UiO : Department of Technology Systems
University of Oslo

TEK5110: L3 Propagation

Propagation Characteristics

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TEK5110 - Before we start

- Questions to L2 - radio characteristics?

- Paper selection, state of the art based on your interest
  - preparation, evaluation
  - when to present

- Group work (later)

- Questions for Exam: http://its-wiki.no/wiki/TEK5110/List_of_Questions (to be completed)
  - Compendium:

Learning outcomes

http://its-wiki.no/wiki/Building_Mobile_and_Wireless_Networks_Compendium

- ➡ Antennas
  - Gain and directivity
- ➡ Multipath propagation
  - Non Line of Sight (NLOS) communications
  - Multipath
- ➡ Propagation Models
  - Outdoor, impulse response
  - Indoor

⌘ B-Antennas and Propagation

Free Space Propagation

Antennas, Gain, Radiation Pattern

Multipath Propagation, Reflection, Diffraction

Attenuation, Scattering

Interference and Fading (Rayleigh, Rician, ...)

Mobile Communication dependencies

C-Propagation models

Environments (indoor, outdoor to indoor, vehicular)

Outdoor (Lee, Okumura, Hata, COST231 models)

Indoor (One-slope, multiwall, linear attenuation)

Free space propagation

L2

- ➡ Questions/Tasks:
  - Propagation equation in dB
  - provide examples for *f* = *10* MHz,

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

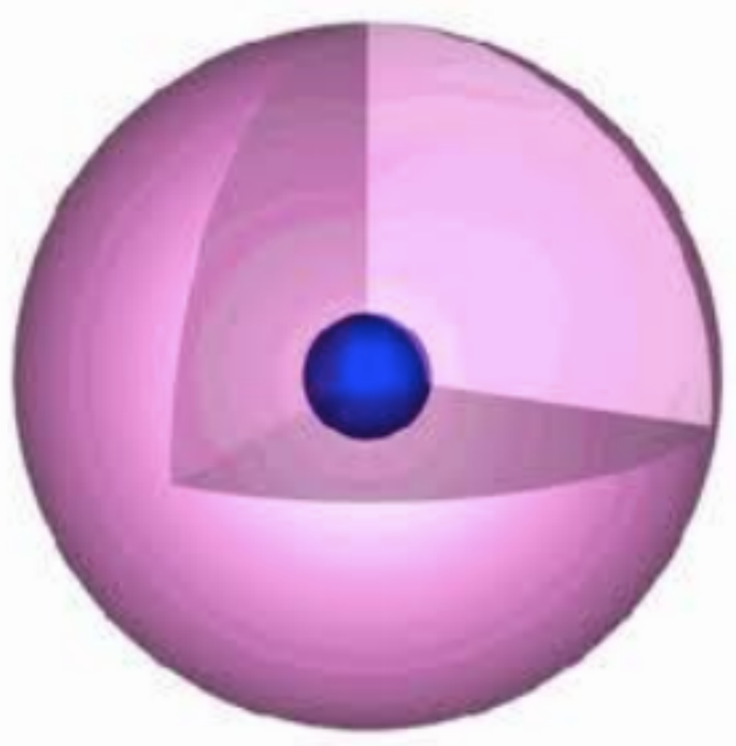
$$\left(\frac{\lambda}{4\pi r}\right)^2.$$

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

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

see (http://www.antenna-theory.com/basics/friis.php)

B2-Antenna Basics



- The gain is the radiation intensity of an antenna into the main direction as compared to an isotropic antenna (omnidirectional).

$$D = D_{main}/D_{isotropic}$$

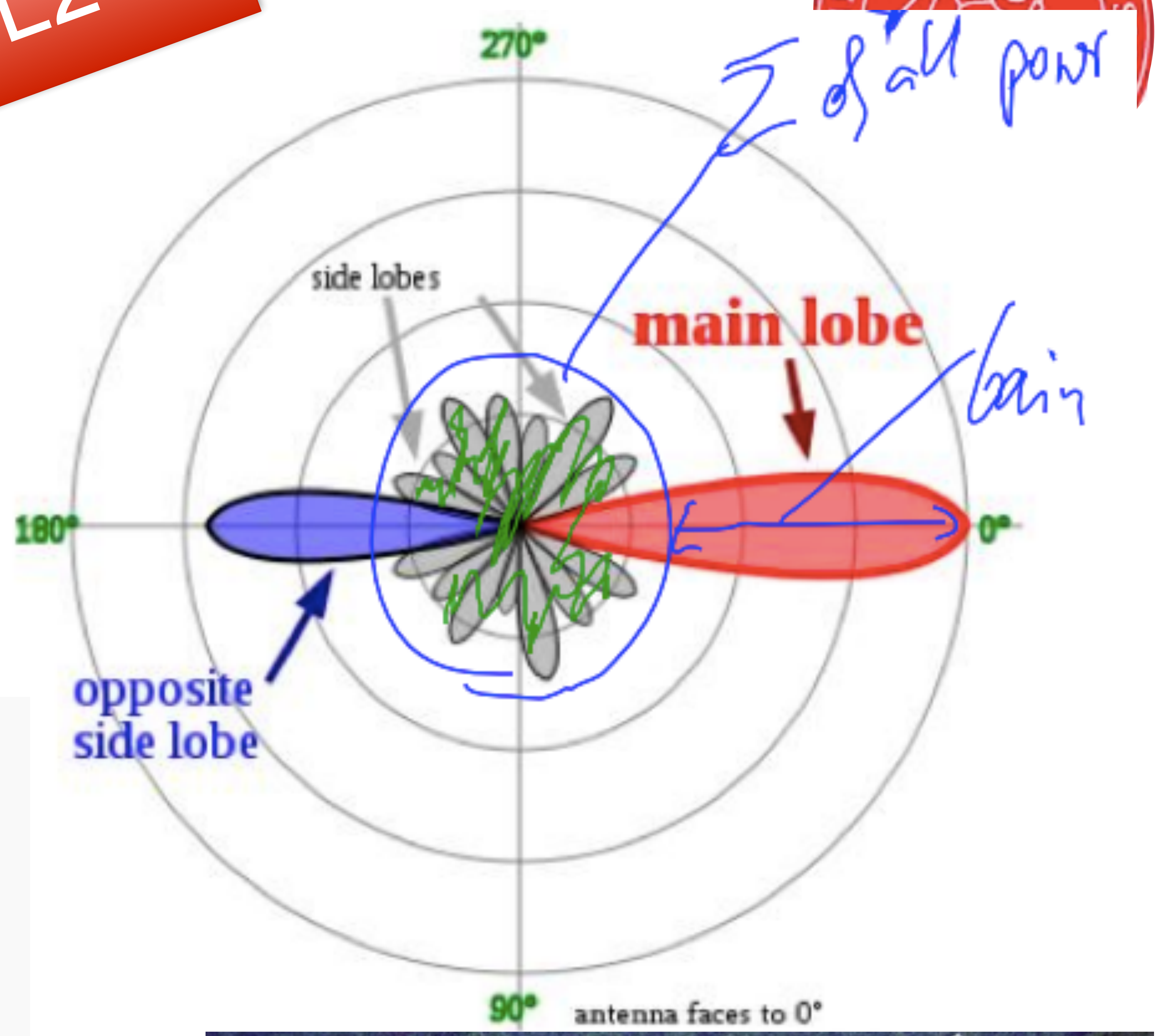
- For a perfect antenna without any losses, the gain *G* will be identical to the directivity *D*.

$$D_{rad} = \frac{4\pi F_{max}(\theta, \varphi)}{\int_0^{2\pi} \int_0^{\pi} F(\theta, \varphi) sin(\theta) d\theta d\varphi}$$

Antenna pattern

L2

➡ If the antenna pattern is known, then the gain can be easily calculated.



- Isotropic antenna = point source: $G_s = 0\mathrm{dB}$
- Hertz Dipol = Short dipol: $G_s = 1,5 = 1,76\mathrm{dB}$
- $\lambda/2$-Dipol: $G_s \approx 1,64 = 2,15\mathrm{dB}$
- draw electrical field of dipole
- Aperture antennas: $A_{eff} = e_{ap} A_{phys}$, with $e_{ap} = 0.65...0.75(0.85)$,

$$G_s = A_{eff} \frac{4\pi}{\lambda^2}$$

- examples of reflector antennas (effective aperture)

For more info, see intro course: http://www.cv.nrao.edu/course/astr534/AntennaTheory.html

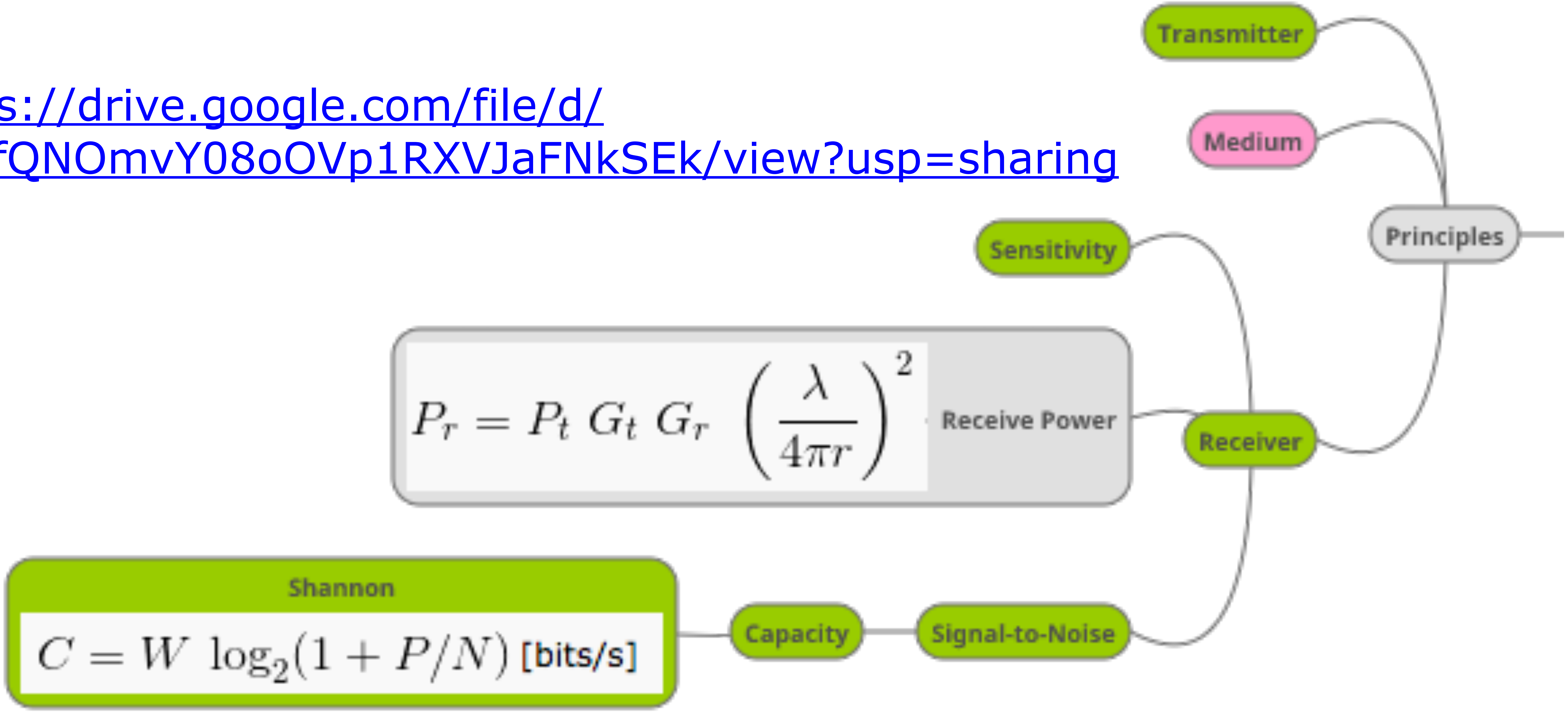
- Media:Antennas_for_communications_Haavard.pdf (by Håvard Austad)

Antenna Questions

- Q: draw typical antenna pattern (Hertz Dipol, $\lambda/2$, reflector antenna)
- Q: what is the diagram of a lambda antenna?
- What else affects propagation?

Receiver

- https://drive.google.com/file/d/0B2fQNOmvY08oOVp1RXVJaFNkSEk/view?usp=sharing



Signal to Noise, Shannon

- ➡ in-band vs out-of-band noise
- ➡ interference vs noise

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

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

- ➡ Shannon theorem (1948)
  - almost 30 years after Hartley *C* ~ *W*

$$C = W \log_2(1 + P/N) \text{ [bit/s]}$$

  - interference free environment: $P/N = \frac{P}{N_0 W}$
  - with Interference

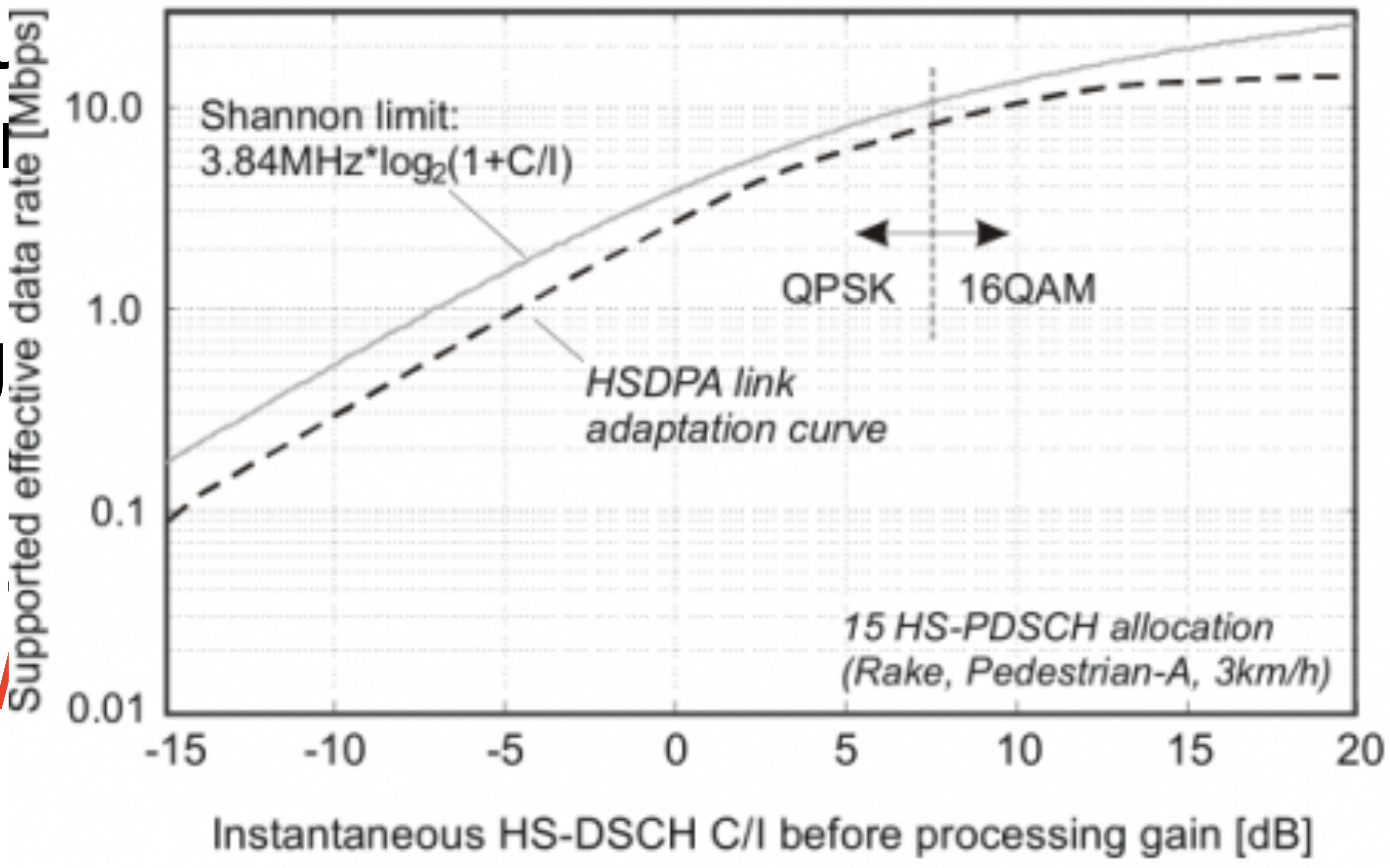
$$N_0 W + N_{\text{interference}}$$

Shannon - Excercises

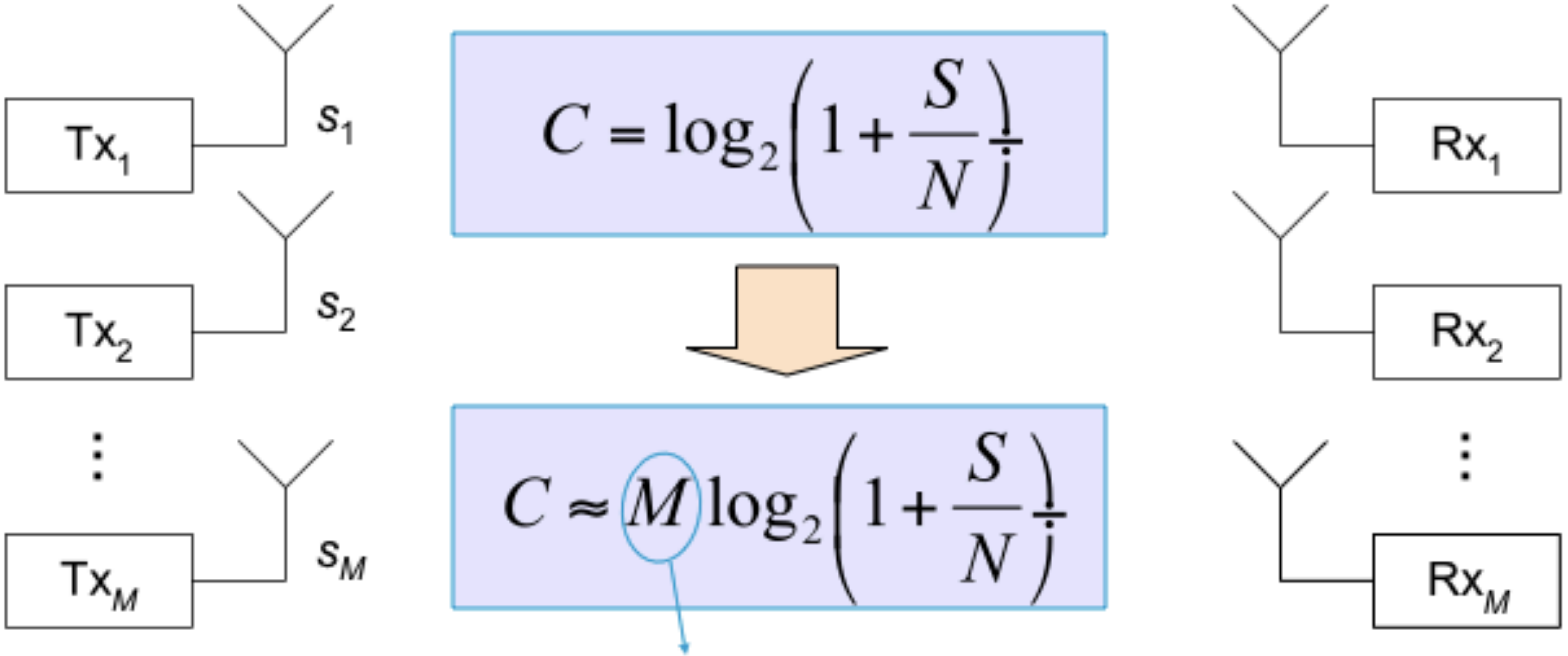
- calculate capacity for W= 200 kHz, 3.8 MHz, 26 MHz, (all cases P/N = 0 dB, 10 dB, 20 dB)
- If the SNR is 20 dB, and the bandwidth available is 4 kHz, what is the capacity of the channel?
- If it is required to transmit at 50 kbit/s, and a bandwidth of 1 MHz is used, what is the minimum S/N required for the transmission?

Cell capacity

- UMTS has already good spectru
efficiency with respect to Shann
- Modulation schemes like QPSK
QAM are applied to achieve hig
bandwidth.
- Higher modulation schemes ne
higher signal to noise ration, W



Multiple-Input, Multiple-Output (MIMO)



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

$$C \approx M \log_2\left(1 + \frac{S}{N}\right)$$

number of antennas in the smaller of the transmit and receive arrays

source: Reinaldo Valenzuela, Lucent Technology

MIMO laptop

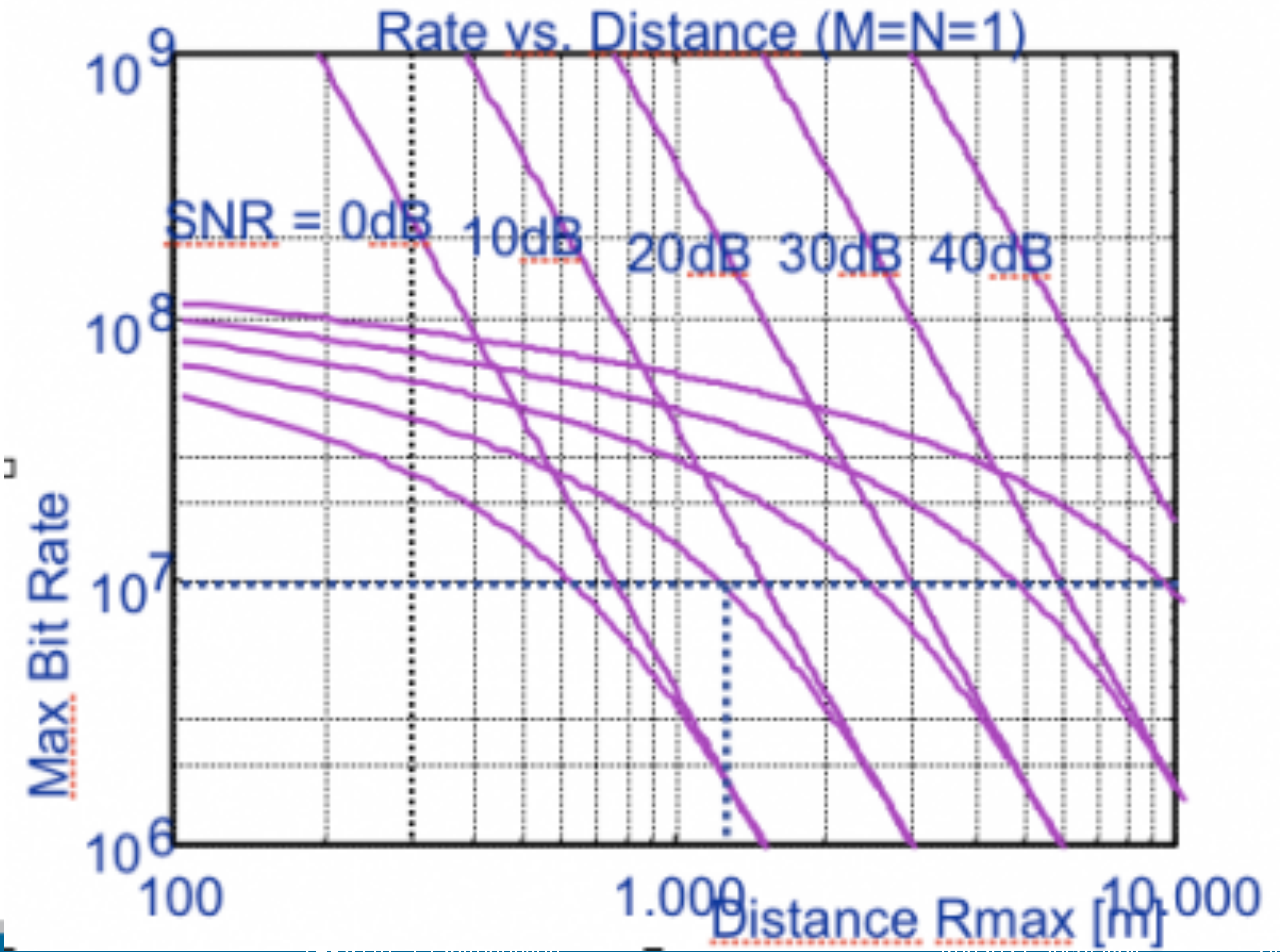
Range versus SNR

- ➡ max range

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

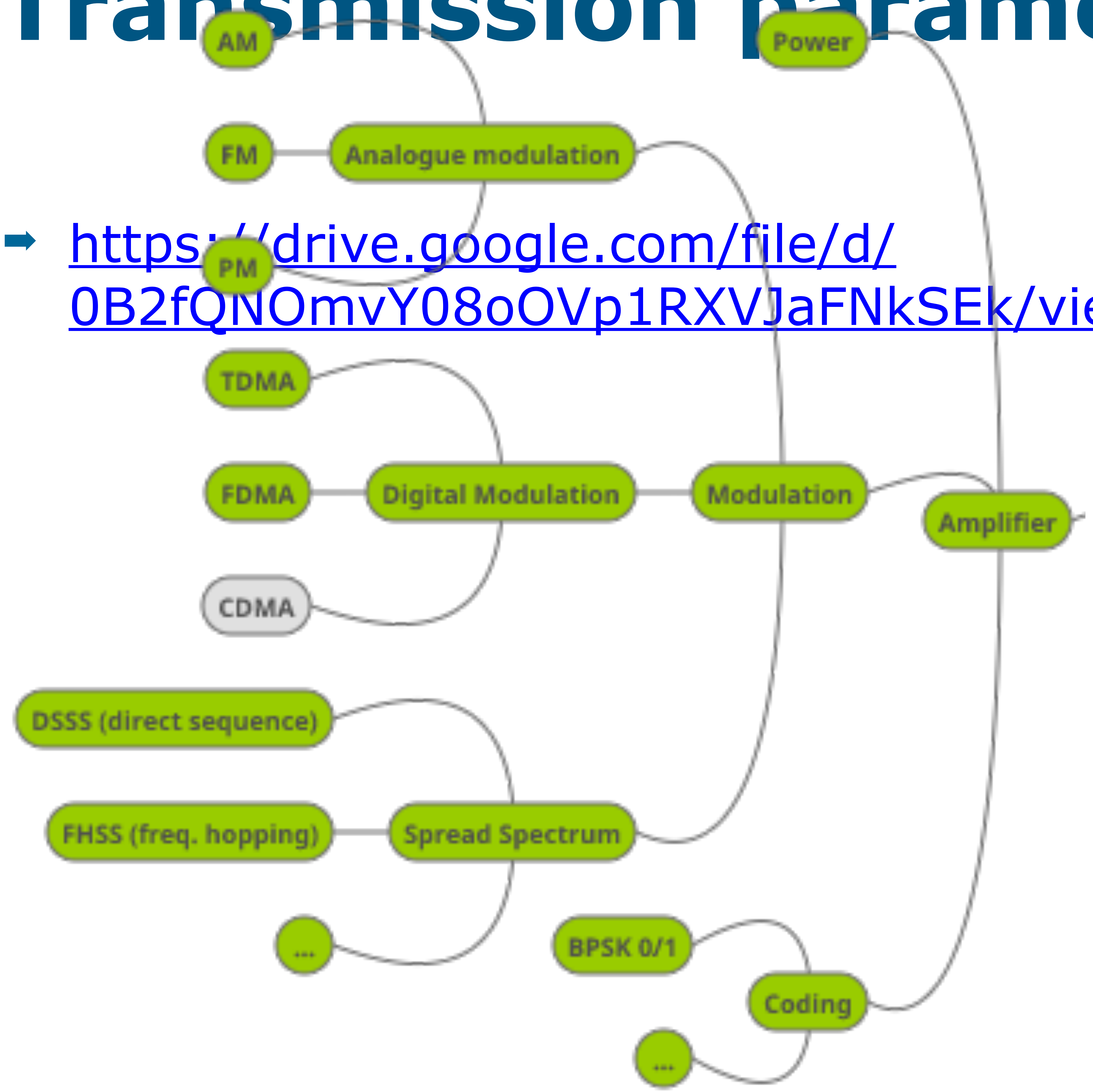
Real system

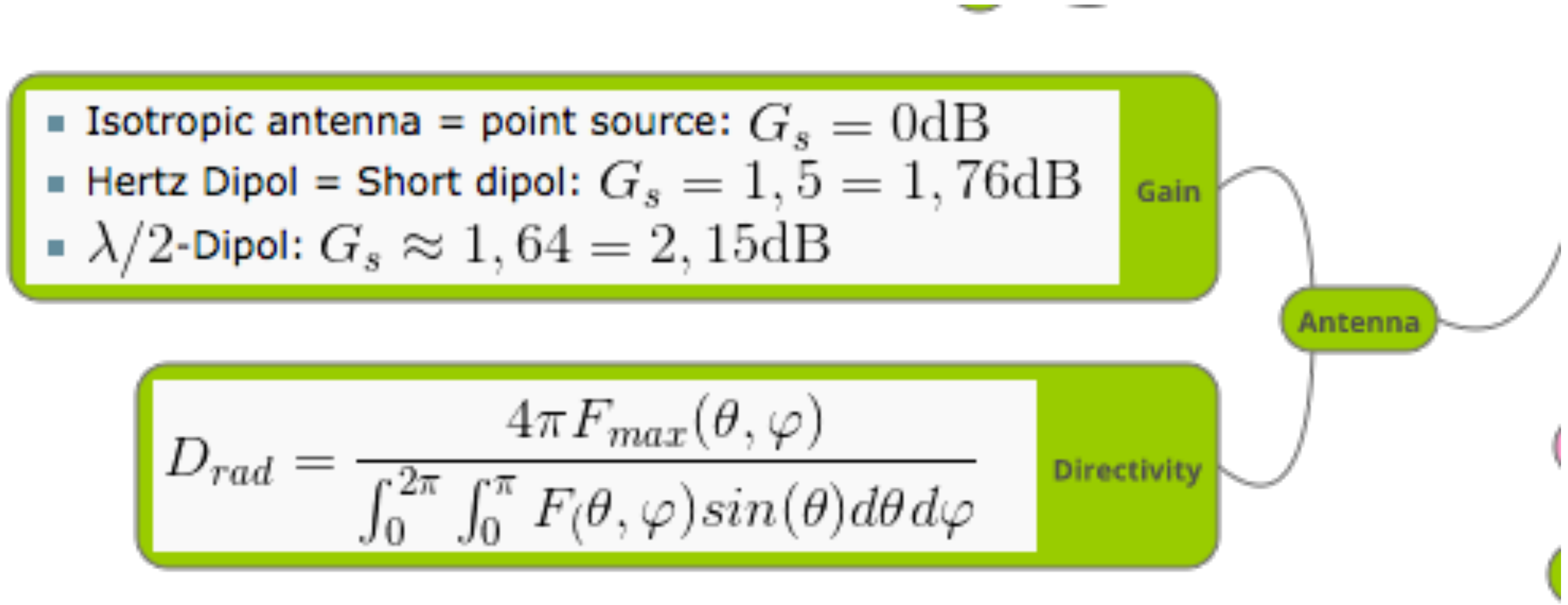
SNR	Range	Capacity
0	600 m	10 Mbit/s
30	300 m	60 Mbit/s
10	3 km(?)	1 Mbit/s (UMTS all capacity)



Transmission parameters

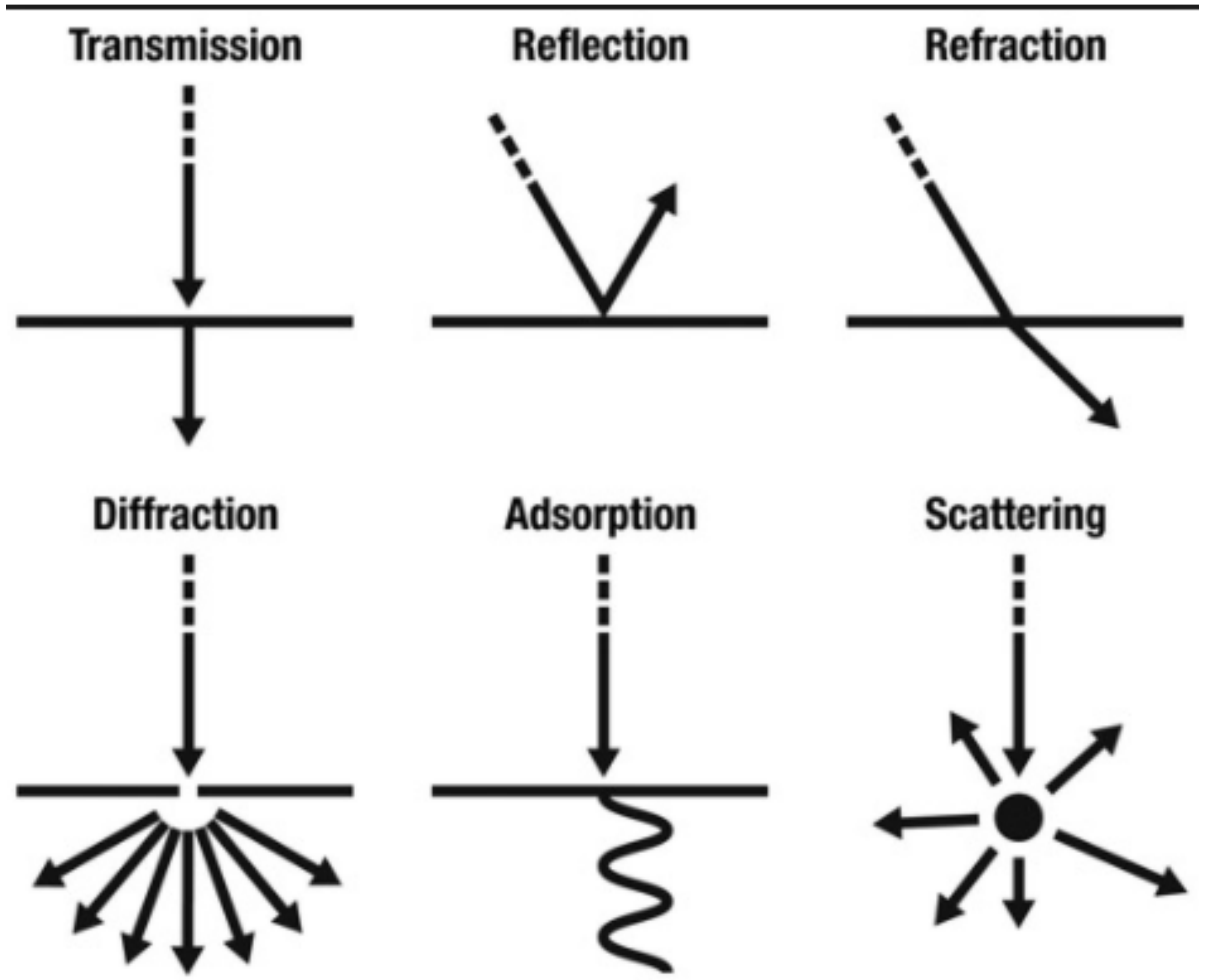
➡ https://drive.google.com/file/d/0B2fQNOmvY08oOVp1RXVJaFNkSEk/view?usp=sharing





Scattering, Reflection, Diffraction

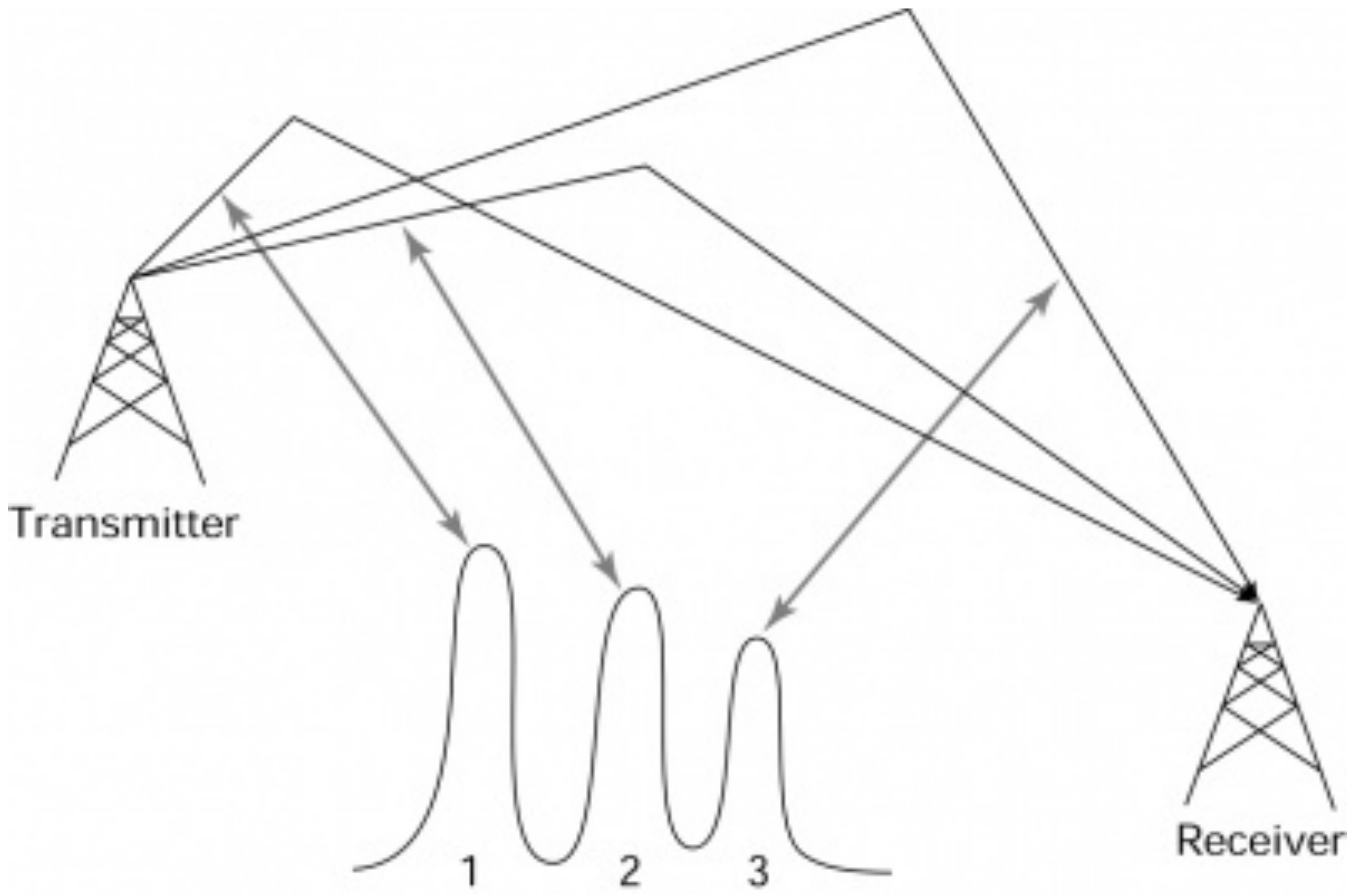
- ➡ Reflection
  - wave hits smooth surface
  - dimension >> lambda
  - typical: buildings, walls, water
  - “ideal” reflection: mirror
- ➡ Diffraction
  - dimension ~ lambda, or
  - edges (roof top)
  - bending wave
- ➡ Scattering
  - dimension << lambda
  - spread out energy



source: https://physicsweekly.weebly.com/reflection-refraction-and-diffraction.html

Multipath propagation

- Mobile phone: no direct link between Tx and Rx
- communication "around the corner" or "over the hill" is called **NLOS** (non line-of-sight)
- typical reduction: 20-30 dB (Q: in power?)
- Effects:
  - rapid change in signal strength (Q: why?)
  - time dispersion (delays)
  - fading (small-scale)



Physics - ideal reflection

- $E_{tan} = 0$ on an ideal reflector

  $|r| = 1, \phi_r = 180\text{deg}$

Attenuation

- wave attenuation, travelling throug lossy material
- EU project Hydra:

$$L = 92{,}4 + 20\log(d[\text{km}]) + 20\log(f[\text{GHz}]) + \sum n_i \alpha_i$$

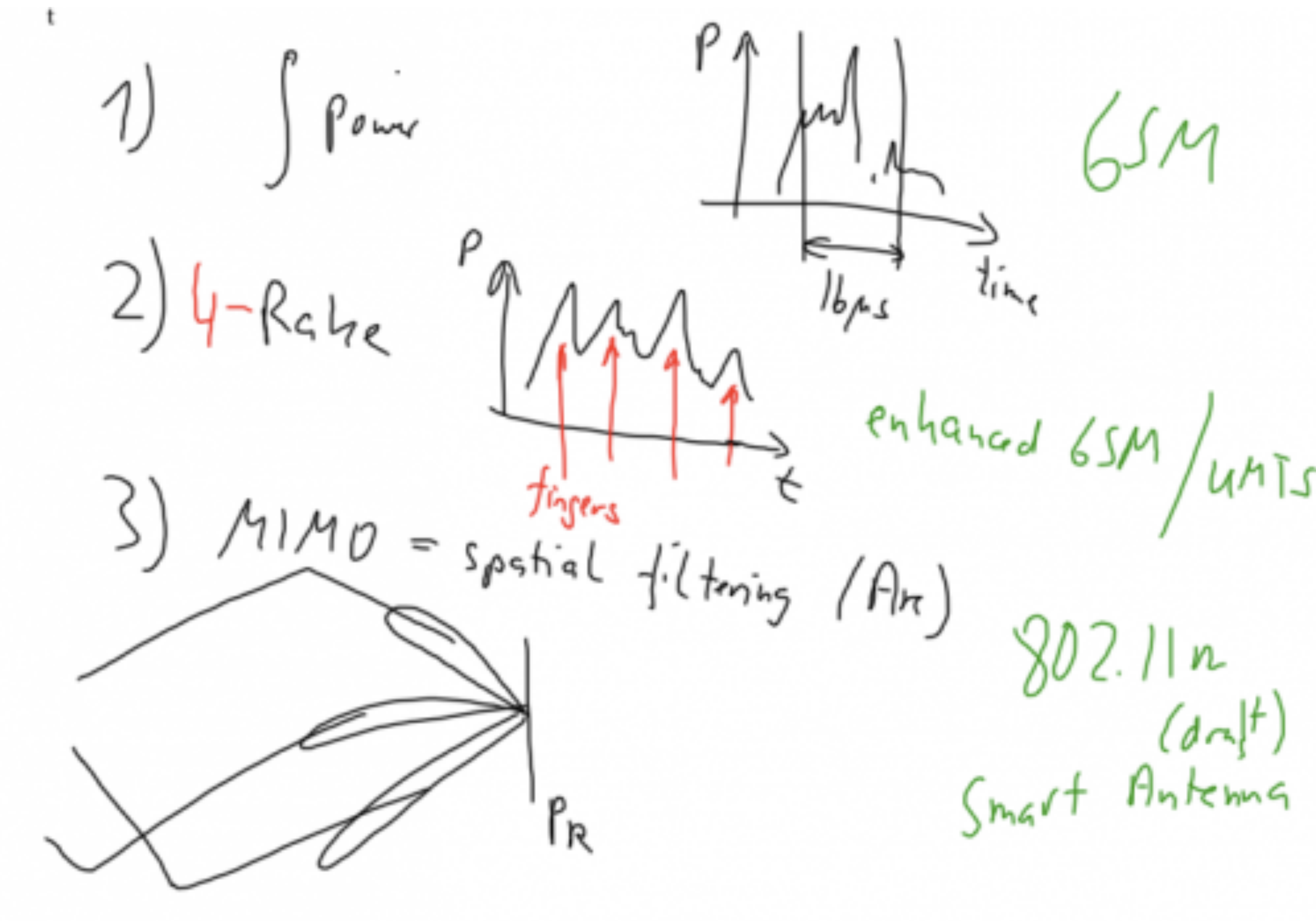
2.4 GHz attenuation, source: Hydra Deliverable D5.4

Obstacle	Attenuation α_i [dB]
Brick wall with window	2
Brick wall next to metal door	3
Cinder Block wall	4
Office wall	6
Metal door in office wall	6
Metall door in brick wall	12.4
Floor	30

- Q: Relation between fading margin and receiver sensitivity?

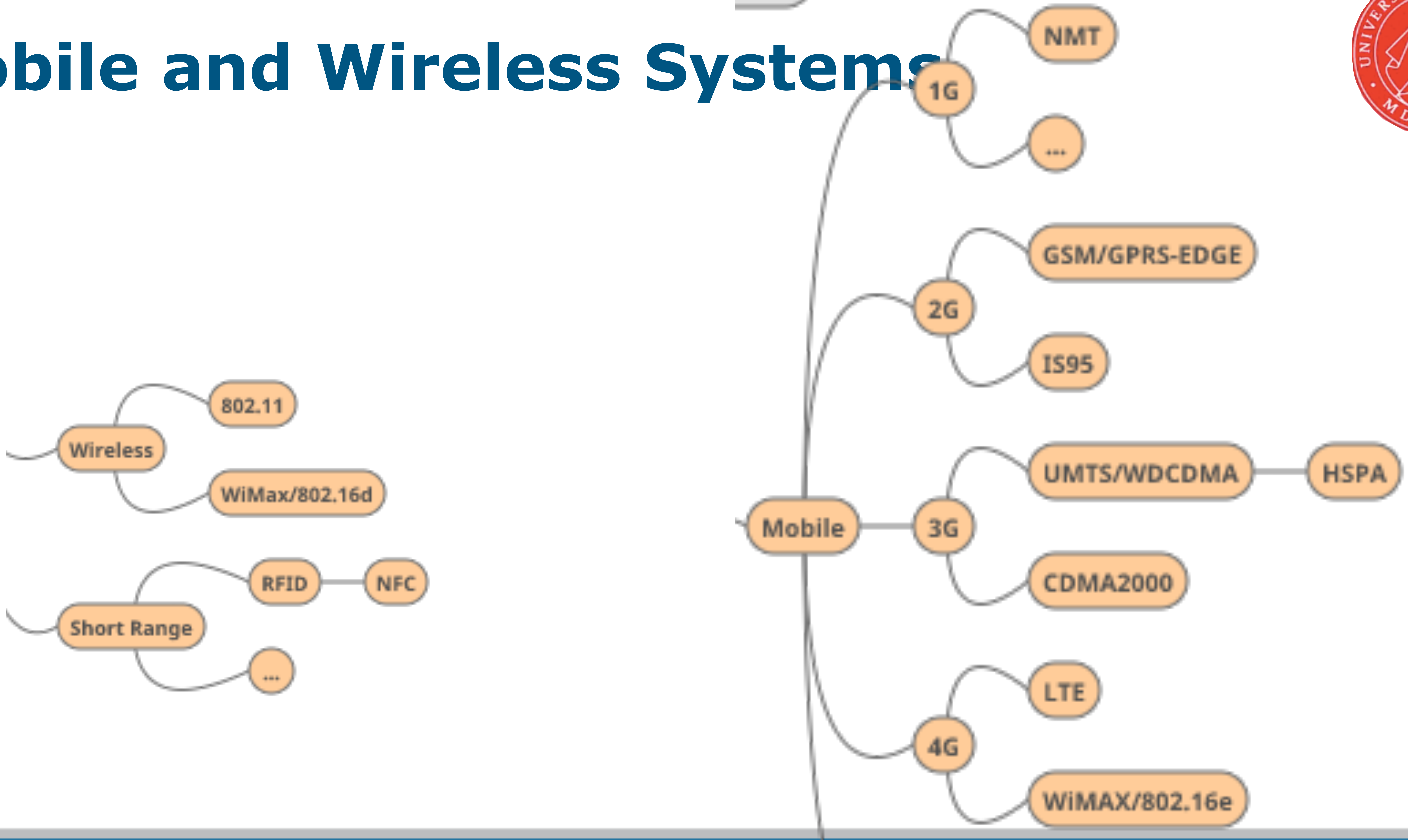
Receiver characteristics - impulse responses

- Sliding 16 mu s window and integr power in this window (typical GSM
- Rake receiver, where each finger c receiver points to one reflection (t enhanced GSM, UMTS)
- MIMO (Multiple input, multiple out smart antenna arrays. Spatial filte radiation from different directions 802.11n, smart antennas for UMT



Mobile Systems and Propagation Characteristics

Mobile and Wireless Systems



ITU-R propagation scenarios

➡ indoor, outdoor to indoor, vehicular

Typical Propagation parameters

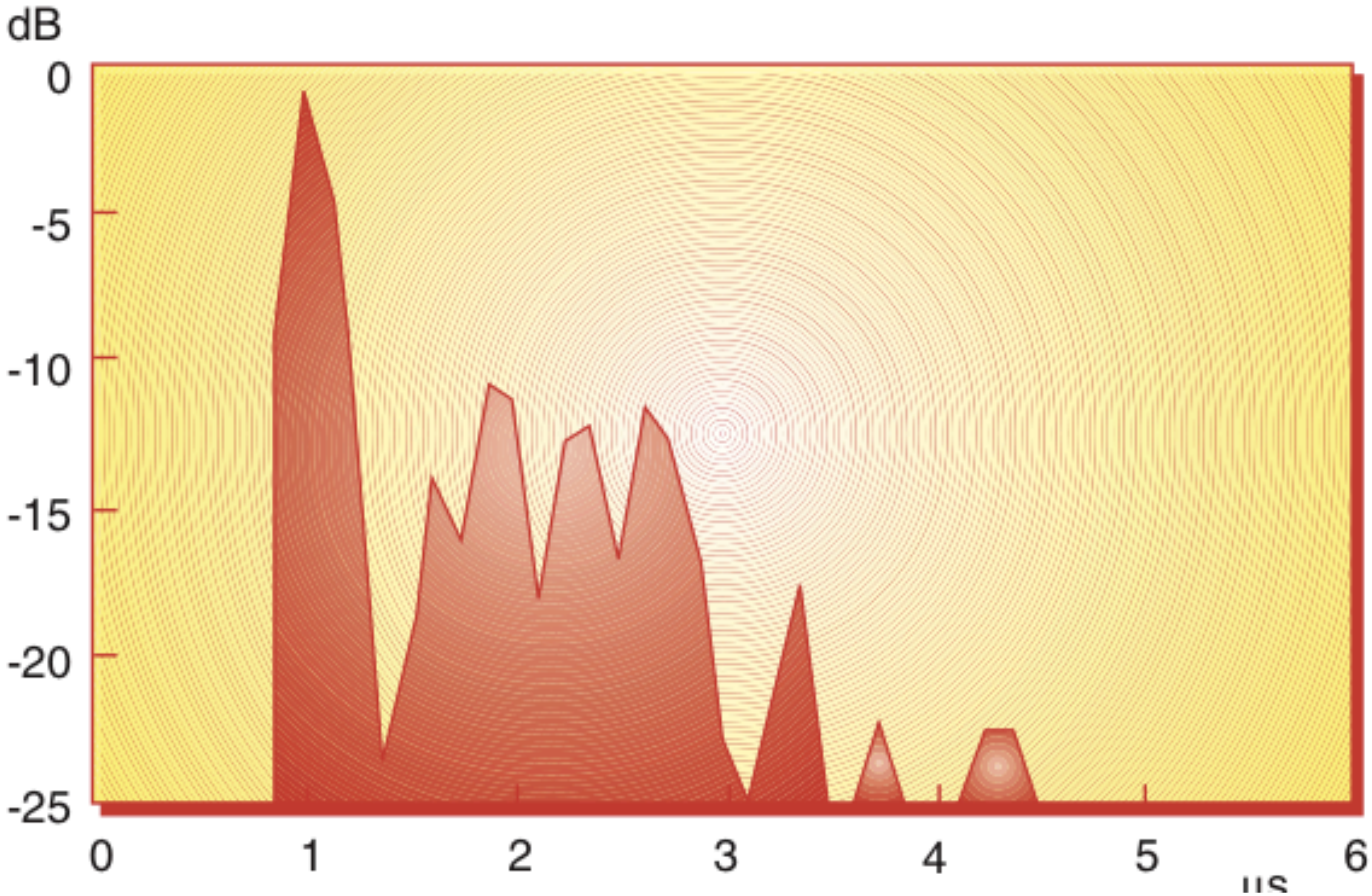
	Radio coverage [km^2]	Distance [km]	speed of mobile [km/h]	type of cell
Indoor office environment	0.01	0.1	3	picocell in open space environment
Pedestrian mode	4	2	3	Microcell
Vehicle	150	13	120	Macrocell

- see page 31 of ETSI TR 101 120 report for test environments

Impulse Response, rural farmland

- 1718 MHz. P_{RX) = –
- 20 dB above GSM sens

- Q (all impulse response
  - describe characteristics of reflection
  - from delay, calculate reflection facto

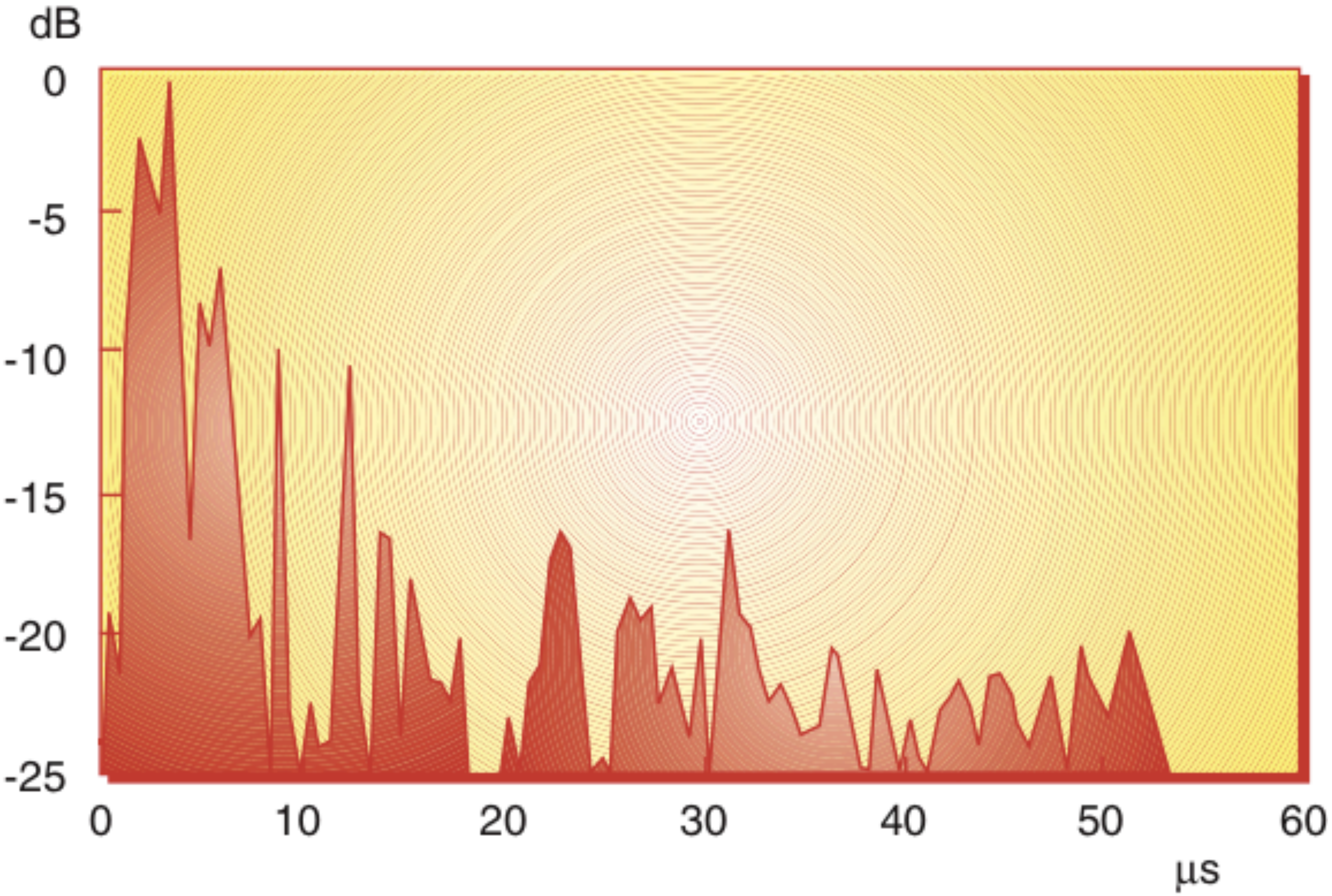


[Source:R Rækken, G. Løvnes, Telektronikk]

Impulse Response, rural farmland

- 953MHz.
- Total received power was

- Q (all impulse responses):
  - describe characteristics of reflection
  - from delay, calculate reflection factor anc

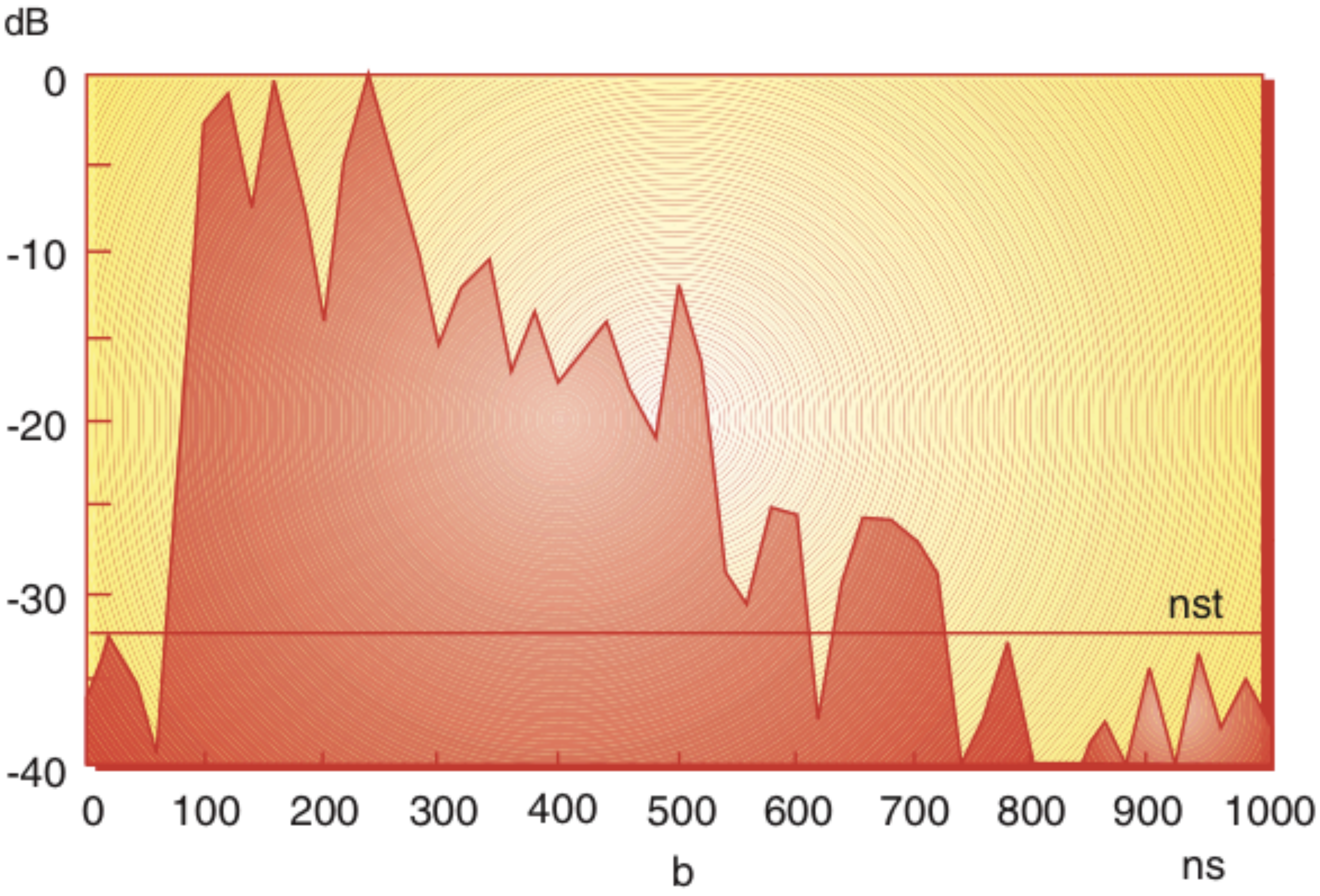


[Source:R Rækken, G. Løvnes, Telektronikk]

Impulse Response, Urban Measurements

- ➡ 1950 MHz, Oslo.
- ➡ Output power 25 dBm

- ➡ Q (all impulse response
  - describe characteristics of reflection
  - from delay, calculate reflection facto
  - why almost equal distribution?
  - Physical effects?



[Source:R Rækken, G. Løvnes, Telektronikk]

How did we measure?

ETSI urban pedestrian

$$L_{pedest}[dB] = 40\log r + 30\log f + 49$$

- Outdoor to indoor and pedestrian test environment, based on Non LOS (NLOS)
- Base stations with low antenna height are located outdoors, pedestrian users are located on streets and inside buildings and residences
- TX power is 14 dBm, f = 2000 MHz and r is distance in m
- Assumes average building penetration loss of 12 dB
- Q: Difference to Free space propagation model?

COST Walfish-Ikegami Model

- propagation over roof tops
- assumes antennas below roof top

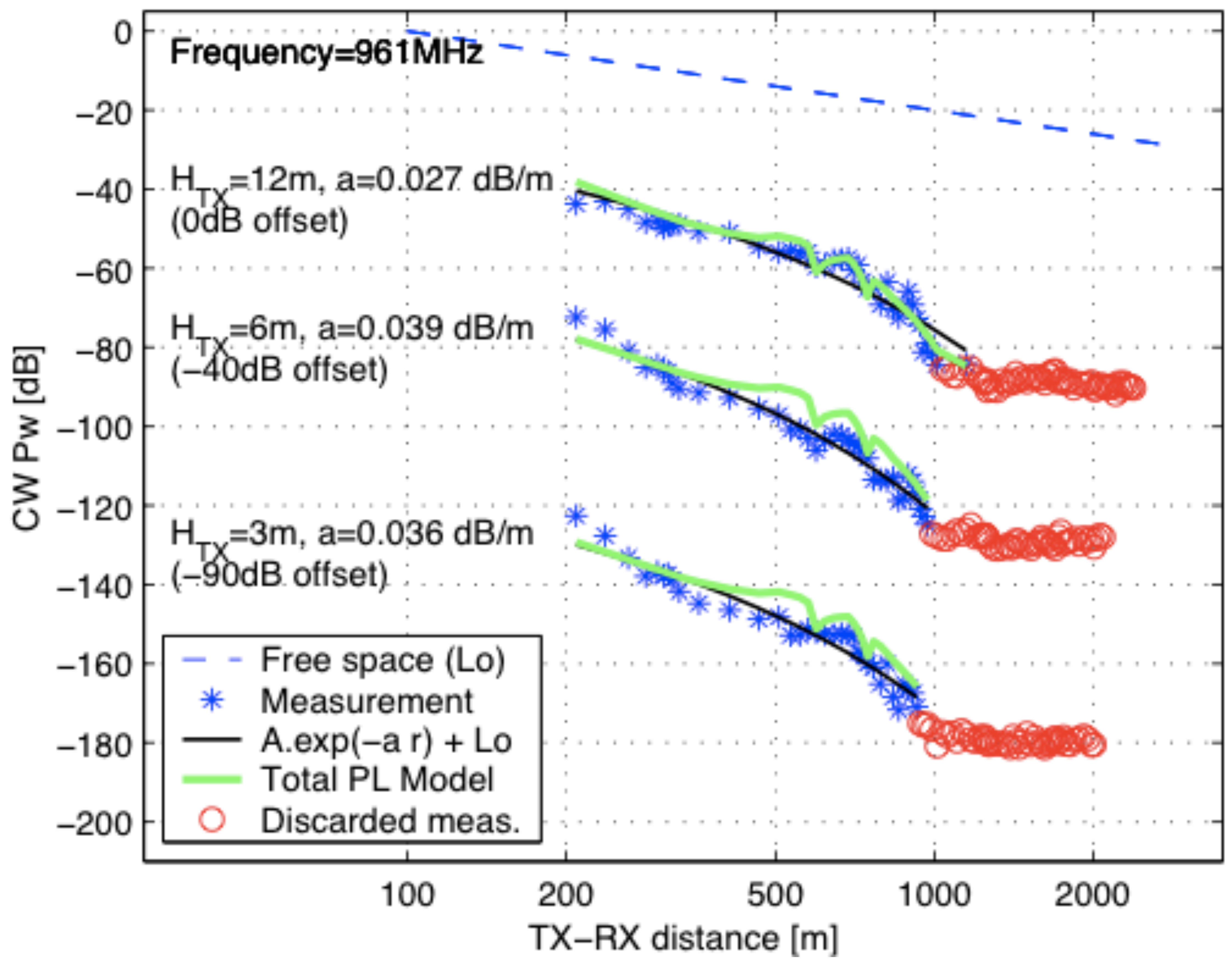
$$L_{rooftop}[dB] = 45\log(r + 20) + 24$$

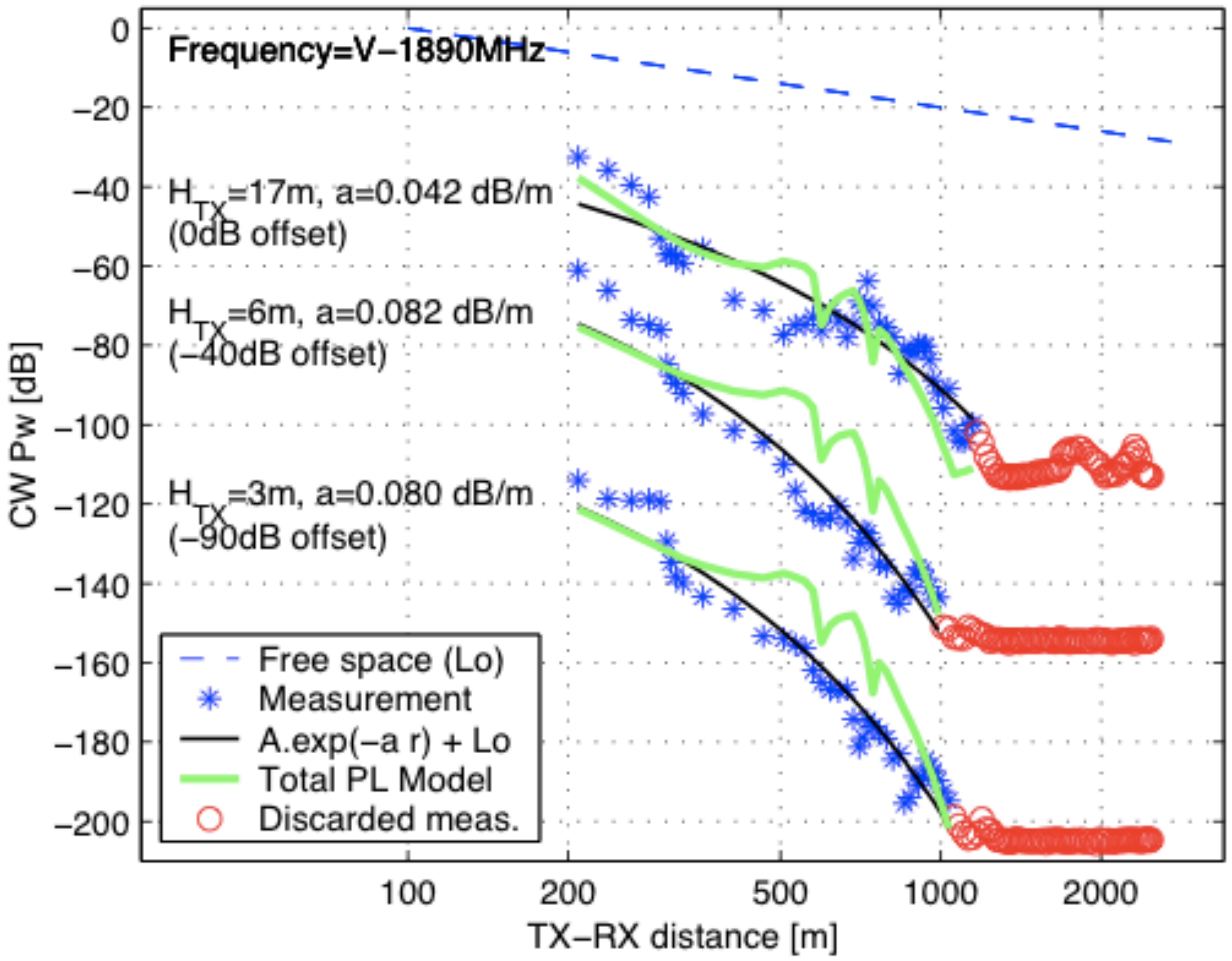
ETSI vehicular

- large cells, typical few km
  - TX power 24 dBm for mobile phone,
  - transmit antenna height Δh over roof top (typical 15 m),
  - distance *r* in km,
  - *f = 2000 MHz*

$$L_{vehicular}[DB] = 40(1 - 4 \cdot 10^{-3}\Delta h)\log r - 18\log\Delta h + 21\log f + 80$$

Forest, Path Loss *L*, slightly hilly terrain, forest





(Source:István Z.Kovács,Ph.D.Lecture,CPK, September6, 2002;p.27/45)

Exercise

- establish table (L free space, pedestrial, outdoor vehicular) with typical values
- $f = 900$ MHz, $f = 2000$ MHz
- $r = 100 \ldots 3000$ m

ETSI indoor office environment

- *r* is transmitter-receiver distance in m;
- *n* is number of floors in the path
- path loss L should always be more tha free space loss. Log-normal shadow fading standard deviation of 12 dB

$$L_{indoor}[dB] = 37\log r + 18.3n^{((n+2)/(n+1)-0.46}$$

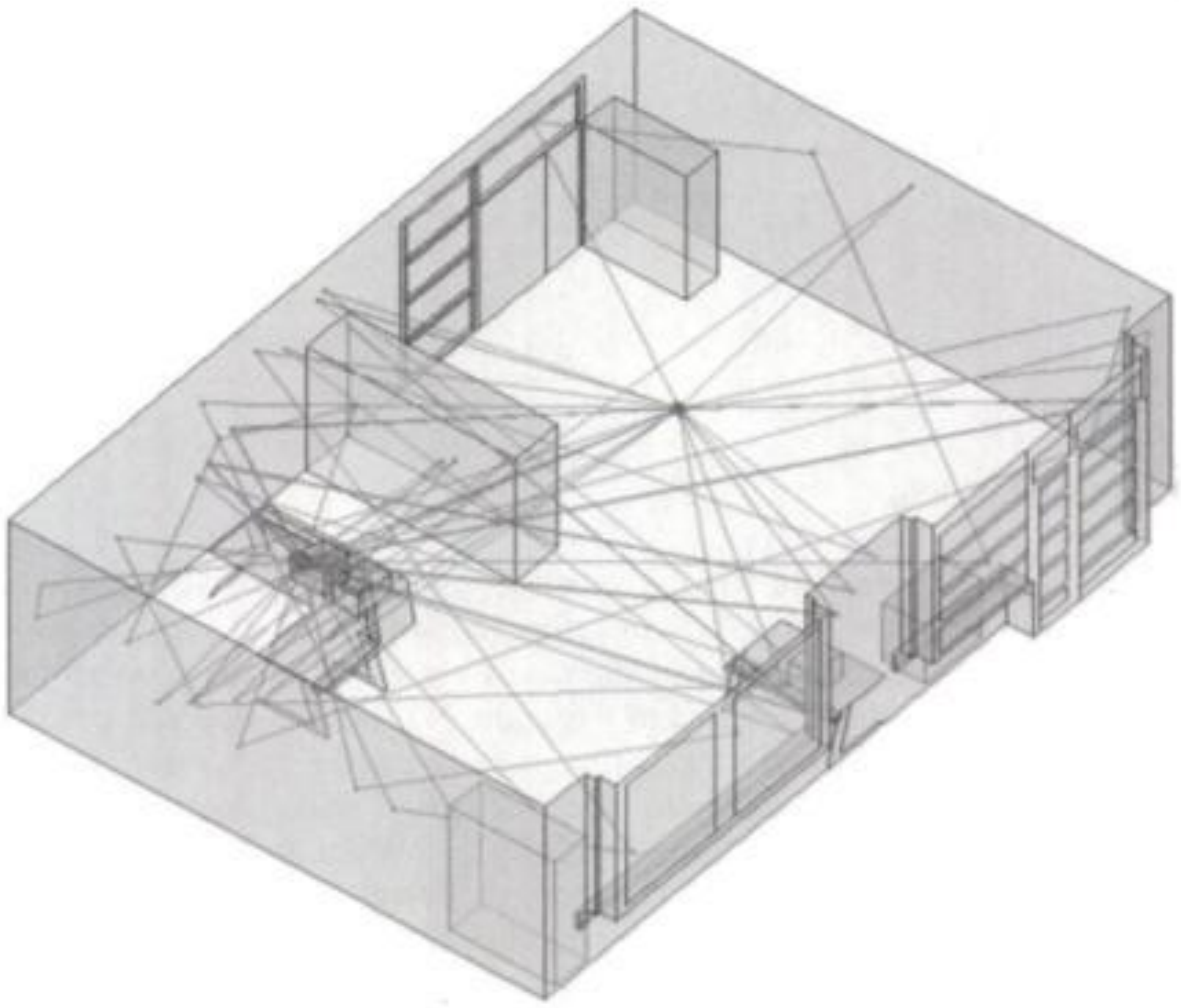
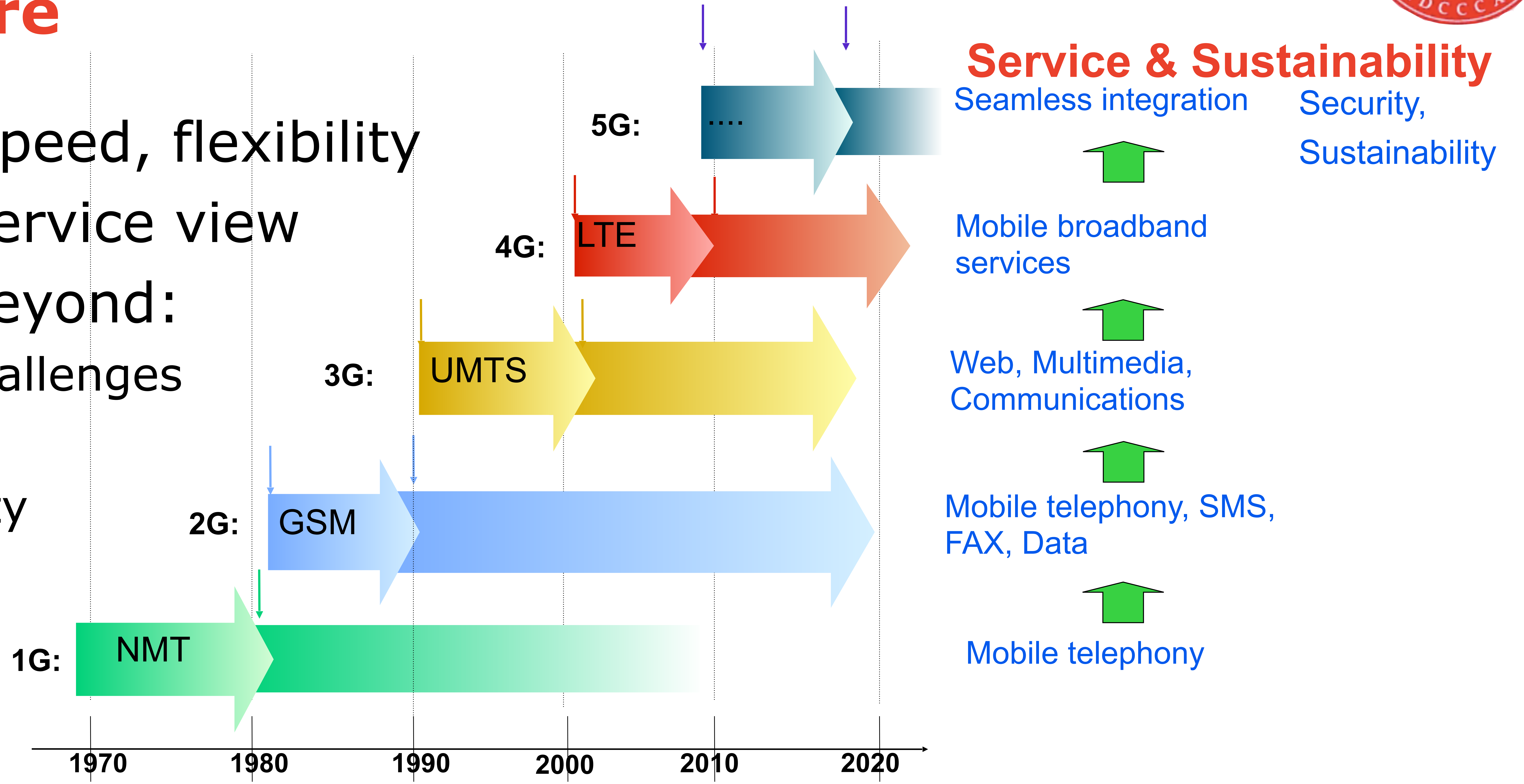


Fig. 7.26. Ray tracing in indoor environment

5G: Speed, Bandwidth, latency and much more

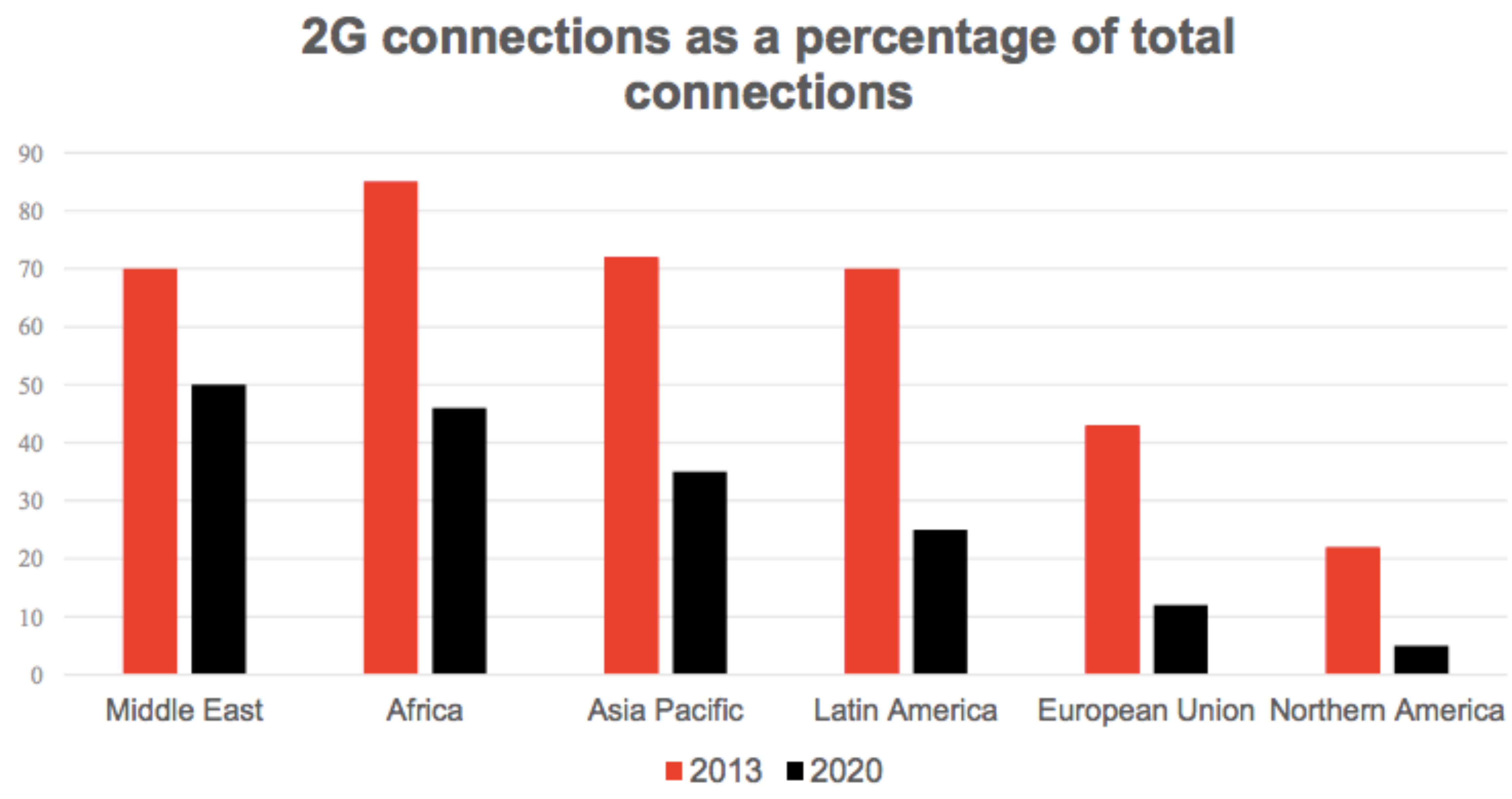
- 1G-3G: Speed, flexibility
- 3G-4G: service view
- 5G and beyond:
  - Business challenges
  - ownership
  - sustainability



[adapted from Per Hjalmar Lehne, Telenor, 2000]

The challenge of area coverage

- Land area Norway, 385.178 km^2 - 7500 basestasjons
  - http://www.mynewsdesk.com/no/telenor/pressreleases/sjekk-naar-du-faar-4g-der-du-bor-1399662
- Tanzania 947,303 km^2 = 3 x Norway,
- Mali 1.240.000 km^2 = 4 x Norway
- DR Congo 2.345.000 km^2 = 8 x Norway
- Economy in building Wireless Broadband
  - #5Gforall - *Discuss*



Upcoming Topics

Upcoming Topics / To do for next week

Upcoming Topics

- ➡ Measurement of radio propagation

To Do:

- ➡ Ideas for Group Work
- ➡ State-of-the-art Literature papers