UNIK 4700

L3 h13

UNIK4700 - CWI | Basics of Communication | UNIK4700/UNIK9700 Intro

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Homogeneous Electromagnetic Wave

single frequency

$\vec{E}(\vec{r}) = E_0 e^{j(\omega t - \vec{k}\cdot\vec{r})}$,

$\vec{B}(\vec{r}) = B_0 e^{j(\omega t - \vec{k}\cdot\vec{r})}$,

[Source: Wikipedia]

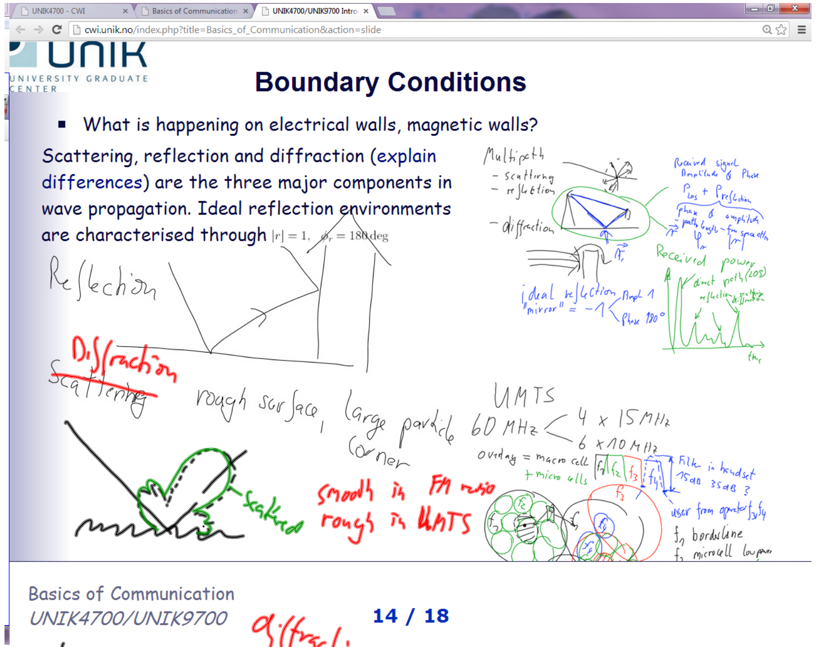
where

- $\vec{r} = (x, y, z)$ and $\vec{k} = (k_x, k_y, k_z)$ so?
- j is the imaginary unit
- $\omega = 2\pi f$ is the angular frequency, [rad/s]
- f is the frequency [1/s]
- $e^{j\omega t} = \cos(\omega t) + j\sin(\omega t)$ is Euler's formula

with $c = \frac{c_0}{n} = \frac{1}{\sqrt{\mu\varepsilon}}$ and $n = \sqrt{\frac{\mu\varepsilon}{\mu_0\varepsilon_0}}$

room for comments

- What is the difference between a static and a dynamic field


Boundary Conditions
What is happening on electrical walls, magnetic walls?
Scattering, reflection and diffraction (explain differences) are the three major components in wave propagation. Ideal reflection environments are characterised through $|r| = 1$, $\phi_r = 180$ deg
Reflection
Diffraction
Scattering
rough surface, large particle
corner
UMTS
60 MHz
4 x 15 MHz
6 x 10 MHz
smooth in FM radio
rough in UMTS
Multipath
- scattering
- reflection
- diffraction
ideal reflection
Received power
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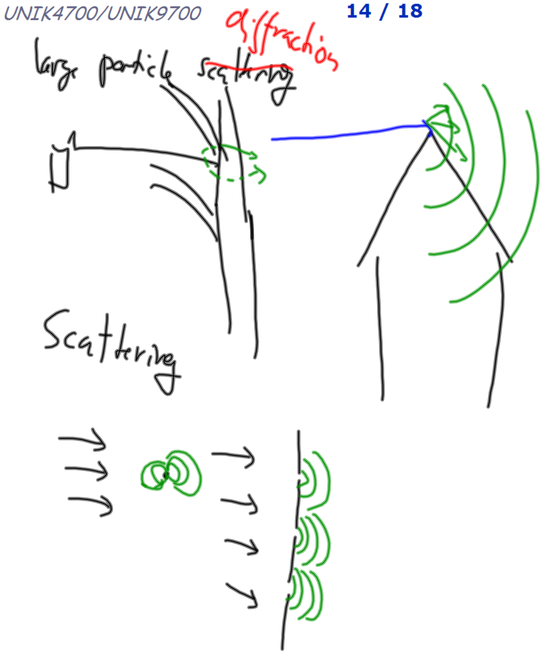

large particle scattering
diffraction
Scattering

Disturbance of EM wave

$\frac{d}{\lambda}$ ← diameter, length

$\frac{\lambda}{20}, \frac{\lambda}{10} < \frac{d}{\lambda} < 2\lambda$

Resonance: $d \sim \frac{\lambda}{2}, \lambda, 2\lambda$

$\lambda = \frac{c}{f} = \frac{3\,E8\,\frac{m}{s}}{1\,E9\,\frac{1}{s}}$ ← 1 GHz

$= \frac{0.3\,m}{f\,[GHz]} = 30\,cm$

f	λ	$\frac{\lambda}{2}$
100 MHz	3 m	1.5 m

$\frac{3\,E8\,\frac{m}{s}}{100\,E6\,\frac{1}{s}}$

"FM Radio" $\frac{\lambda}{2} \hat{=}$ arms

1.5 m

Interaction

$\frac{\lambda}{10} \dots d \dots 2\lambda$

$\lambda = \frac{30\,cm}{f\,[GHz]}$

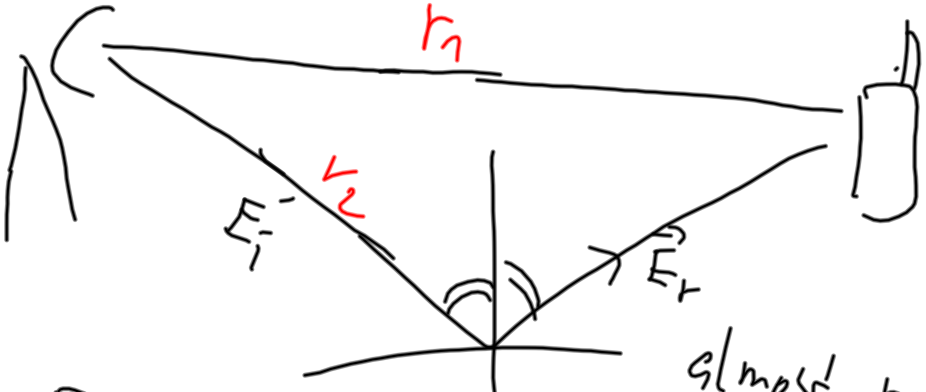
f	λ	$\lambda/2$	d_{range}	
100 MHz	3 m	1.5 m	no 30 cm .... 6 m full attenuation	house, mountain
GSM				
900 ~ 1 GHz	30 cm	15 cm	3 .... 60 cm	thick tree trunks, houses
1800 ~ 2 GHz	15	7.5 cm	1.5 .... 30 cm	tree
UMTS				
2100 ~ 2 GHz				
Wifi				
2400 ~ 2.5	~12	6 cm	1.2 ... 24 cm	office wall
5100 .. 5600 ~ 5 GHz	6	3 cm	6 mm ... 12 cm	door, vegetation
LTE				
2600				

<700 Ultra Wifi
Digital Dividend
Cognitive radio in TV

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

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

Perfect reflection



almost perfectly flat

sea surface

$$r = \frac{E_r}{E_i} = -1$$

perfectly flat

$$E_{tot} = E_d e^{-jkr_1} + E_r e^{-jkr_2}$$

$$j = \sqrt{-1}$$

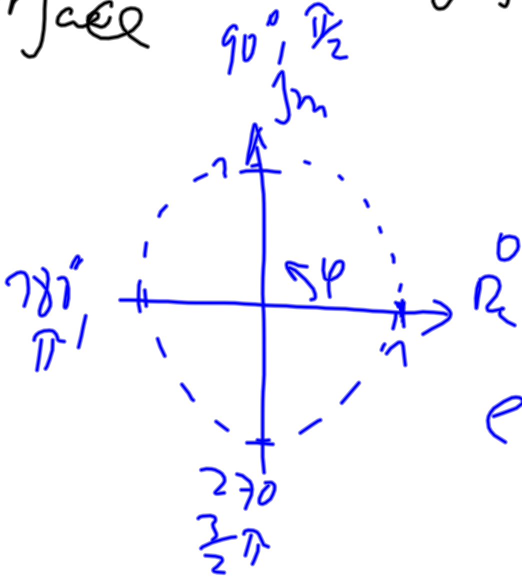
$E_r = r \cdot E_i$

perfect refl. $-E_i$

$$E_{tot} = E_0 \left(1 - e^{-jk\Delta r}\right)$$

$\Delta r = 0, \lambda, 2\lambda, \ldots$

$$E_{tot} = 0$$



$$e^{+j\varphi} = \cos\varphi + j\sin\varphi$$

rad π

deg $180°$

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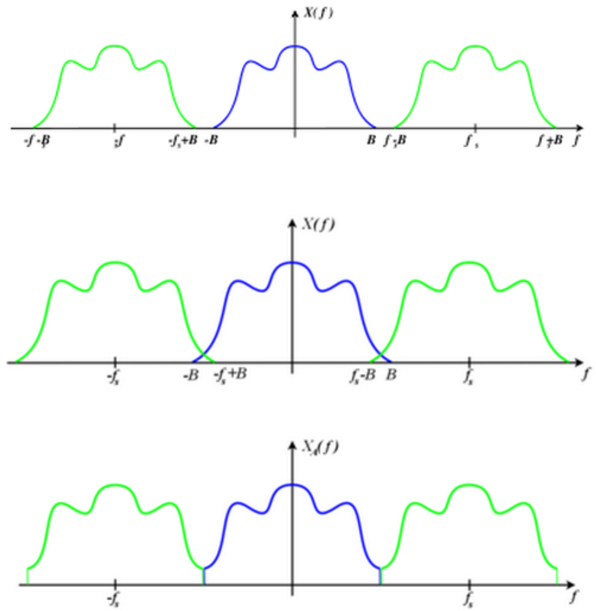
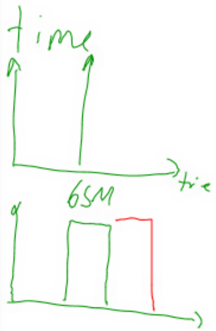
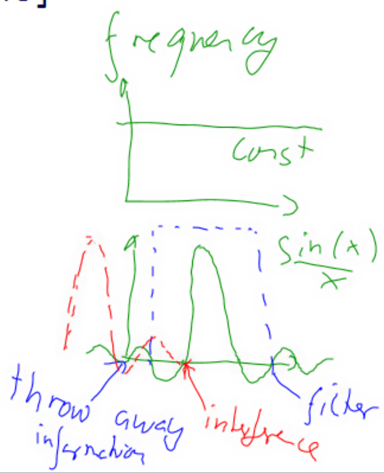
Nyquist Theorem

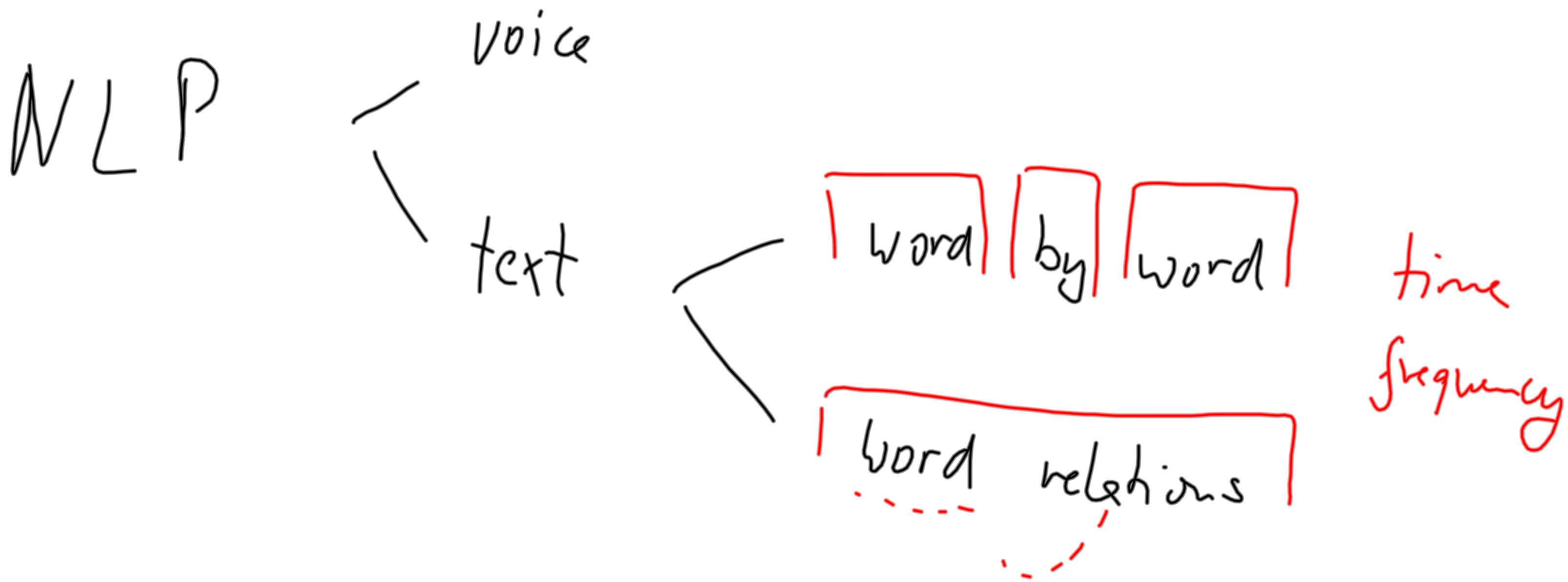
- Shannon: If a function $f(t)$ contains no frequencies higher than W [cycles/s], it is completely determinded by giving its ordinates at serires of points spaced $\frac{1}{2W}$ seconds apart
- band-limitation versus time-limitation
- Fourier transform

[source: Shannon, 1948]








NLP
voice
text
word by word
word relations
time
frequency

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Signal/Noise Ratio

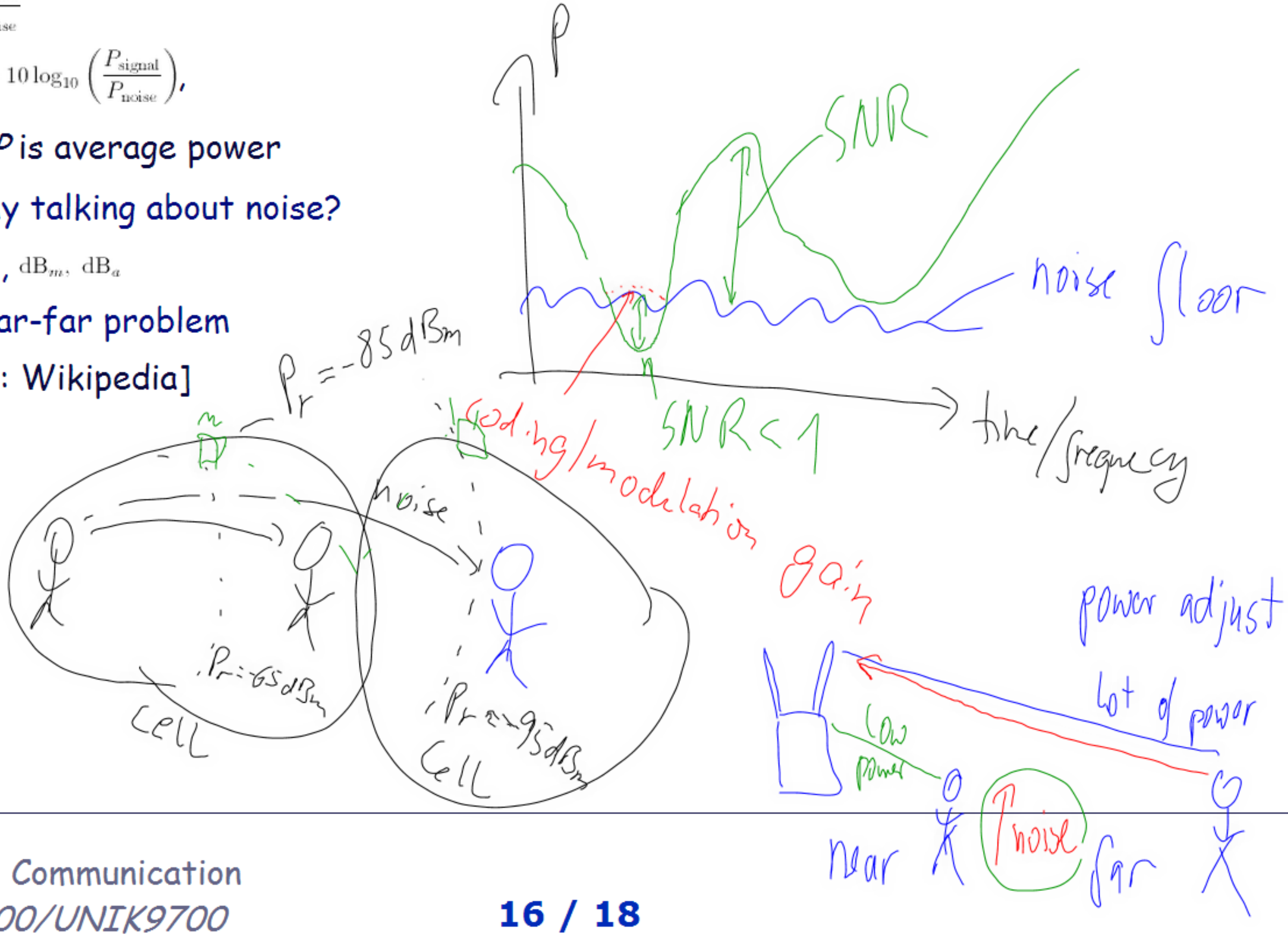
$$\mathrm{SNR} = \frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}}$$

$$\mathrm{SNR(dB)} = 10\log_{10}\left(\frac{P_{\mathrm{signal}}}{P_{\mathrm{noise}}}\right),$$

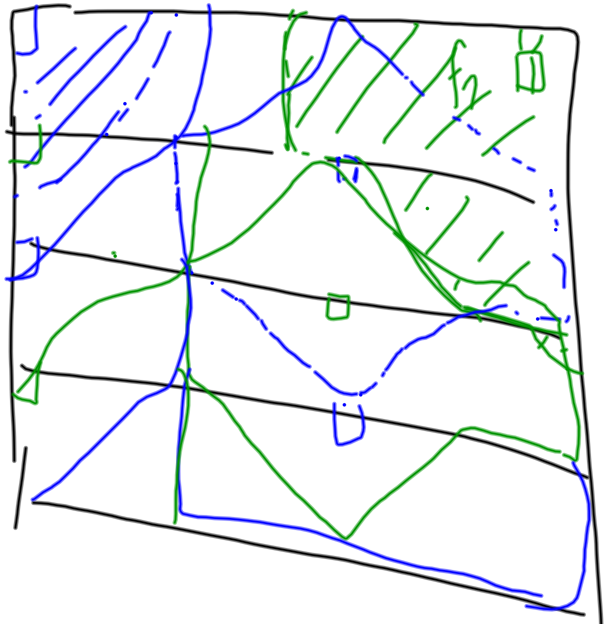
where P is average power

- why talking about noise?
- dB, dB_m, dB_a
- near-far problem

[source: Wikipedia]



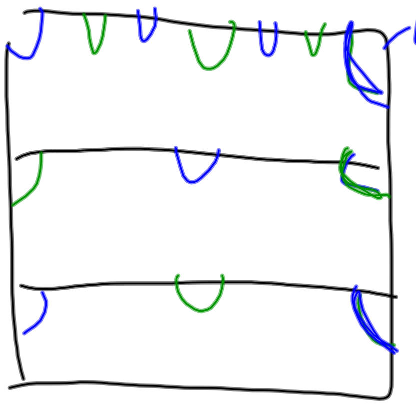
office building



range ~ $\frac{1}{2}$ building length

2 freq

lots of users "capacity" 3 freq



lower power of each

2 freq

frequency re-farming

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Shannon Theorem

$C = 20$ Mbit/s

$R \leq 20$ Mbit/s

R_1 R_2 R_3

- The fundamental theorem of information theory, or just Shannon's theorem, was first presented by Claude Shannon in 1948.
- Given a noisy channel with channel capacity *C* and information transmitted at a rate *R*, then if *R* < *C* there exist codes that allow the probability of error at the receiver to be made arbitrarily small. This means that theoretically, it is possible to transmit information nearly without error at any rate below a limiting rate, *C*.

$R_1 + R_2 + R_3 < C$

W bandwidth

- See File:LarsLundheim-Telektronikk2002.pdf: The channel capacity of a band-limited information transmission channel with additive white, Gaussian noise. This capacity is given by an expression often known as "Shannon's formula": $C = W \log_2(1 + P/N)$ [bits/s]

SNR

with W as system bandwidth, and $P/N = \frac{P}{N_0 W}$ in case of interference free environment, otherwise $N_0 W + N_{\text{interference}}$, where $N_0 = k_B T_K$ with k_B as Boltzmann constant and T_K as temperature in Kelvin.

Exercises:

- If the SNR is 20 dB, and the bandwidth available is 4 kHz, what is the capacity of the channel?
- If it is required to transmit at 50 kbit/s, and a bandwidth of 1 MHz is

Shannon $C = W \cdot \log_2(1 + SNR)$

WLAN GSM

$C_{Wlan} \sim 900\, C_{GSM}$

~~33 Mbit/s~~ ← 384 kbit/s

11 Mbit/s

← 1) radio unit is bad

2) GSM & ~~modulation~~ coding gain in GSM is higher

GSM	200 kHz	const. 10 dB
UMTS	3.8 MHz	
WLAN	20 MHz (40 MHz, (100 MHz))	

2.4 5. GHz

$C_{UMTS} \sim 20\, C_{GSM}$

8 Mbit/s ← 384 kbit/s

2008 : UMTS < 2 Mbit/s

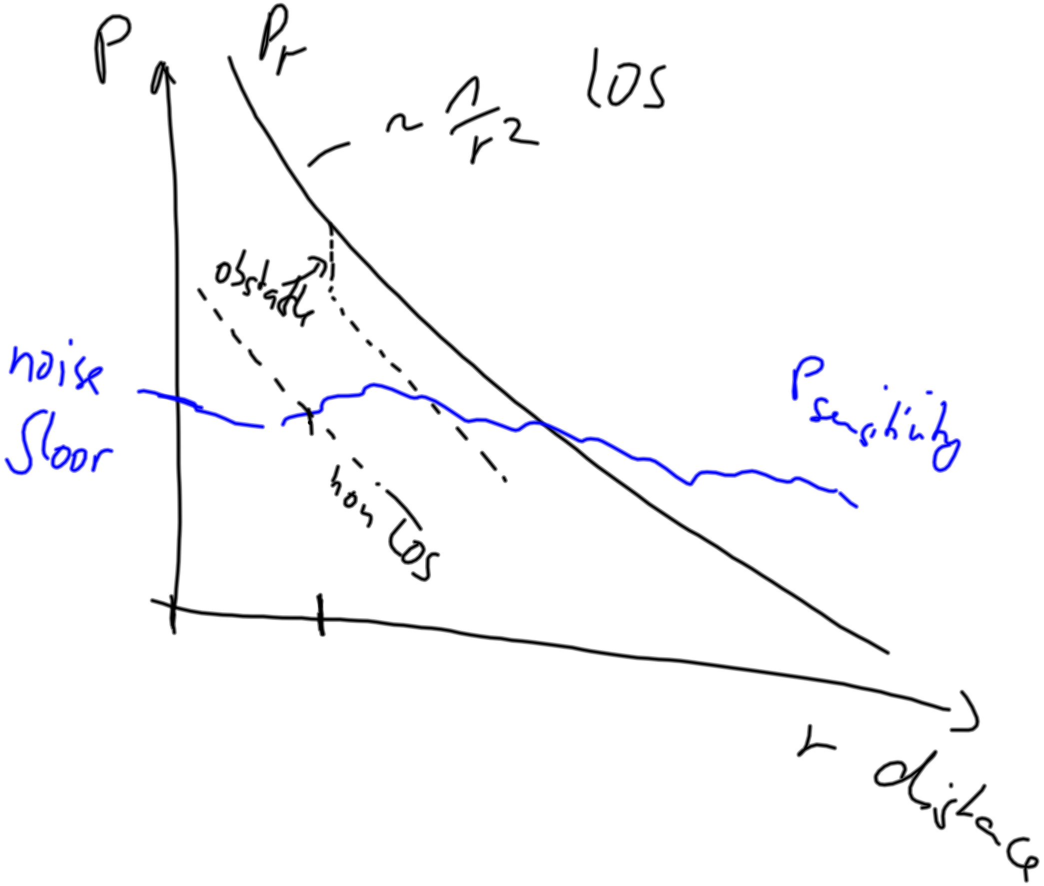
typical 1 Mbit/s

2011: HSPA 8 Mbit/s

2012: HSPA+ 12 Mbit/s ← higher coding/modulation gain

Radio propagation

$$P \sim \frac{1}{r^2}$$



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

40dB

0dB