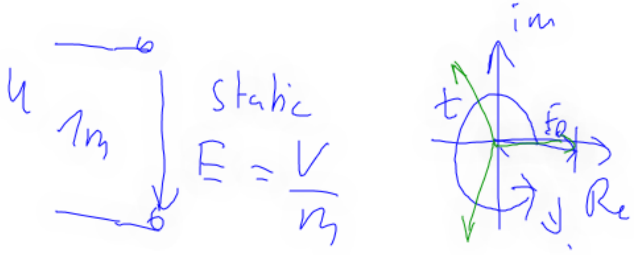
- Convert dBm to mW is: mW = 10^(x/10), x = number of dBm
- Convert mW to dBm is: dBm = 10*log10(y), y = number of mW

So you get:

- 0 dBm = 10^(0/10) = 1 mW
- 10 dBm = 10^(10/10) = 10 mW

Free space attenuation $L = 92,4 + 20\log(d[\text{km}]) + 20\log(f[/\text{GHz}])$

Relation between propagation values



Field strength for a given isotropically transmitted power:

$$E = P_t - 20 \log d + 74.8$$

Isotropically received power for a given field strength:

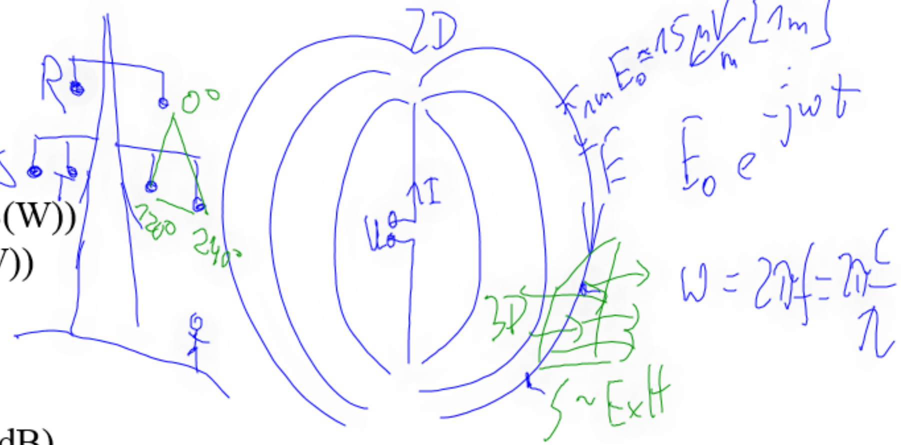
$$P_r = E - 20 \log f - 167.2$$

Free-space basic transmission loss for a given isotropically transmitted power and field strength:

$$L_{bf} = P_t - E + 20 \log f + 167.2$$

Power flux-density for a given field strength:

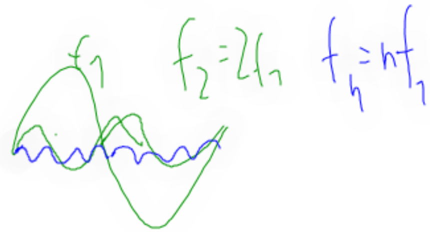
$$S = E - 145.8$$



where:

- P_t : isotropically transmitted power (dB(W))
- P_r : isotropically received power (dB(W))
- E : electric field strength (dB(μV/m))
- f : frequency (GHz)
- d : radio path length (km)
- L_{bf} : free-space basic transmission loss (dB)
- S : power flux-density (dB(W/m²)).

Taken from International Council for Science - www.iucaf.org/SSS2010/presentations/day2/Wilson(Propagation).ppt



$$P_{dB} = 10 \log_{10} \frac{P = 20W}{1W}$$

$\log(\;)$ ← no unit

$$P_{dBm} = 10 \log_{10} \frac{P}{1mW}$$

typical examples

I. Receive Power

II. Shannon Capacity

Typical Mobile

$P_T = 25W$

$G_T = 14 dB$

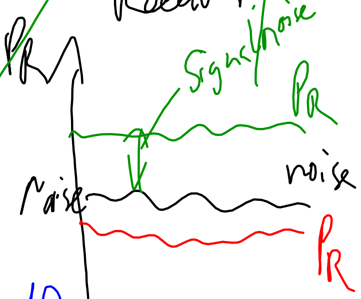
$G_R = 3 dB$

$R = 0.1km \quad 1km \quad 3km \quad 10km$

$f = 900 MHz, \quad 2.1 GHz$

$P_R = ?$

Receiver



Typical WLAN

$G_T + P_T = 20 dBm$ (rule!)

$G_R = 6 dB$

$f = 2.4, 5.2 GHz$

$R = 1, 10, 50m, 150m?$

$P_{Sens\ GSM} = -104 dBm$ (?)

$P_{Sens\ UMTS} = -112 dBm$ (?)

$P_{Sens\ WLAN} = -95 dBm$

Shannon

$$C = B \log_2\left(1 + \frac{S}{N}\right)$$

B: Bandwidth

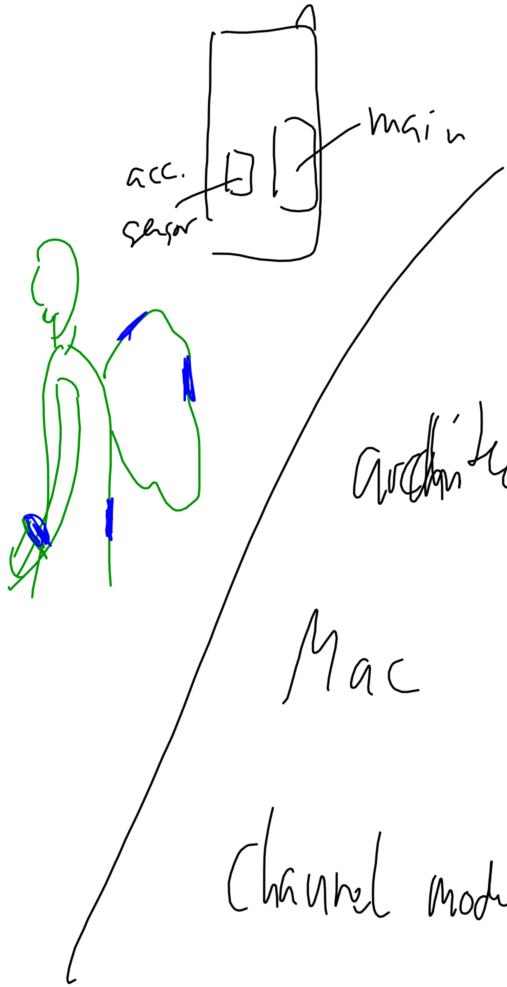
S/N: results from P_R / P_{Noise}

GSM

UMTS

LTE

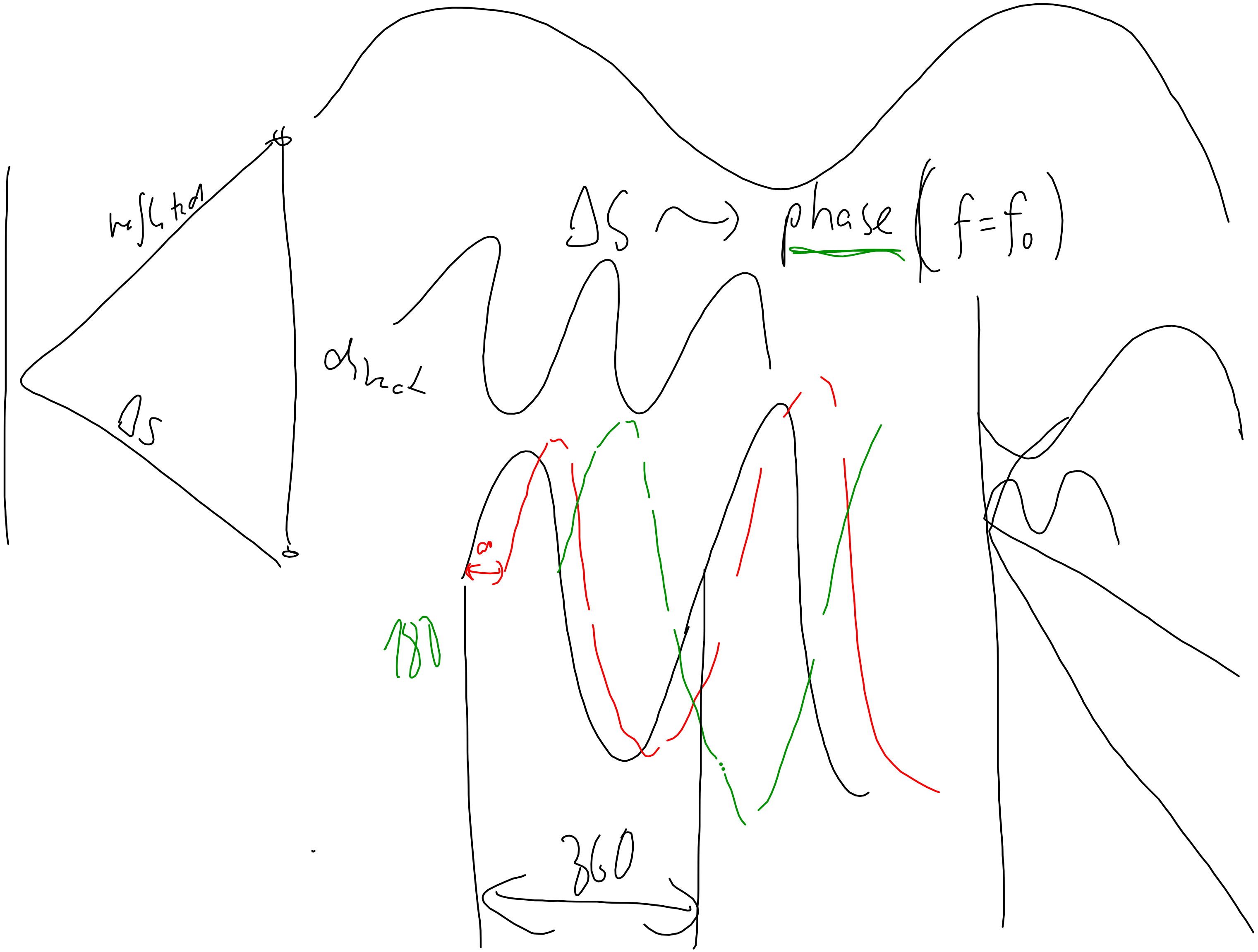
WiFi

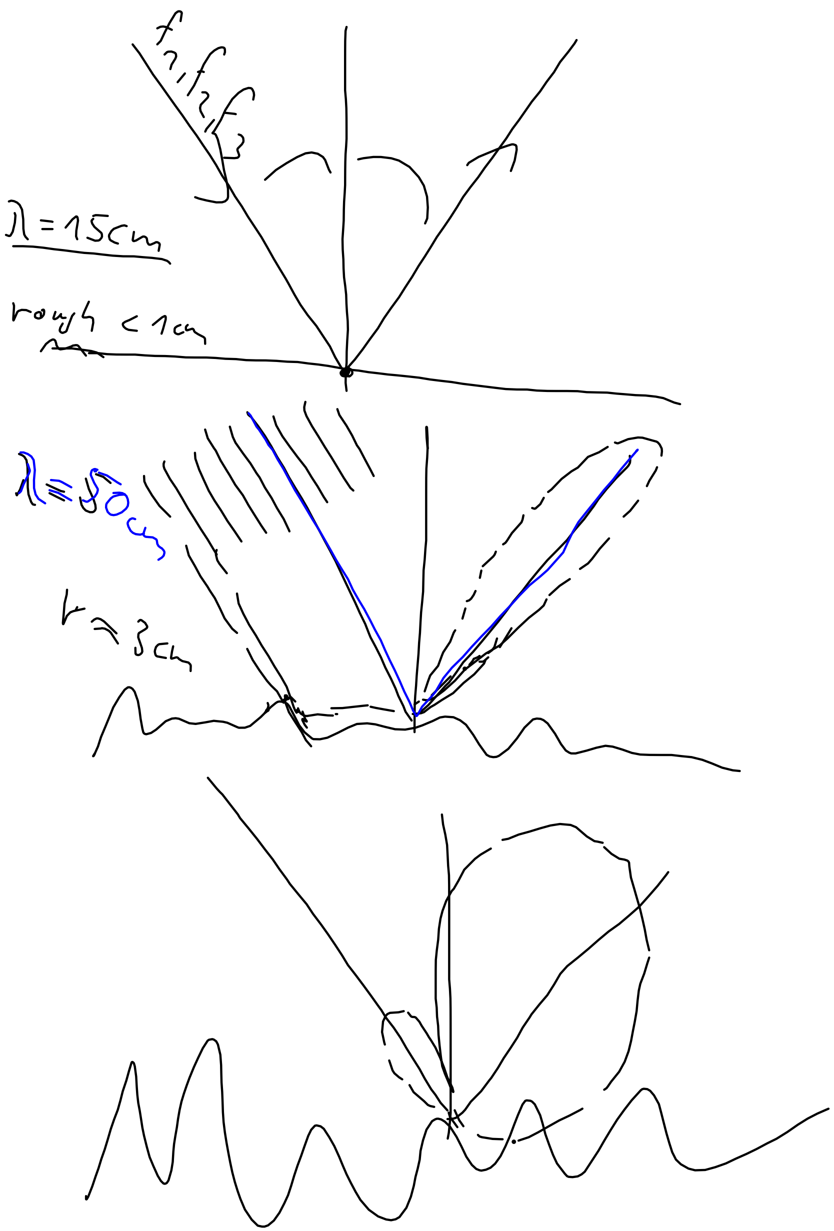


architecture

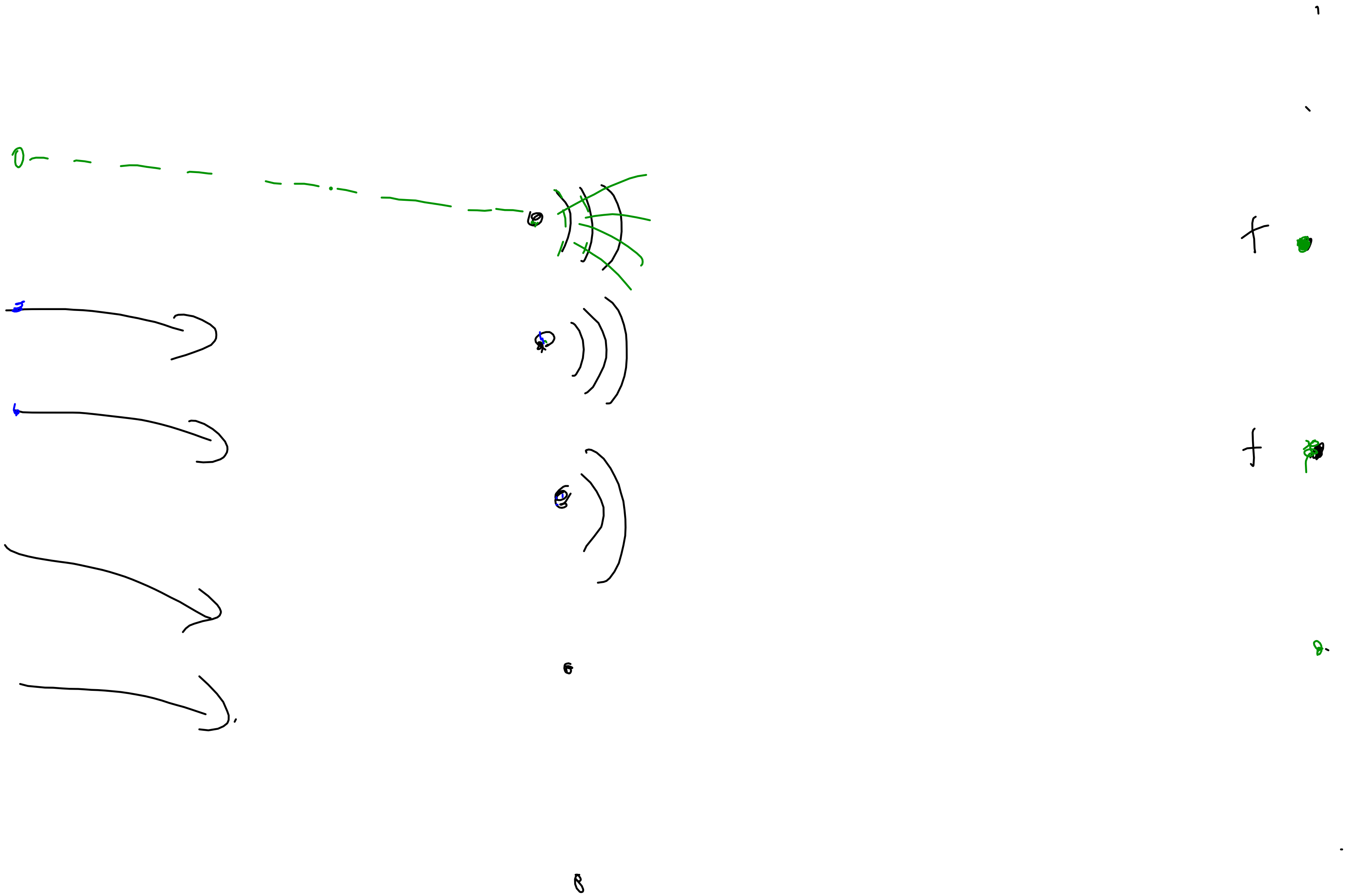
Mac

Channel models/adapt


Δs ~> phase (f = f₀)
Δs
360
180

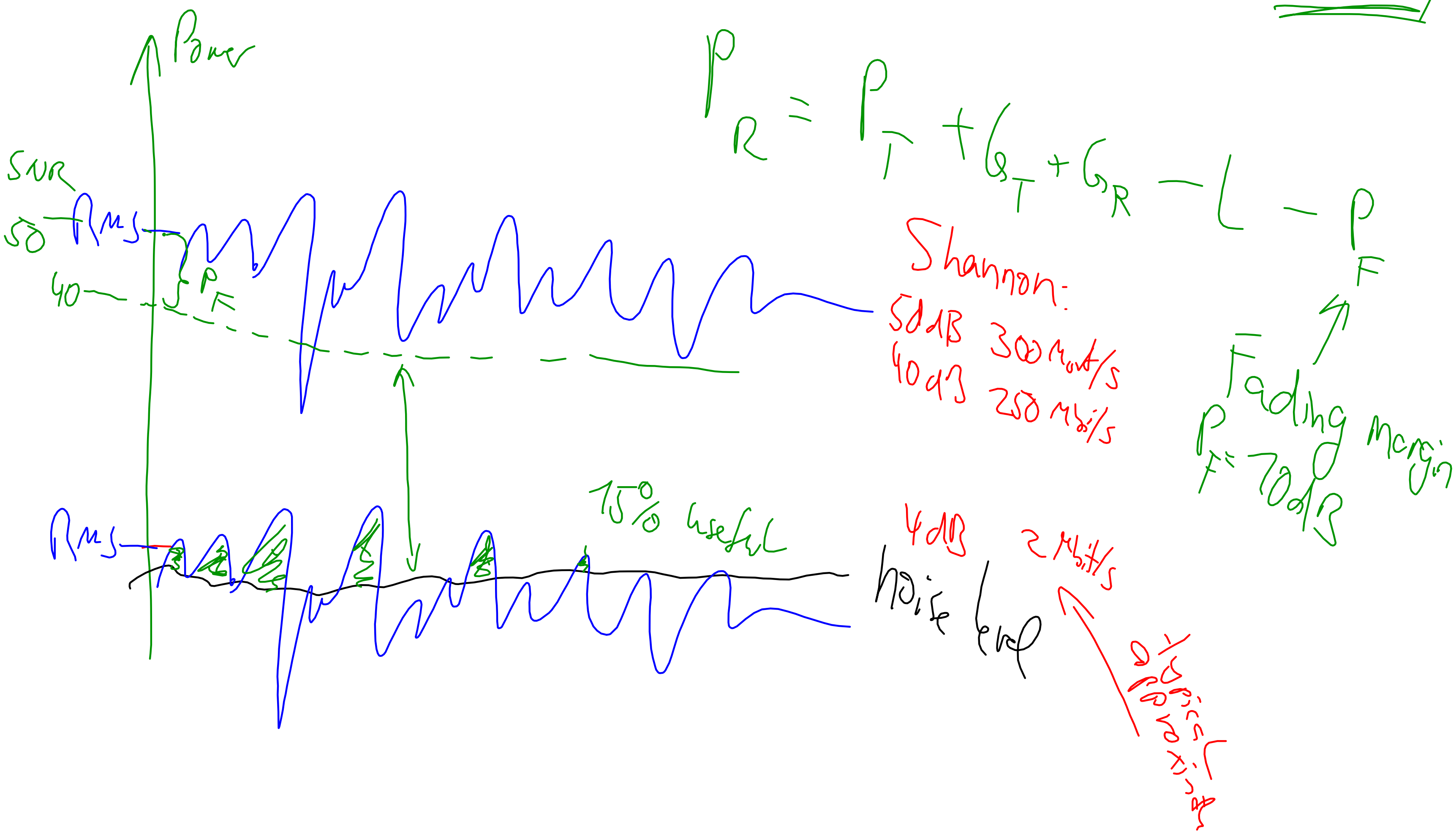


f_1, f_2, f_3
λ = 15cm
rough < 1cm
λ = 50cm
r ≈ 3cm



Effect of Signal to Noise (SNR)

$$P_R = P_T + G_T + G_R - L - P_F$$



Shannon

$$C = B \log_2 (1 + SNR)$$

dominant

B – Bandwidth

Watt ratio

→ 28. Oct

SNR, capacity

Qn: Capacity increase

~80 kbit/s GSM/GPRS 8…10 kbit/s (8 slots) 200 kHz

~1.6 Mbit/s UMTS Edge 8 slots 3.8 MHz

~2 … 16 Mbit/s LTE 2, 5, 10, 20, 40 MHz

~8 Mbps WLAN b/g 20 MHz

~16 Mbps WLAN C 20+20

simplification: P noise, no traffic

P_{sens}	P_T	G_T dB	G_R
−104 dBm	2W	3	14
−116 dBm	25W	14	3
−116 dBm ?	25W	14	3
−95 dBm	100 mW		3
−95 dBm	100 mW		3

Q_1: Given a constant SNR, increase of capacity C from GSM to …

⌘MIMO laptop

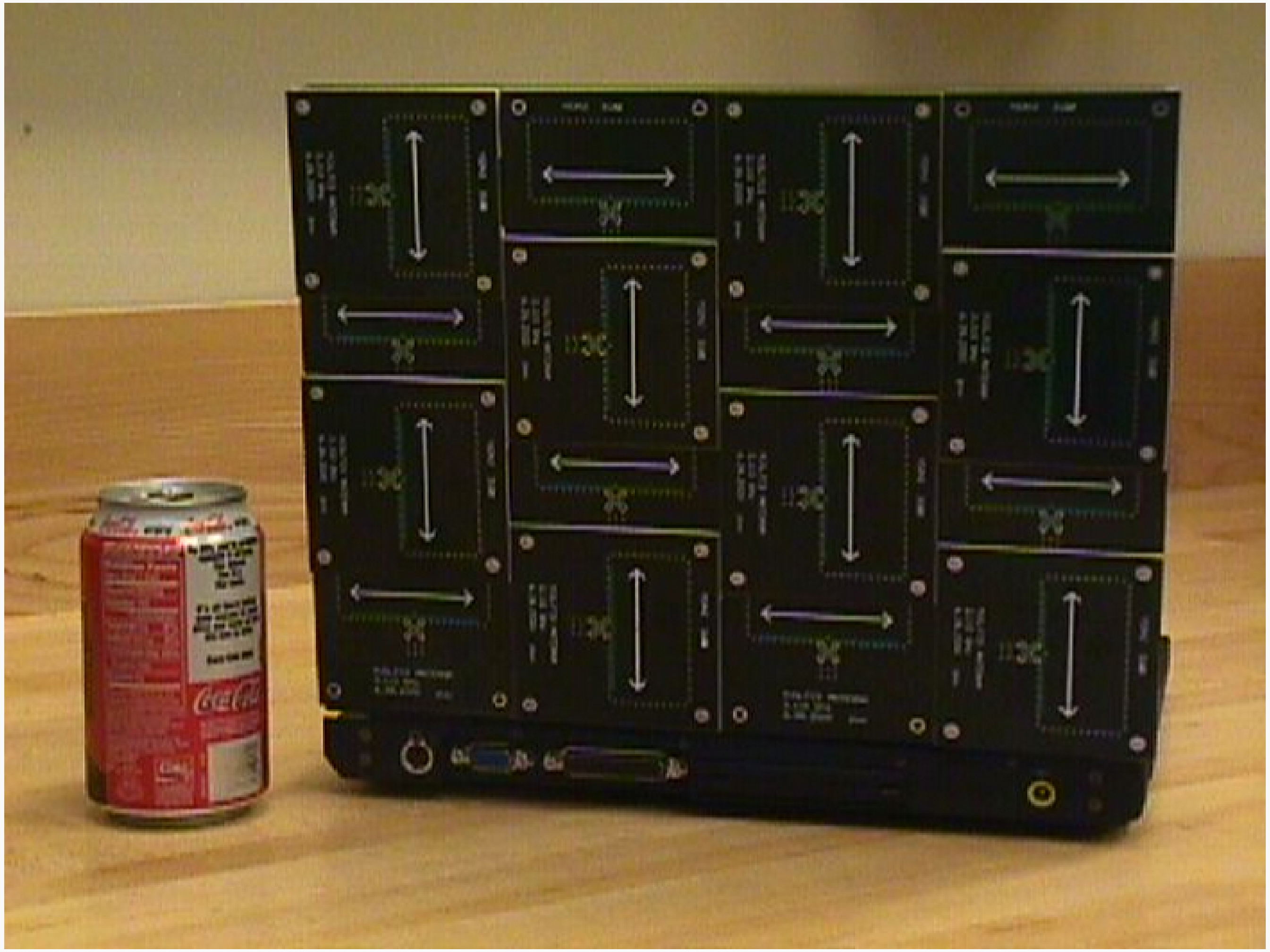
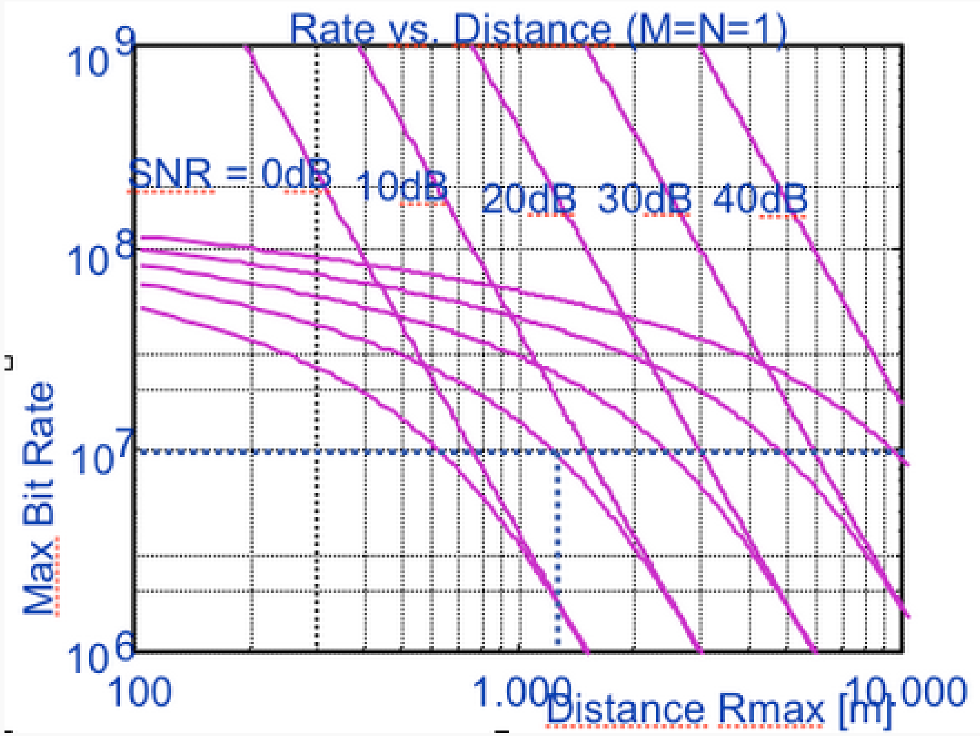


Figure: A MIMO equipped laptop (Source:Valenzuela, BLAST project)

⌘ Range versus SNR



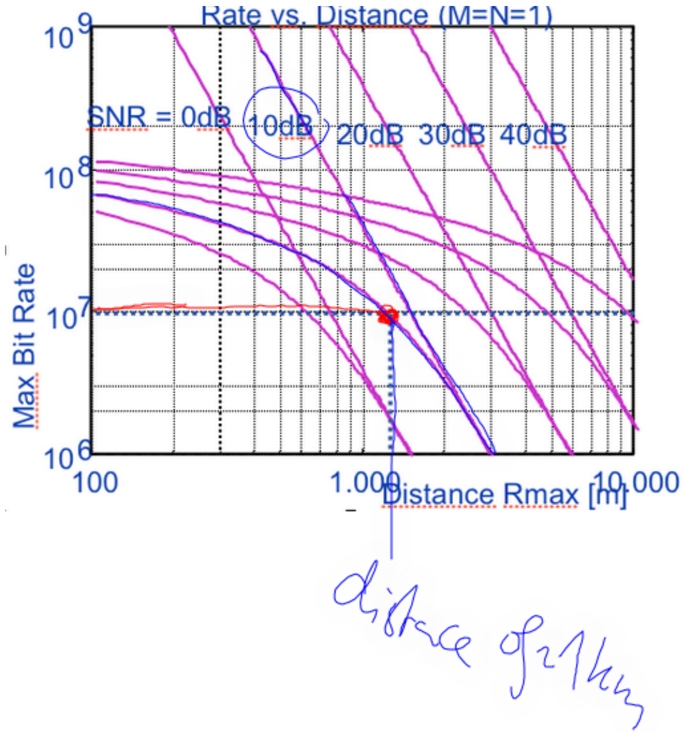
$$R_{\max} = \log_2(1 + SNR)$$

[Source:Valenzuela, BLAST project]

Lessions learned

Let's start What have we learned?

- antenna characteristics and gain
- what happens if I double the frequency (900 - 1800 - 2400 MHz)?
- minimum GSM receiver sensitivity
- *other questions related to radio*?



10 Mbit/s ≈ 10^7

↳ distance 1 km