

$$\lambda = \frac{c}{f} = \frac{0.3 \text{ m}}{f [1.9 \times 10^8]} = \frac{30 \text{ cm}}{f [6 \text{ Hz}]}$$

f	λ
1 Hz	30
10 Hz	3
20 Hz	1.5

Shannon:

Capacity = $W \cdot \log_2 (1 + \text{SNR})$

bandwidth

typical values

128 kbit/s GSM = 200 kHz

1-2 Mbit/s (2.5 Mbit/s) 4 kT5 ~ 5 MHz (3.8 MHz)

2-17 Mbit/s (12.5 Mbit/s) 25 + 653 802.11b 25 MHz ~ 5 x 4 MTS

Signal / noise

all phys systems

$$FM = 88.8 \dots 107 \text{ MHz}$$

$$GSM = 900 / 1800 / 1900 \text{ MHz}$$

$$UMTS = 2100 \text{ MHz}$$

$$W_s \sim \frac{1}{10} f_c \leftarrow \text{carrier frequency}$$

radio system bandwidth

$$f_c = 900 \text{ MHz}$$

$$W_s = 90 \text{ MHz}$$

$$850 \dots 950 \text{ MHz}$$

$$802.11b$$

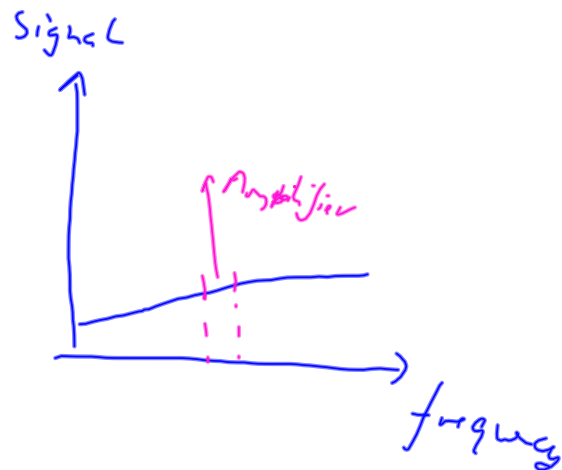
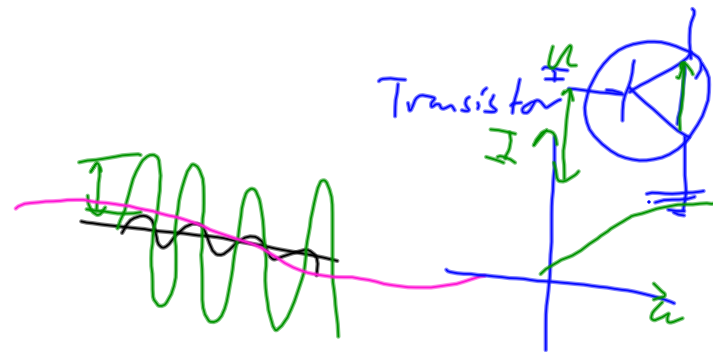
$$2.4 \text{ GHz}$$

$$240 \text{ MHz}$$

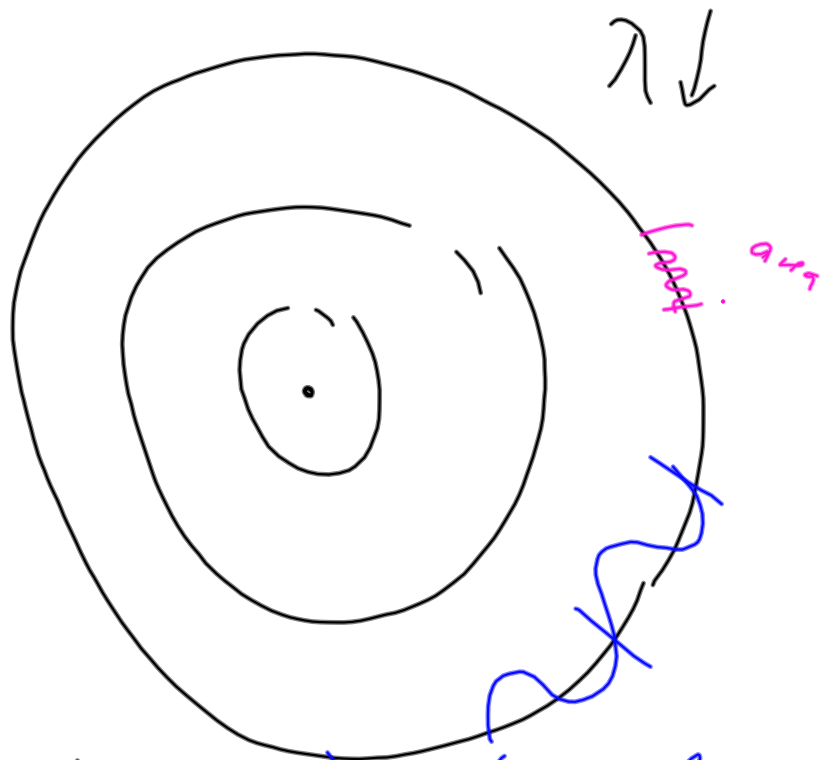
$$802.11g$$

$$5.1 \text{ GHz}$$

$$570 \text{ MHz}$$



$f \uparrow$
 $W \uparrow$
Capacity $\uparrow$



$\lambda \downarrow$

range $\downarrow$
 attenuation $\uparrow$
 obstacles $\uparrow$

free space attenuation

$$L = \left(\frac{\lambda}{4\pi R} \right)^2$$

$$L = 20 \log \left(\frac{\lambda}{4\pi R} \right)$$

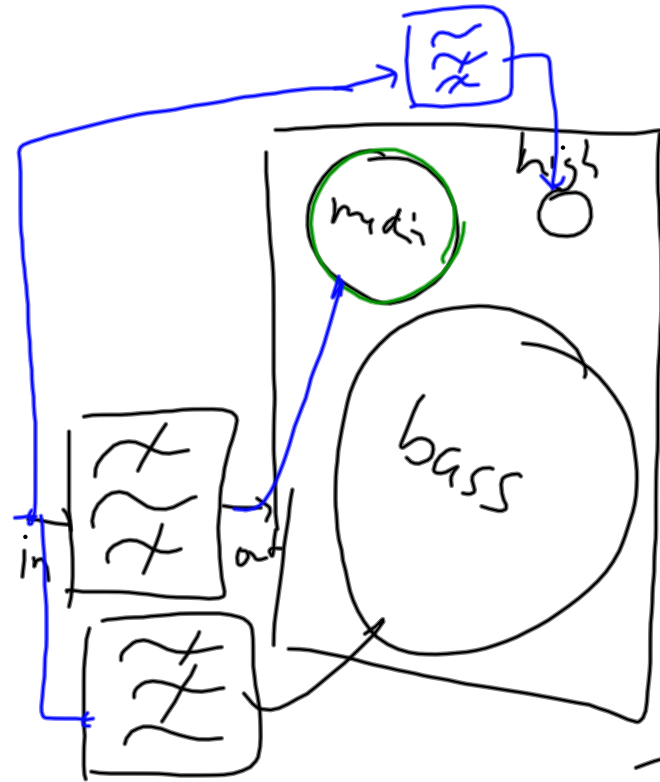
$$\frac{1}{h} \rightarrow r$$

$$\frac{2\pi}{\lambda} \cdot r$$

Surface of
a sphere = $4\pi R^2$

Example

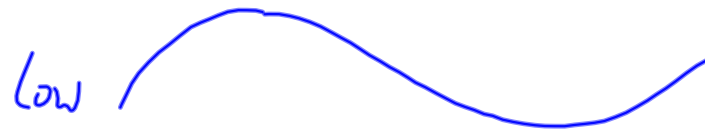
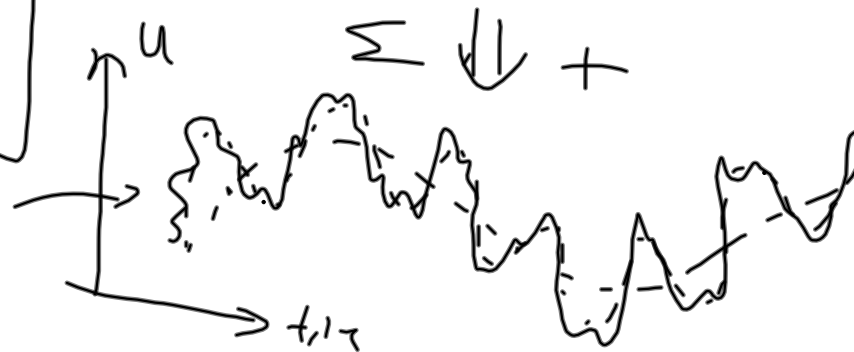
Load speaker



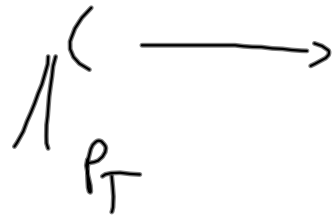
80...20000 Hz



low



Free space propagation equation

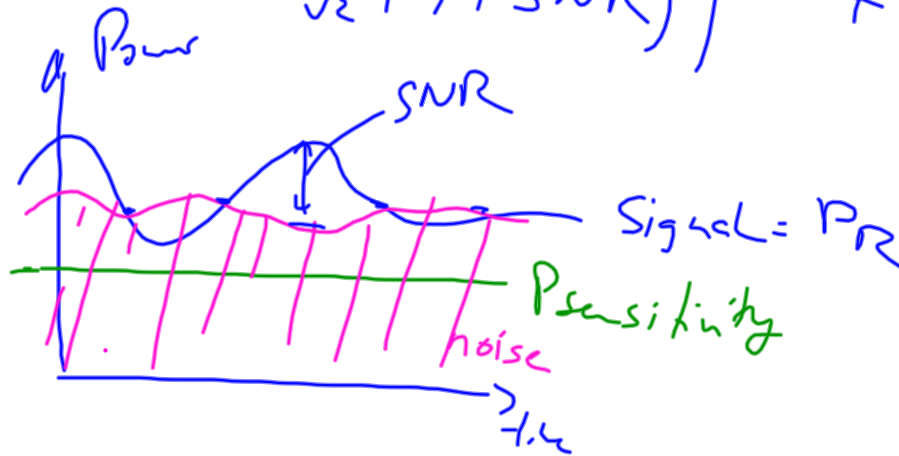


$$P_R = P_T \cdot G_T \cdot G_R \cdot \left(\frac{\lambda}{4\pi R} \right)^2$$

free space
attenuation

$$C = W \log_2 (1 + \text{SNR})$$

$$P_R > P_{\text{sensitivity}} + P_{\text{noise}}$$



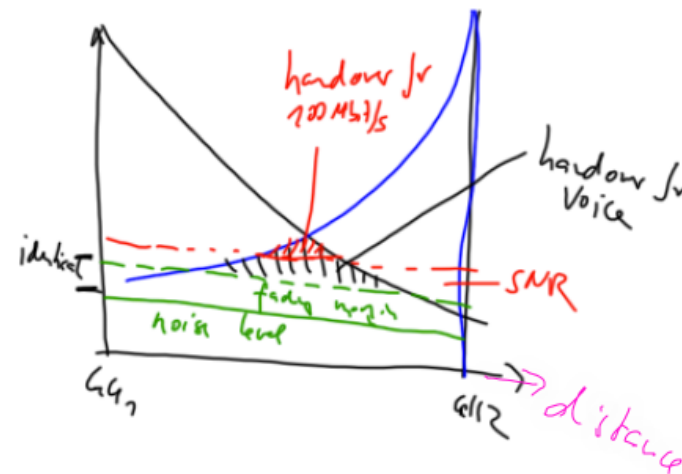
Scenario 1

- 3 minutes and 50 seconds to complete handover (GSM - UMTS)

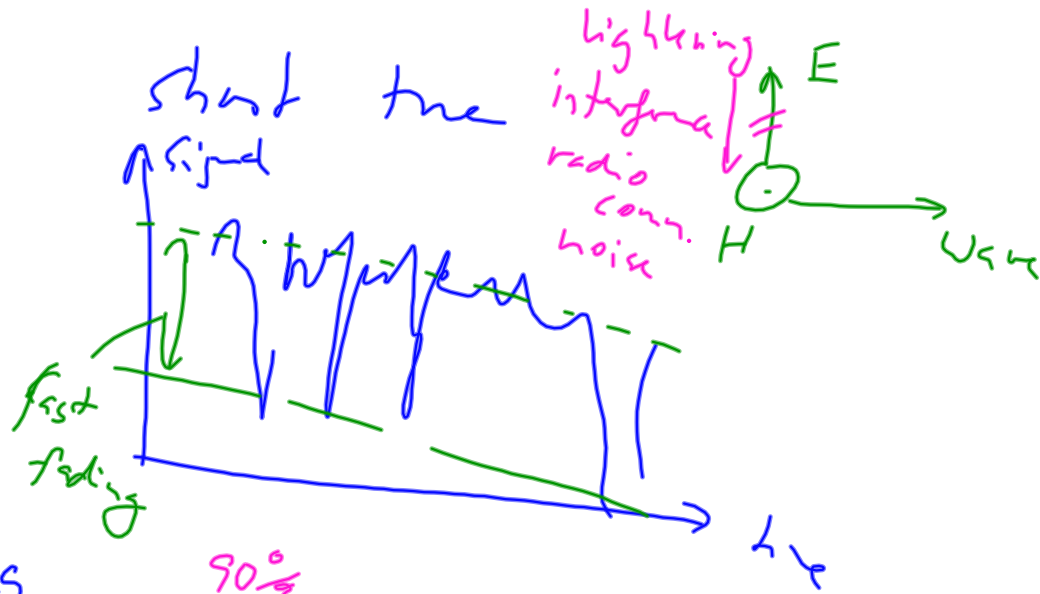
Thoughts:

- precision of results
of input param
- distance?
P_{Receive}

Scenario 1: UMTS - GSM

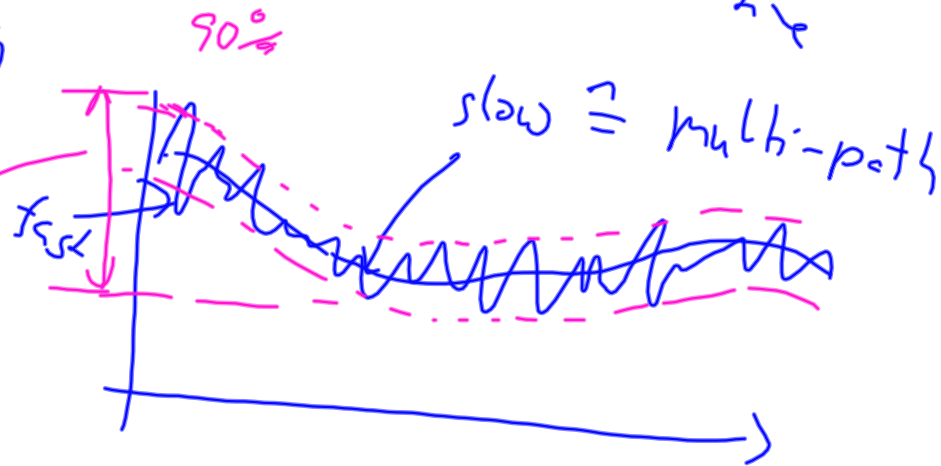


fast
Fading

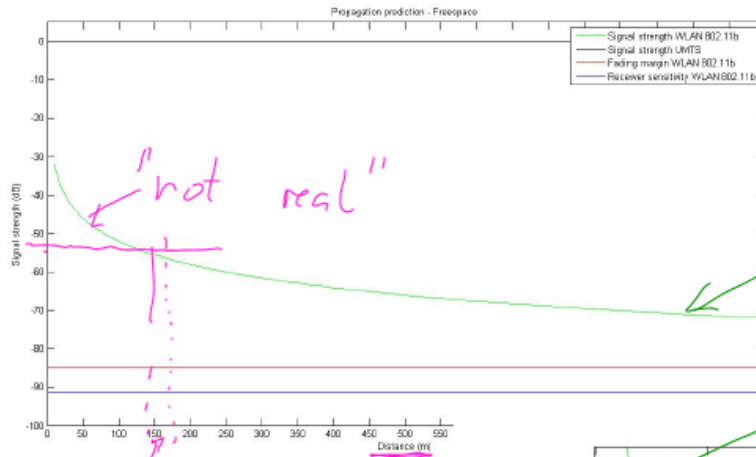


$P_R > -40 \text{ dBm}$
slow fading

$P_R > -40 \text{ dBm}$
slow fading
 $+ P_{\text{Fading}} 30 \text{ dB}$
 $+ P_{\text{noise}} 15 \text{ dB}$
 $P_{\text{sensitivity}} -85 \text{ dBm}$



Scenario 2



→ New propq. model

□ Fading!

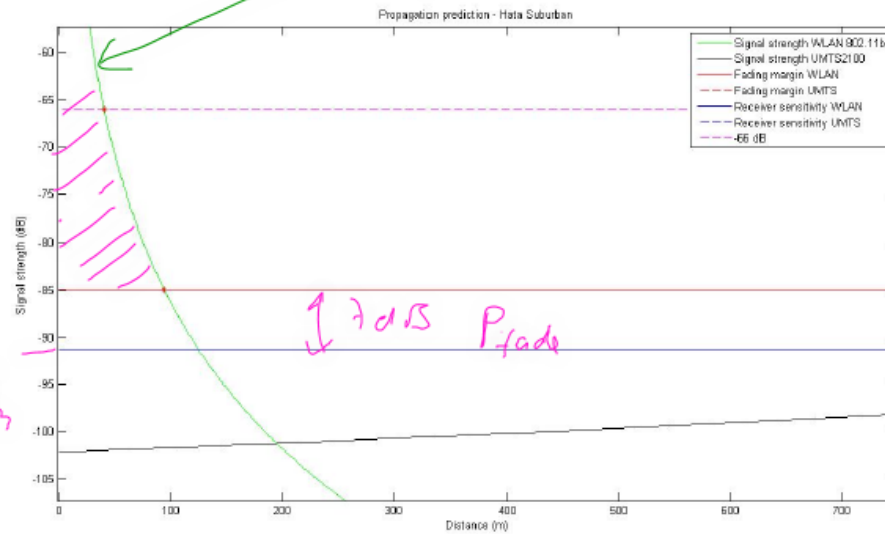
free space loss $\left(\frac{\lambda}{4\pi R}\right)^2$

Hata model / wrong



max range of 802.11b
(b) resp. receive power
here: -53 dB

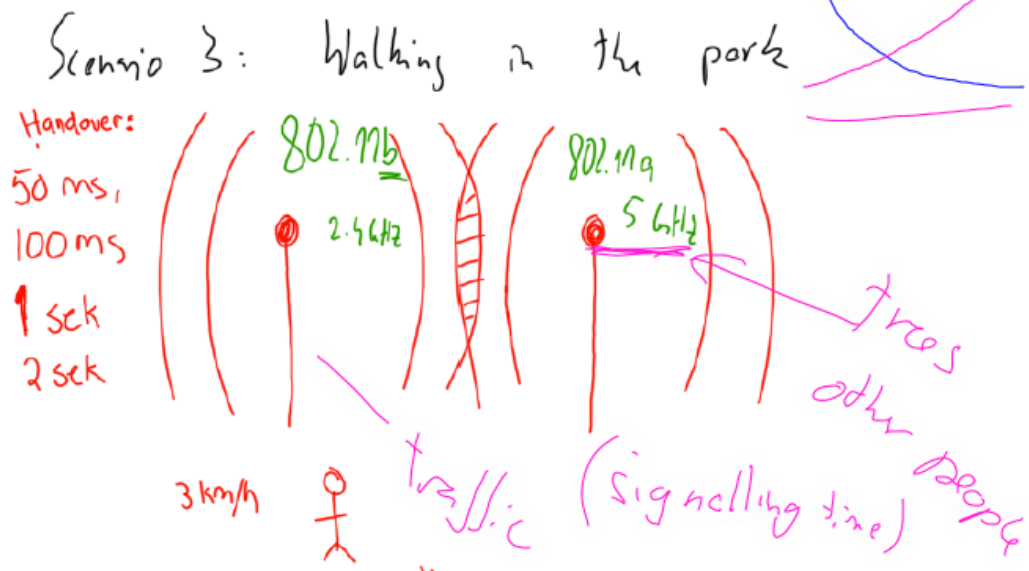
P_{em}
-92 dBm



Scenario 3

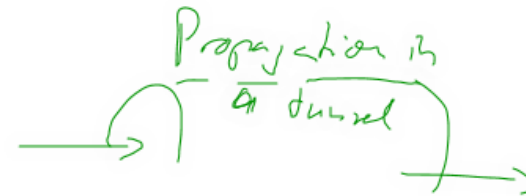
errors
signal distortion

- We never hit the fading margin, and should have no problems doing handovers.



Another scenarios

- Driving through a tunnel ✓



- (Signal source is moving) not this course $F \dots \dots$ effect

- We are moving up the hill

higher than antenna



$h \approx \text{infinite}$ LOS
 $\left(\frac{\lambda}{4\pi R}\right)^2$
 $\frac{1}{r^2}$

World description



realistic model
with variances

$$L = L_{FSL} + A_{MU} - H_{MG} - H_{BG} - \sum K_{correction}$$



negl: close to buildings, ground, ...

System parameters

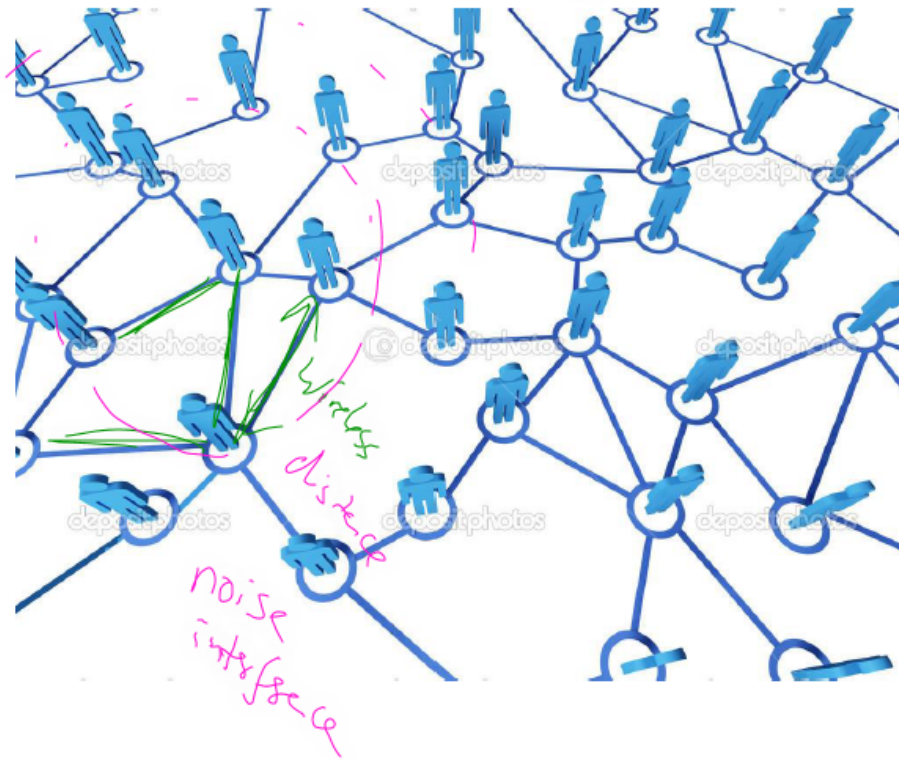
- Other model to compare
- Precise results ?
- Good parameters = success ?
- Wave interference



Examples - trees
- varying environments
- other users
- other networks...

More detailed simulations?

— a) realistic propag models outdoor indoor 802.11
LTE, WLAN



Util. unit. to
 Thomas

distance // walls // floors
 indoor
 outdoor
 802.11
 (LTE)
 (lost 231 ?)
 quasi-natural

- Propagation models
 $L = f(\text{distance}) \cdot \text{correction factor} + \dots$
but statistical

not: ray tracing



1.) IEEE, scholar, search
 3-4 papers

Tools on WiFi (Mobile Networks)

— measure signal strength

Measurements

of 802.11

• description (photo)

• Table

α	2	3	...
P_{level}	-65	-69	

6,9

2.4 GHz

outdoor
indoor

9,9

5 + GHz