

UiO : **Universitetet i Oslo**

TEK5110

L3 Propagation Characteristics



Josef Noll

Secretary General and Co-Founder at BasicInternet.org, Professor at UiO, Head of Research at Movation

Oslo Area, Norway | Telecommunications

Current	Basic Internet Foundation, University Graduate Studies (UNIK), University of Oslo (UiO), Movation AS
Previous	MobileMonday, Telenor R&I, Telenor R&D
Education	Ruhr University Bochum



Maghsoud Morshedi

PhD Fellow at Eye Networks AS

Oslo, Oslo, Norway

| Information Technology and Services

Current	Eye Networks AS
Previous	Høgskolen i Oslo og Akershus, State Organization for Registry of Deed & Property, Karaj Islamic Azad University
Education	University of Oslo (UiO)

TEK5110 - Before we start

- Leftover from L2 - Range, see slide 31 in L2 Radio
- Questions to L2 - Radio?

- Questions to paper?



TEK5110 - Lecture Plan

- 28Aug - L1 Intro
- 4Sep - L2 Radio
- 11Sep - L3 Propagation Characteristics
- 18Sep - L4 Real time monitoring (M)
- 25Sep - (L5) no lecture; presentation preparation
- 20Oct - L6 Presentations
- 9Oct - L7 Network Management (M)
- 16Oct - L8 IoT Raspberry Pi (M)
- 23Oct - L9 Mobile Systems
- 30Oct - L10 Wireless Systems
- 6Nov - L11 Hands-on Wireless (M)
- 13Nov - L12 Basic Internet Infrastructure
- 20Nov - L13 Hands-on monitoring (M)
- 27Nov - L14 Group work/Monitoring
- 4Dec - L15 Group Presentation
- 11Dec Exam



[http://its-wiki.no/wiki/
Building_Mobile_and_Wireless_Networks_Compendium](http://its-wiki.no/wiki/Building_Mobile_and_Wireless_Networks_Compendium)

Learning outcomes

- 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 Equation



Free space propagation

- Questions/Tasks:
 - Propagation equation in dB
 - provide examples for $f = 10$ MHz, 1 GHz, 100 GHz

- $0 \text{ dBm} = 10^{(0/10)} = 1 \text{ mW}$
- $10 \text{ dBm} = 10^{(10/10)} = 10 \text{ mW}$

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

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 $A_r = \lambda^2 / 4\pi$
- power received in $A_r = P_r$

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

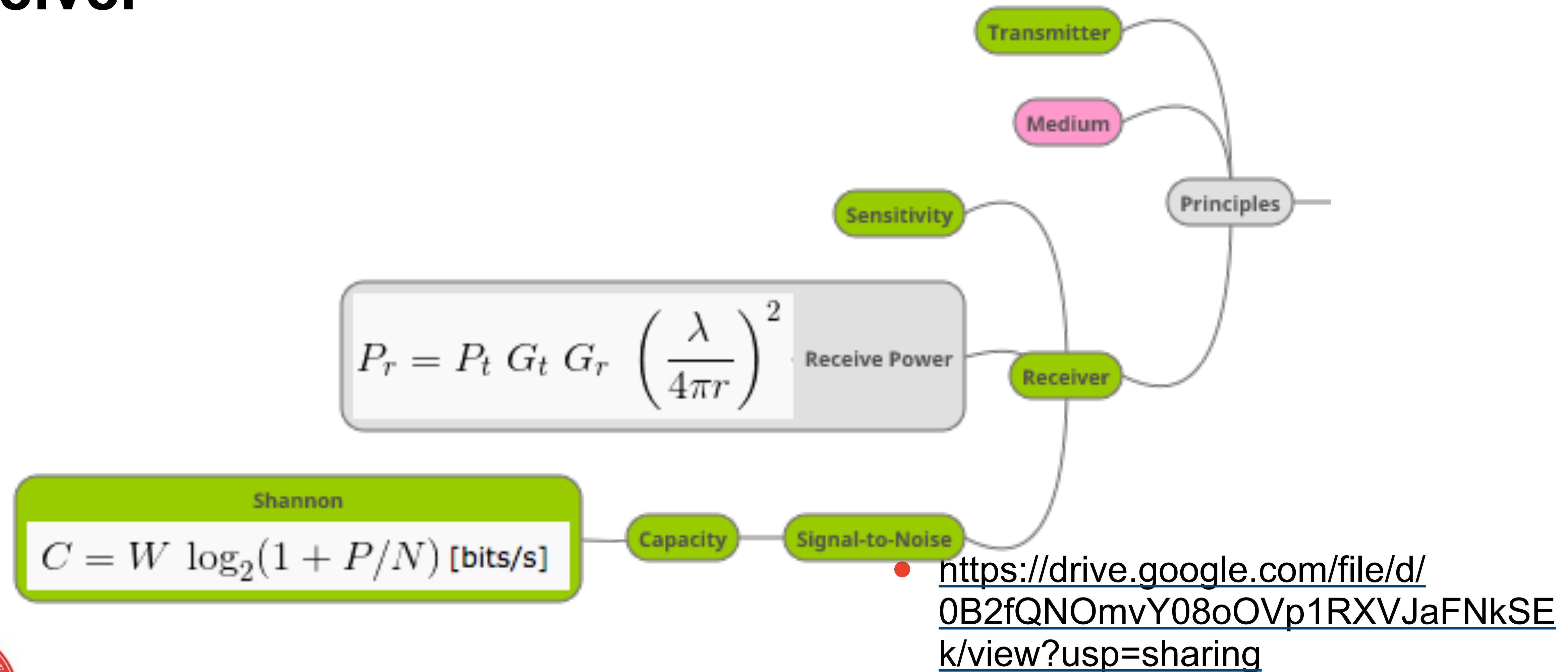
thus

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

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



Receiver

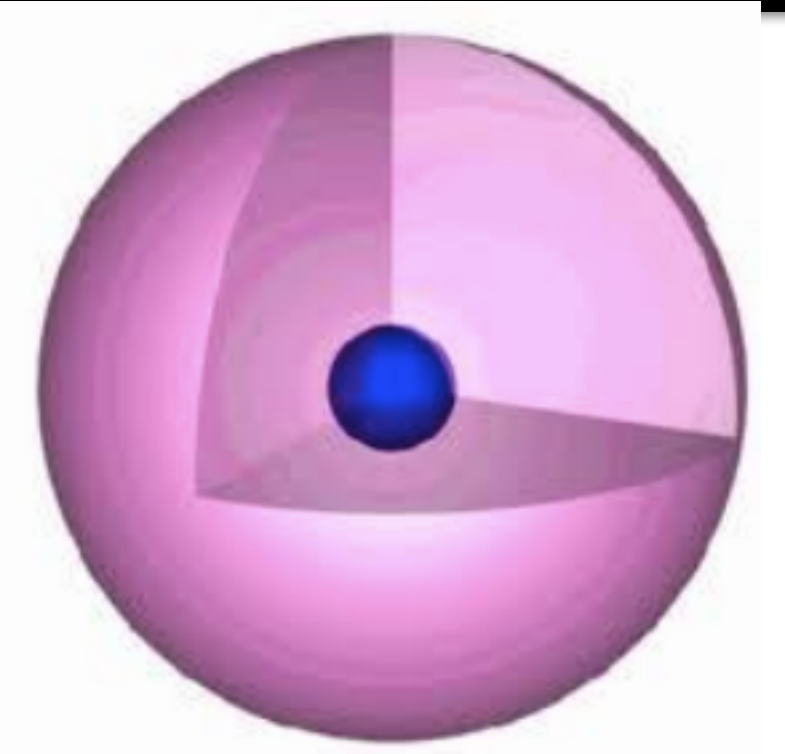


Antennas



B2-Antenna Basics

- The gain is the radiation intensity of an antenna into the main direction as compared to an isotropic antenna (omnidirectional).
- For a perfect antenna without any losses, the gain G will be identical to the directivity D .



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

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

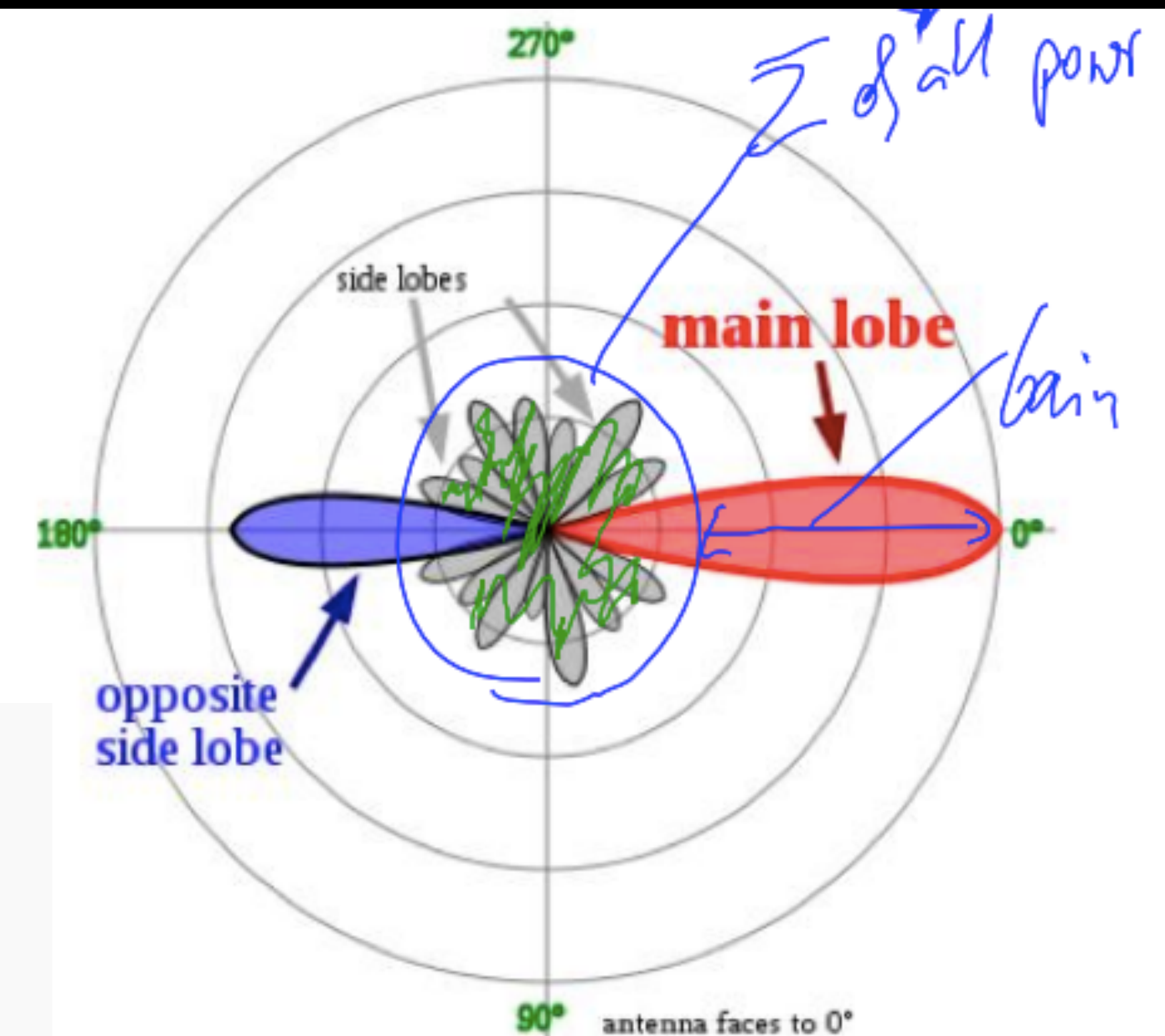


Antenna pattern

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

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

$$G_s = A_{eff} \frac{4\pi}{\lambda^2}$$
- examples of reflector antennas (effective aperture)

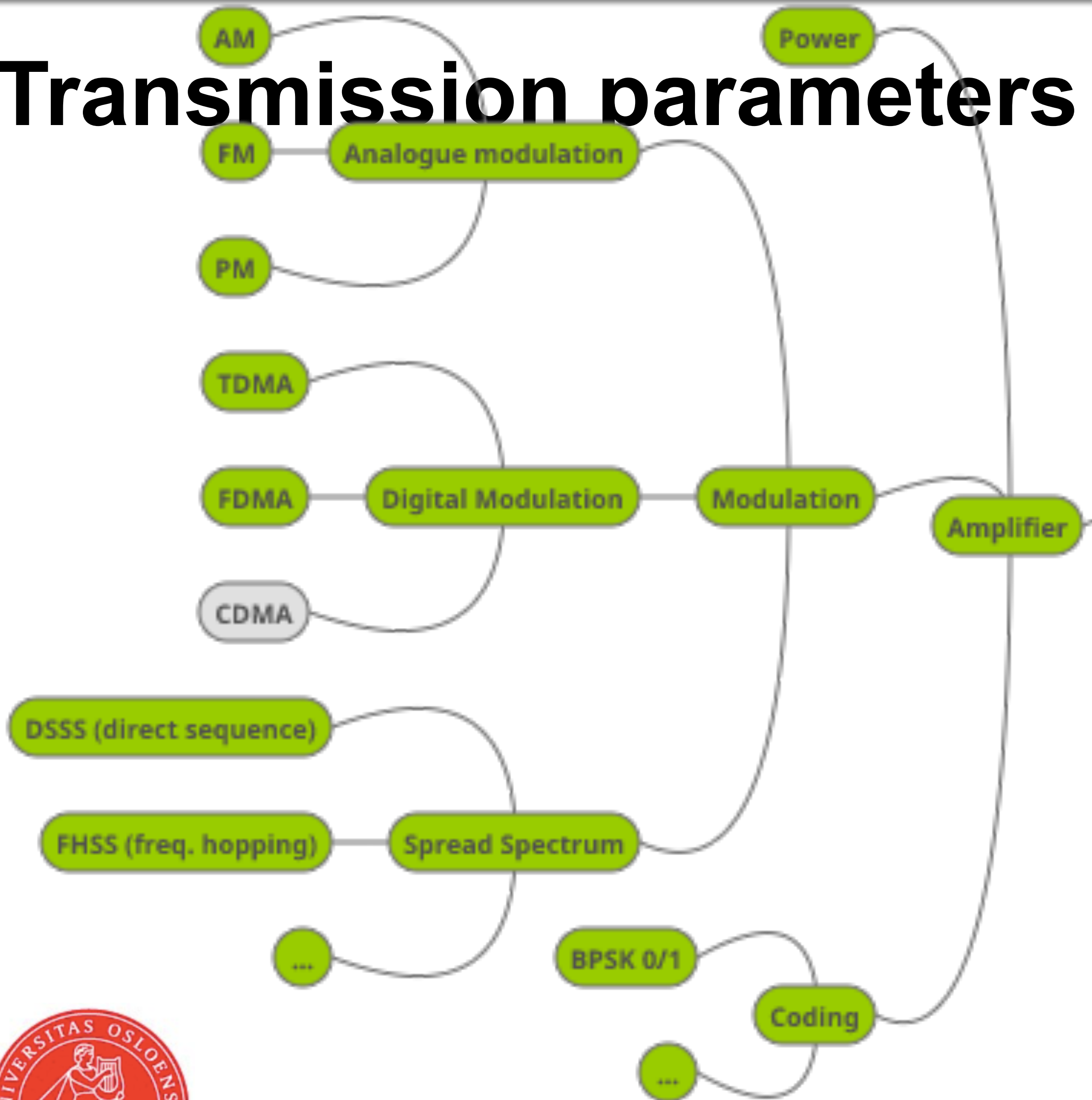


For more info, see intro course: <http://www.cv.nrao.edu/course/astr534/AntennaTheory.html>

- [Media:Antennas_for_communications_Haavard.pdf](#) (by Håvard Austad)



Transmission parameters



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

- Isotropic antenna = point source: $G_s = 0\text{dB}$
- Hertz Dipol = Short dipol: $G_s = 1,5 = 1,76\text{dB}$
- $\lambda/2$ -Dipol: $G_s \approx 1,64 = 2,15\text{dB}$

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



Antenna Questions

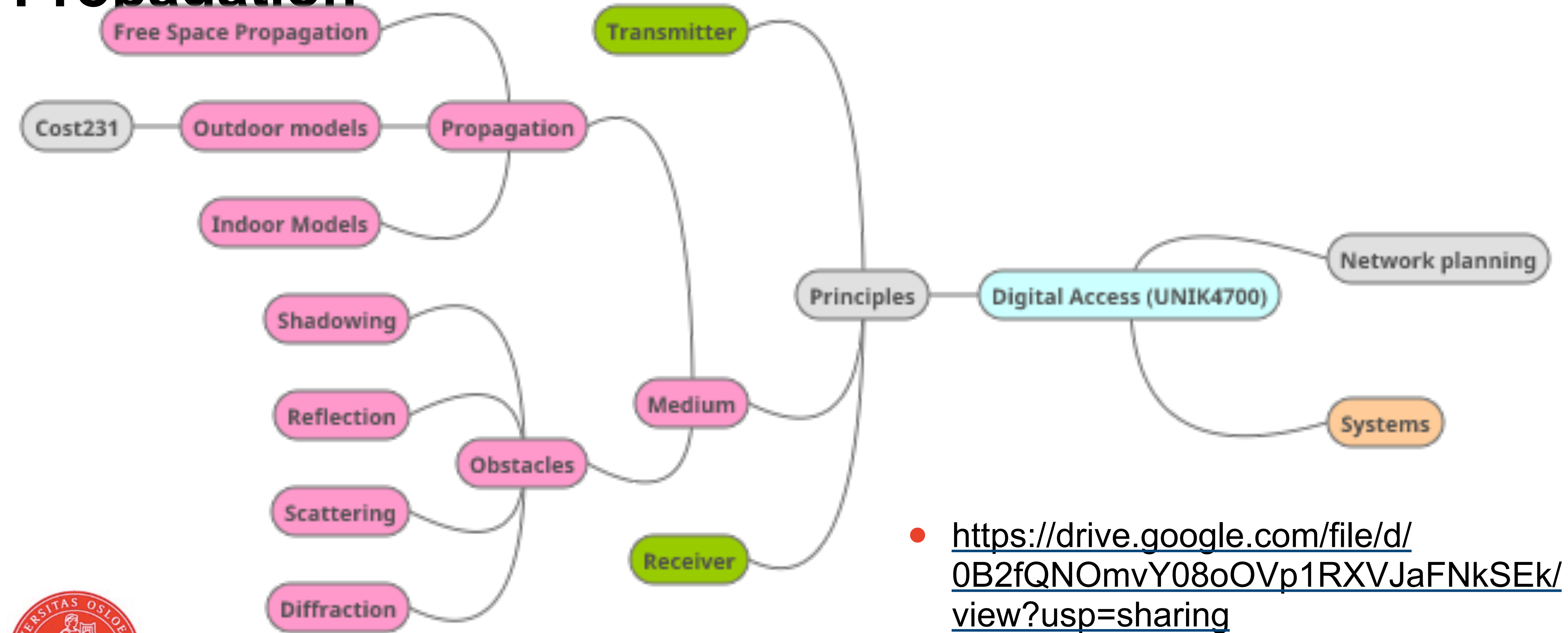
- Q: draw typical antenna pattern (Hertz Dipol, $\lambda/2$, reflector antenna)
- Q: what is the diagram of a lambda antenna?
- What else affects propagation?



Propagation Models



Propagation



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



Scattering, Reflection, Diffraction

- Reflection

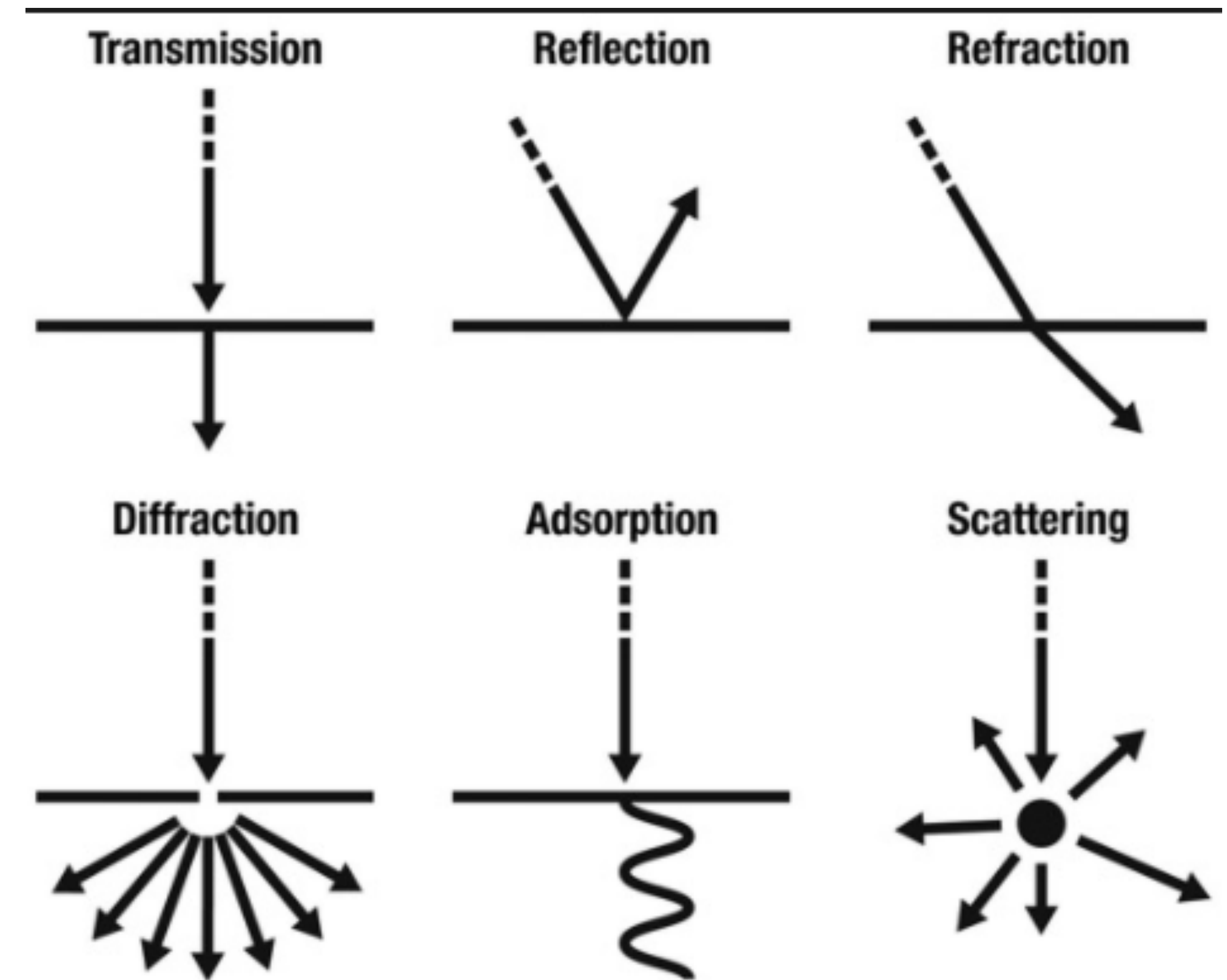
- wave hits smooth surface
- dimension $\gg \lambda$
- typical: buildings, walls, water
- “ideal” reflection: mirror

- Diffraction

- dimension $\sim \lambda$, or
- edges (roof top)
- bending wave

- Scattering

dimension $\ll \lambda$
spread out energy

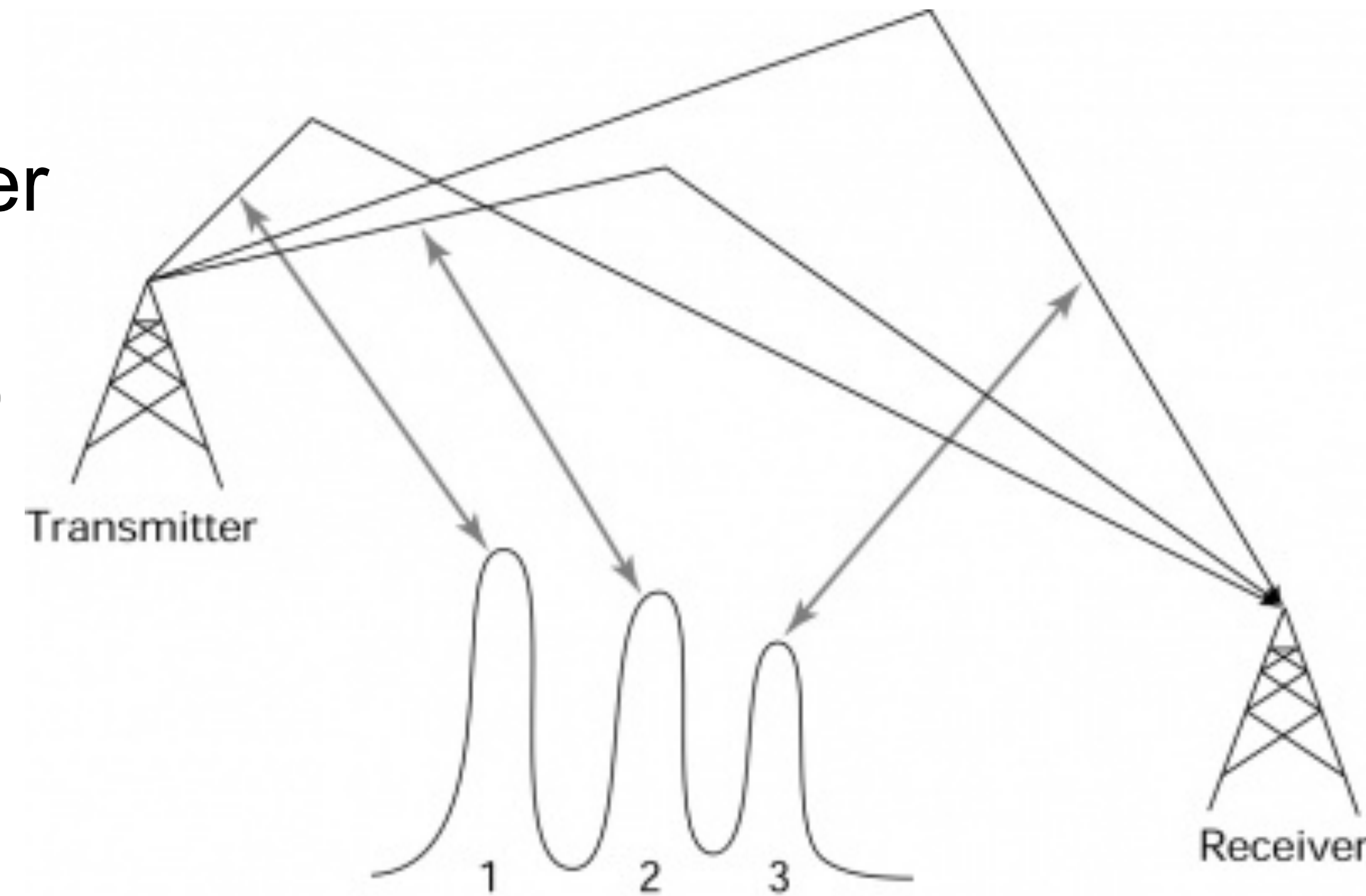


source: <https://physicsweekly.weebly.com/reflection-refraction-and-diffraction.html>



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

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



Attenuation

2.4 GHz attenuation, source: Hydra Deliverable D5.4

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

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

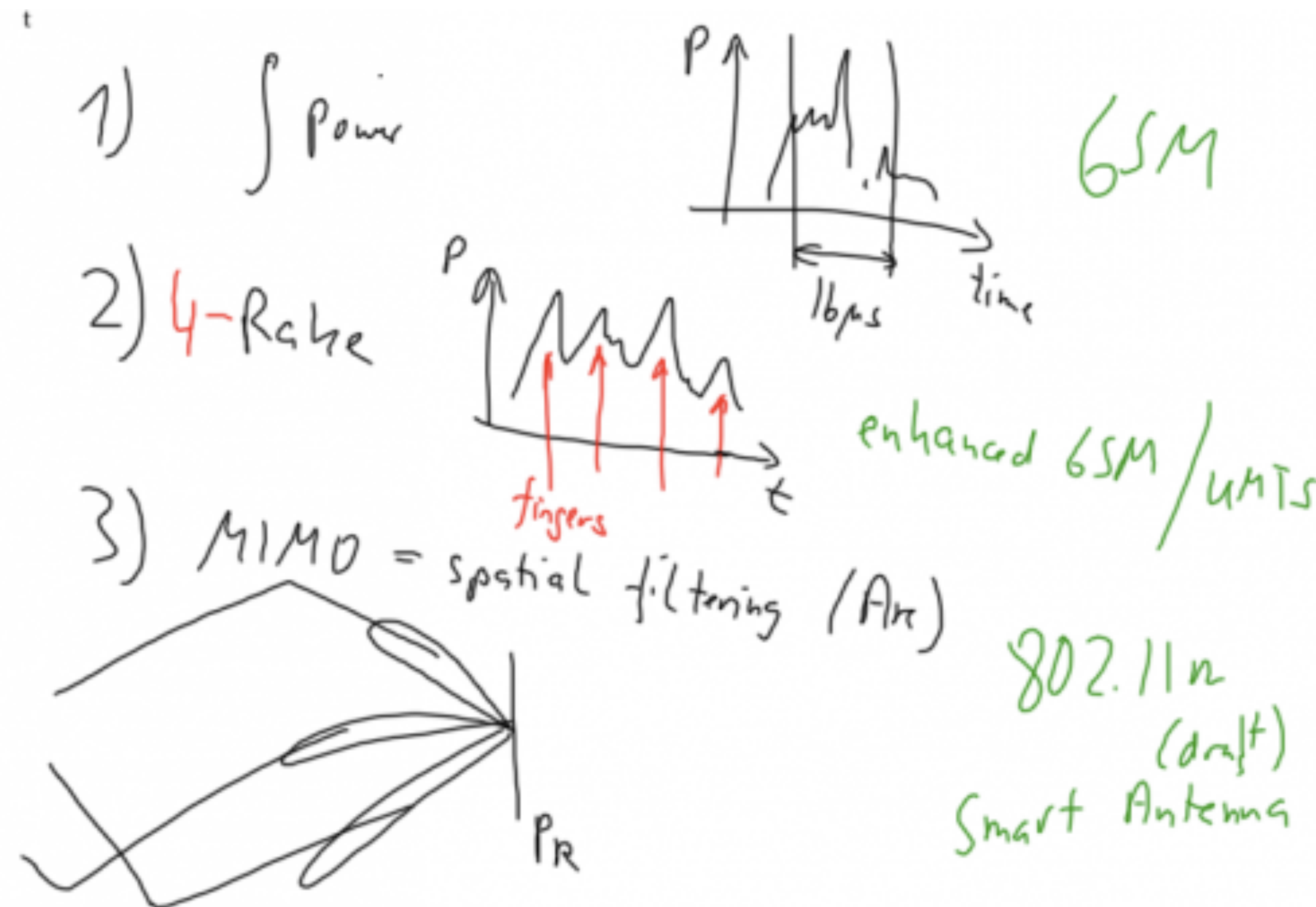
Obstacle	Attenuation α_i [dB]
Brick wall with window	2
Brick wall next to metal door	3
Cinder Block wall	4
Office wall	6
Metal door in office wall	6
Metall door in brick wall	12.4
Floor	30

- Q: Relation between fading margin and receiver sensitivity?



Receiver characteristics - impulse responses

- Sliding 16 μ s window and integration of power in this window (typical GSM)
- Rake receiver, where each finger of the receiver points to one reflection (typical enhanced GSM, UMTS)
- MIMO (Multiple input, multiple output) or smart antenna arrays. Spatial filtering, with radiation from different directions (typical 802.11n, smart antennas for UMTS)

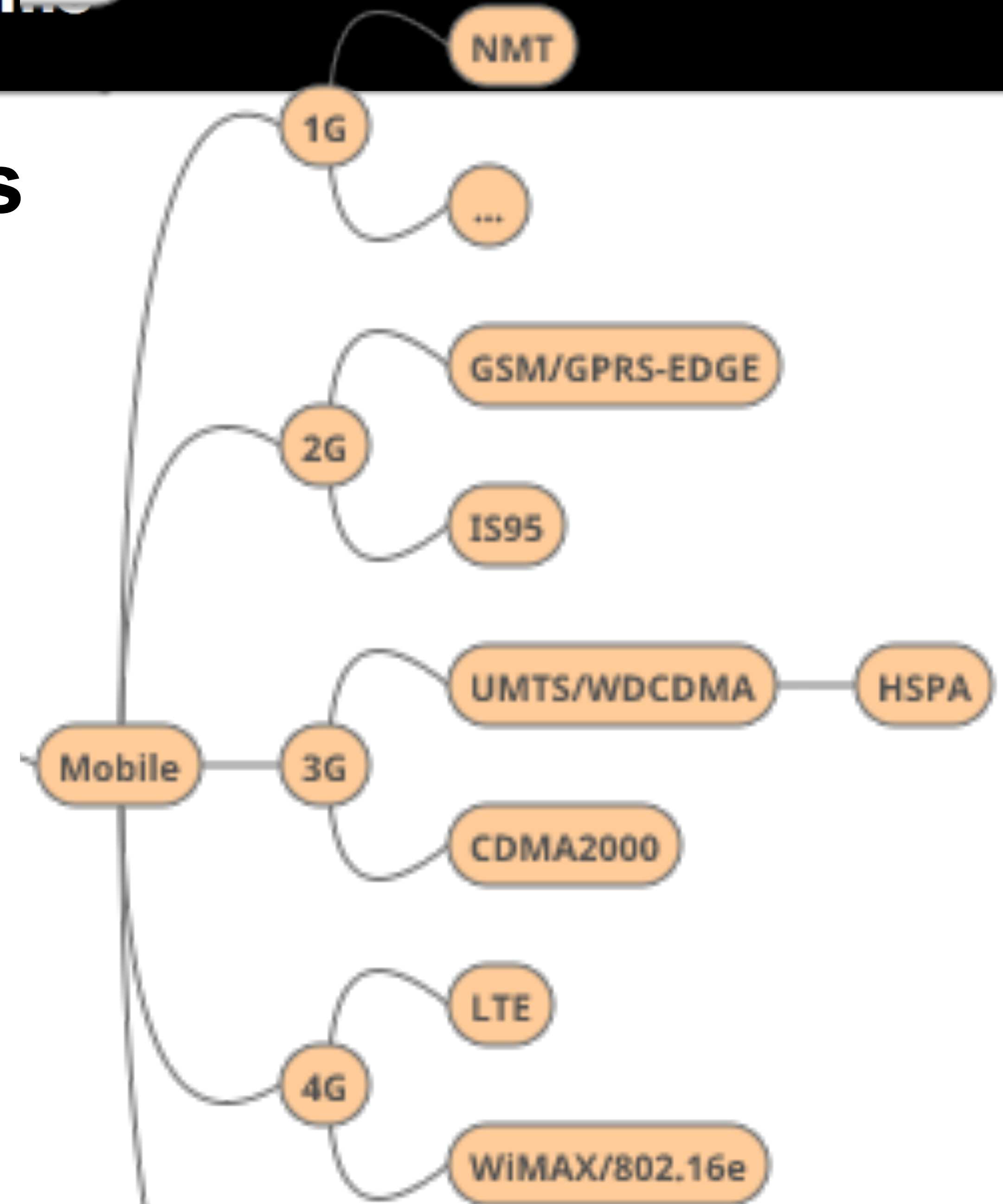
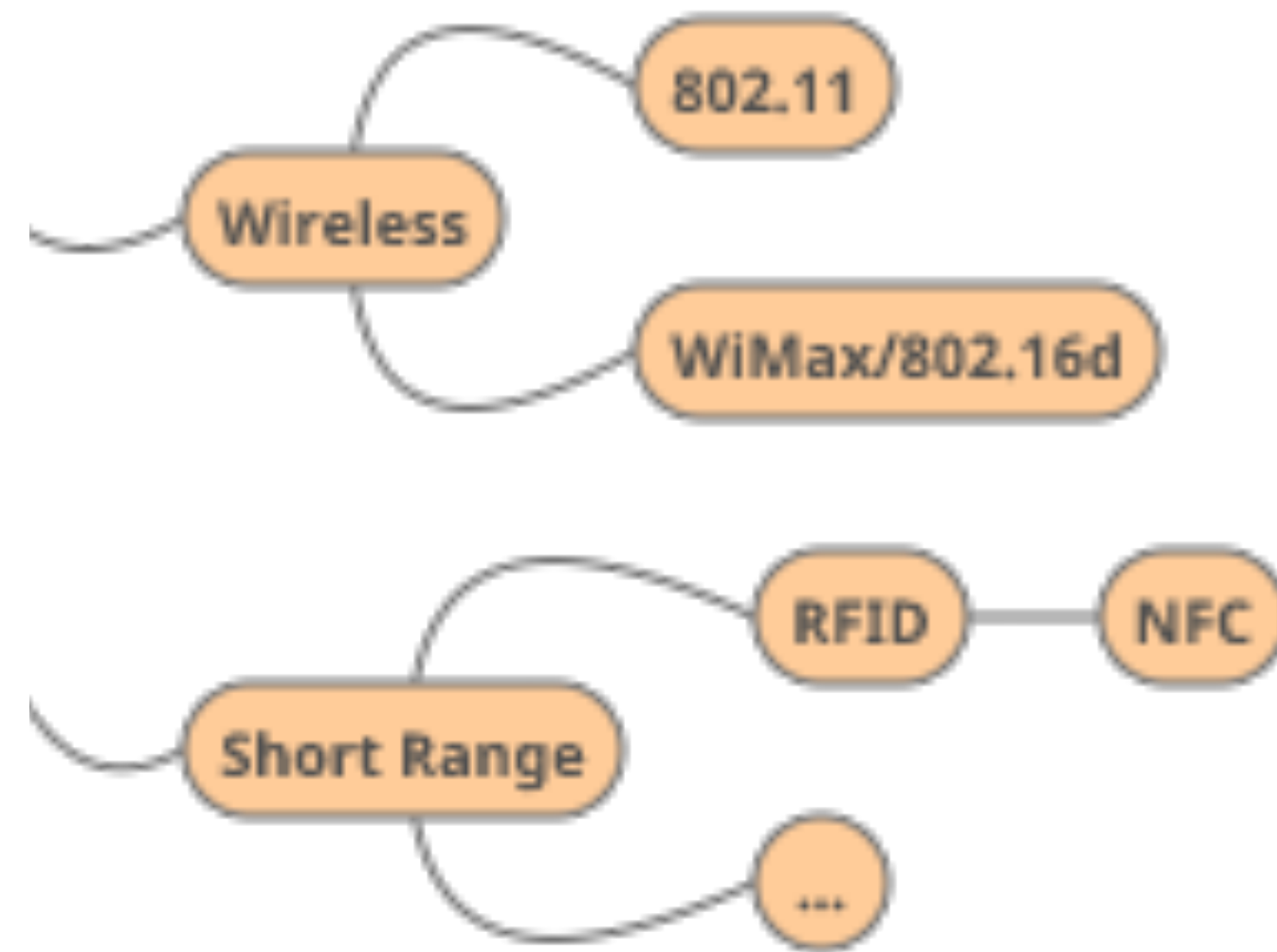


Mobile Systems and Propagation Characteristics



Mobile and Wireless Systems

- <https://drive.google.com/file/d/0B2fQN0mvY08oOVp1RXVJaFNkSEk/view?usp=sharing>



ITU-R propagation scenarios

- indoor, outdoor to indoor, vehicular

Typical Propagation parameters

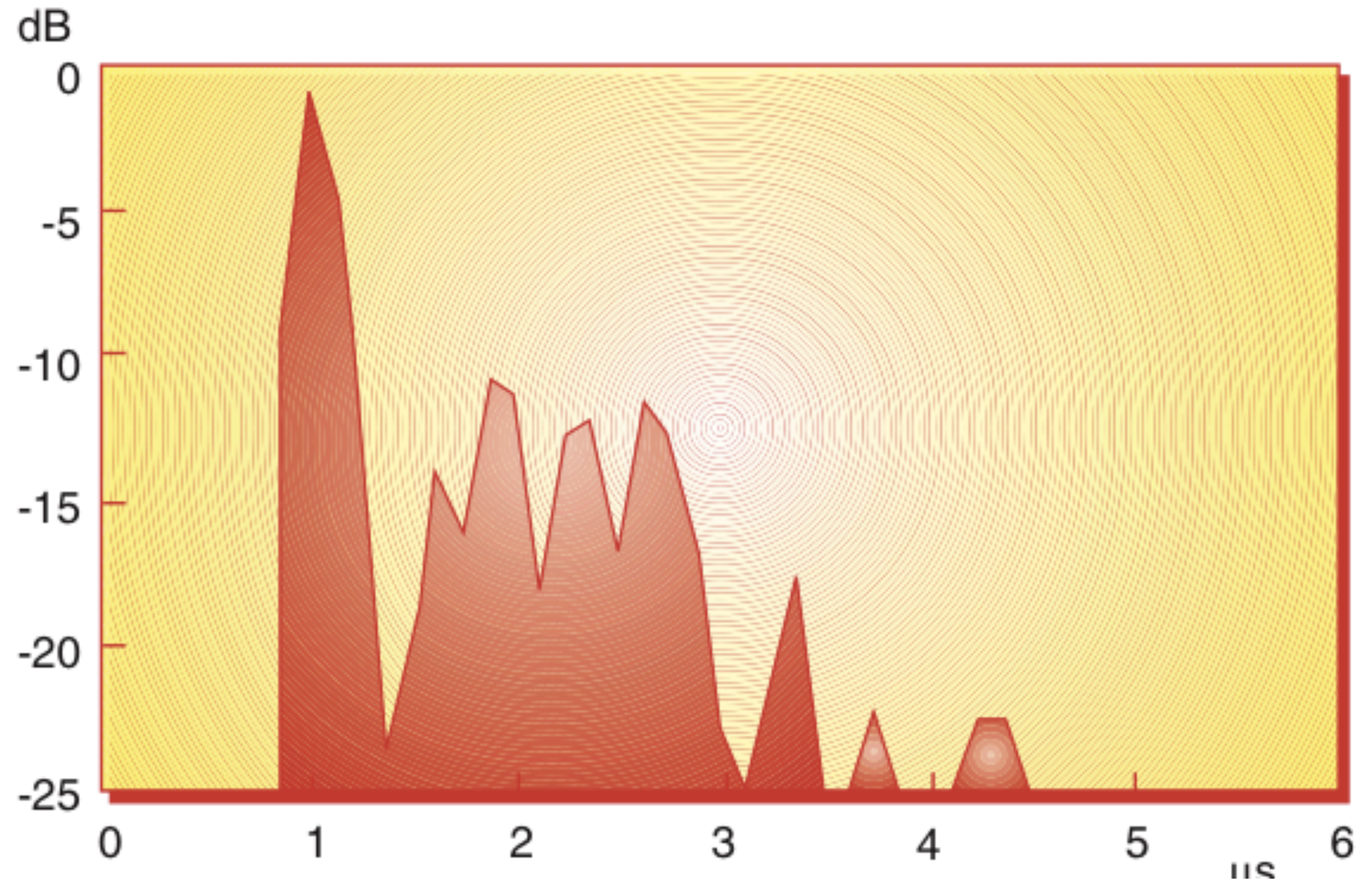
	Radio coverage [km ²]	Distance [km]	speed of mobile [km/h]	type of cell
Indoor office environment	0.01	0.1	3	picocell in open space environment
Pedestrian mode	4	2	3	Microcell
Vehicle	150	13	120	Macrocell

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



Impulse Response, rural farmland

- 1718 MHz. $P_{\{RX\}} = -84$ dBm,
- 20 dB above GSM sensitivity level
- Q (all impulse responses):
 - describe characteristics of reflection
 - from delay, calculate reflection factor and free space attenuation
 -

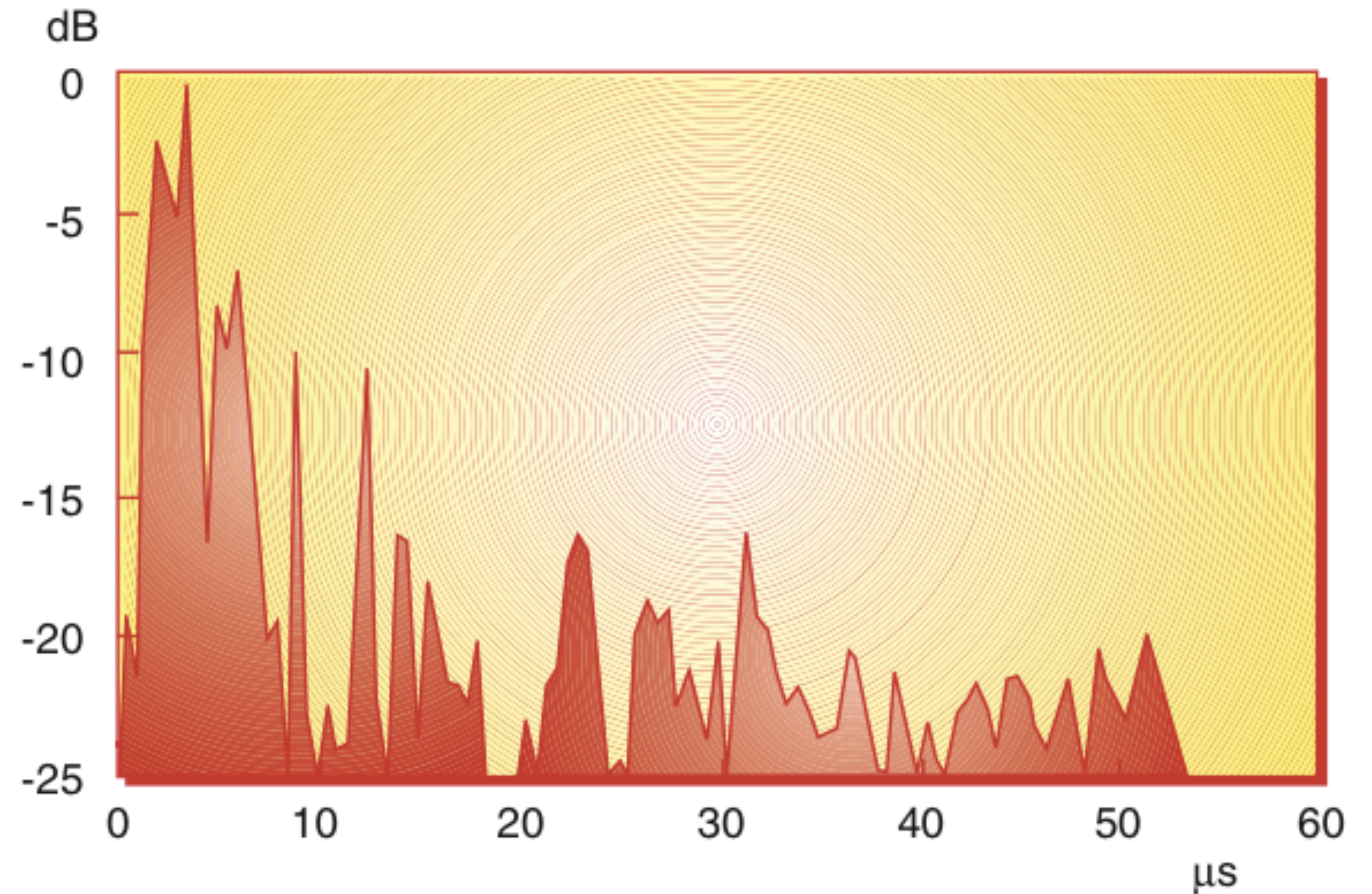


[Source: R Rækken, G. Løvnes, Telektronikk]



Impulse Response, rural farmland

- 953MHz.
- Total received power was <math><93\text{dBm}</math>
- Q (all impulse responses):
 - ➔ describe characteristics of reflection
 - ➔ from delay, calculate reflection factor and free space attenuation
 - ➔

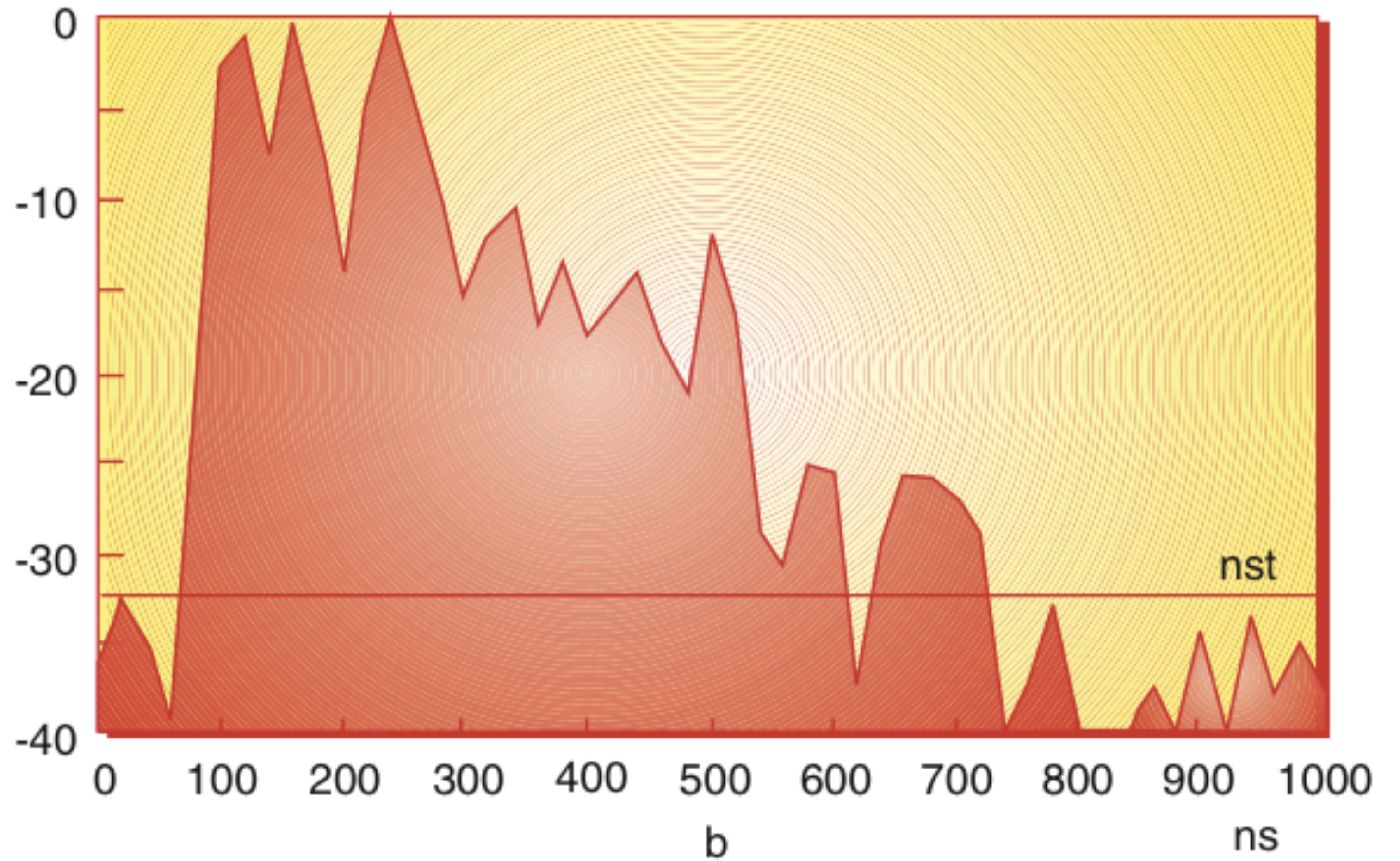


[Source:R Rækken, G. Løvnes, Telektronikk]



Impulse Response, U dB

- 1950 MHz, Oslo.
- Output power 25 dBm
- Q (all impulse responses):
 - describe characteristics of reflection
 - from delay, calculate reflection factor and free space attenuation
 - 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

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

- propagation over roof tops
- assumes antennas below roof top



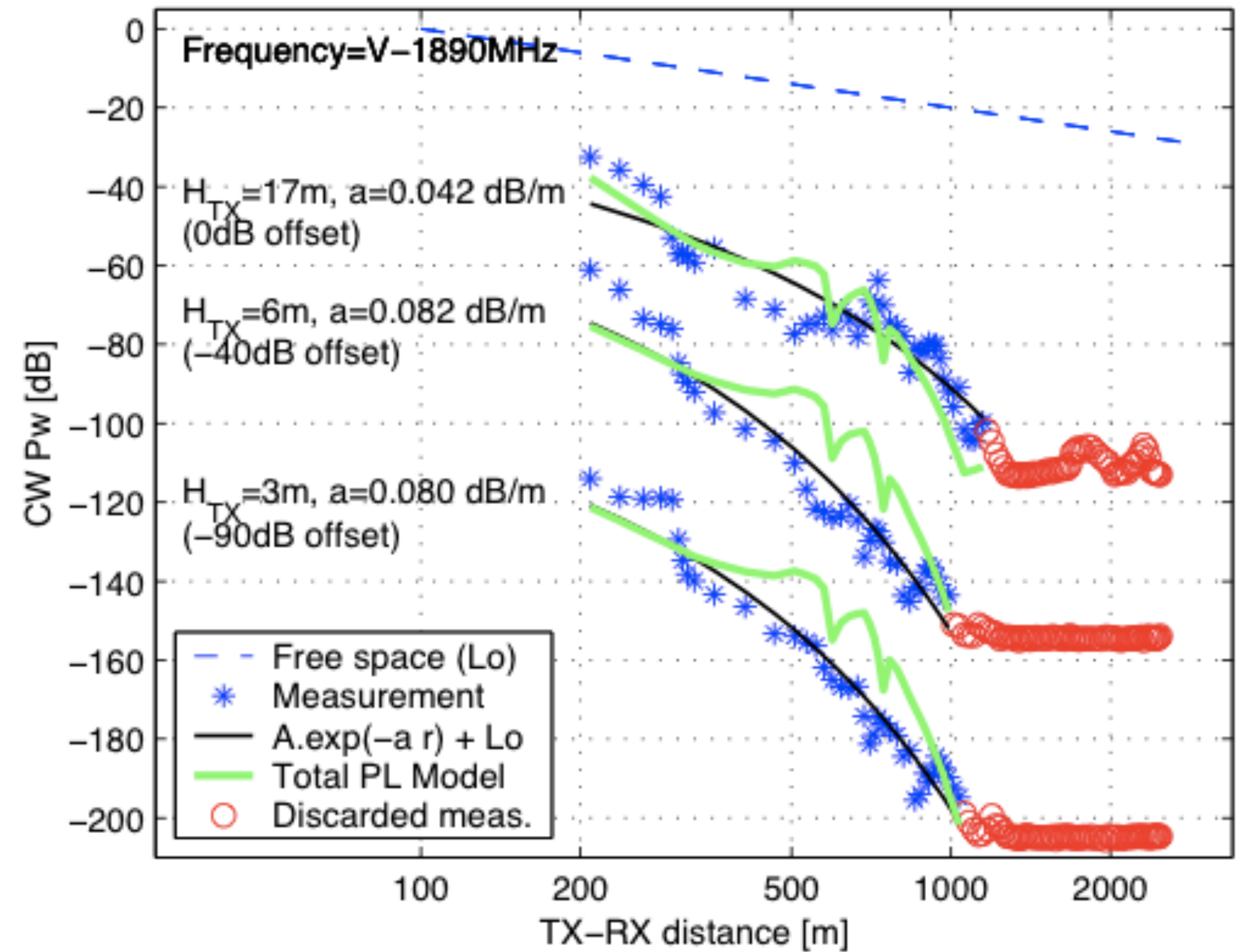
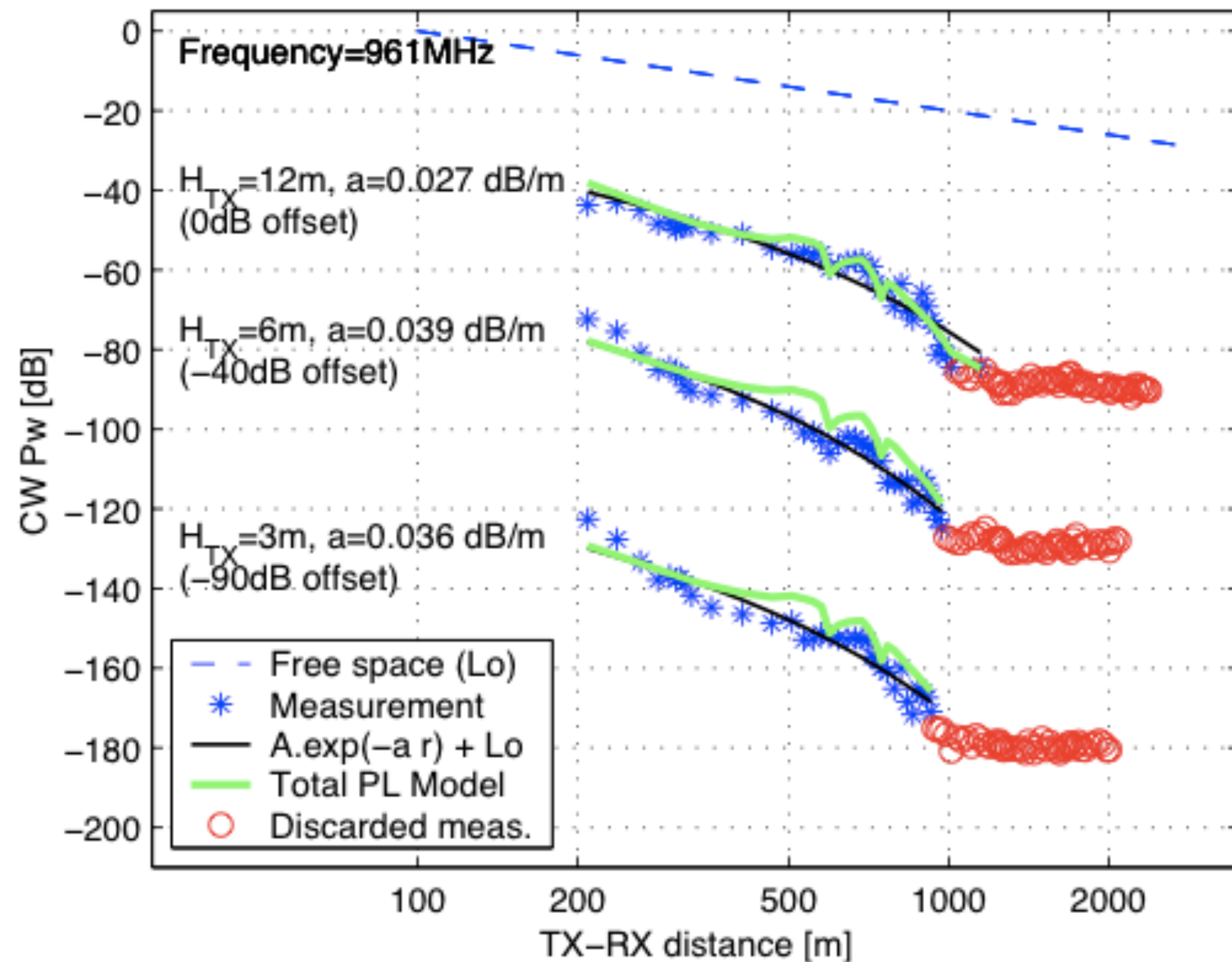
ETSI vehicular

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

- 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



Forest, Path Loss L , slightly hilly terrain, forest



(Source: István Z. Kovács, Ph.D. Lecture, CPK, September 6, 2002; p. 27/45)



Exercise

- establish table (L free space, pedestrian, outdoor vehicular) with typical values
- $f = 900 \text{ MHz}$, $f = 2000 \text{ MHz}$
- $r = 100 \dots 3000 \text{ m}$



ETSI indoor office environment

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

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

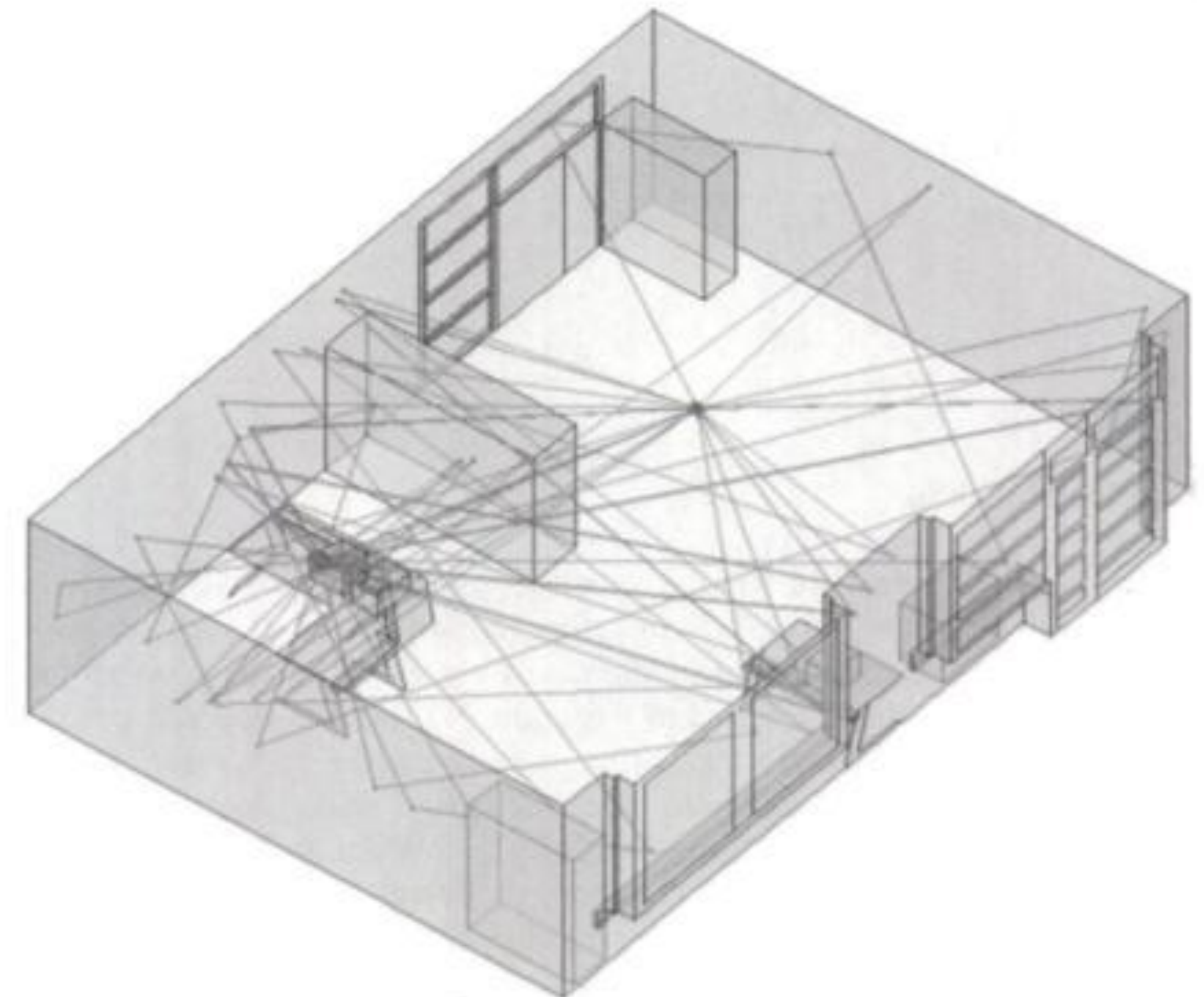
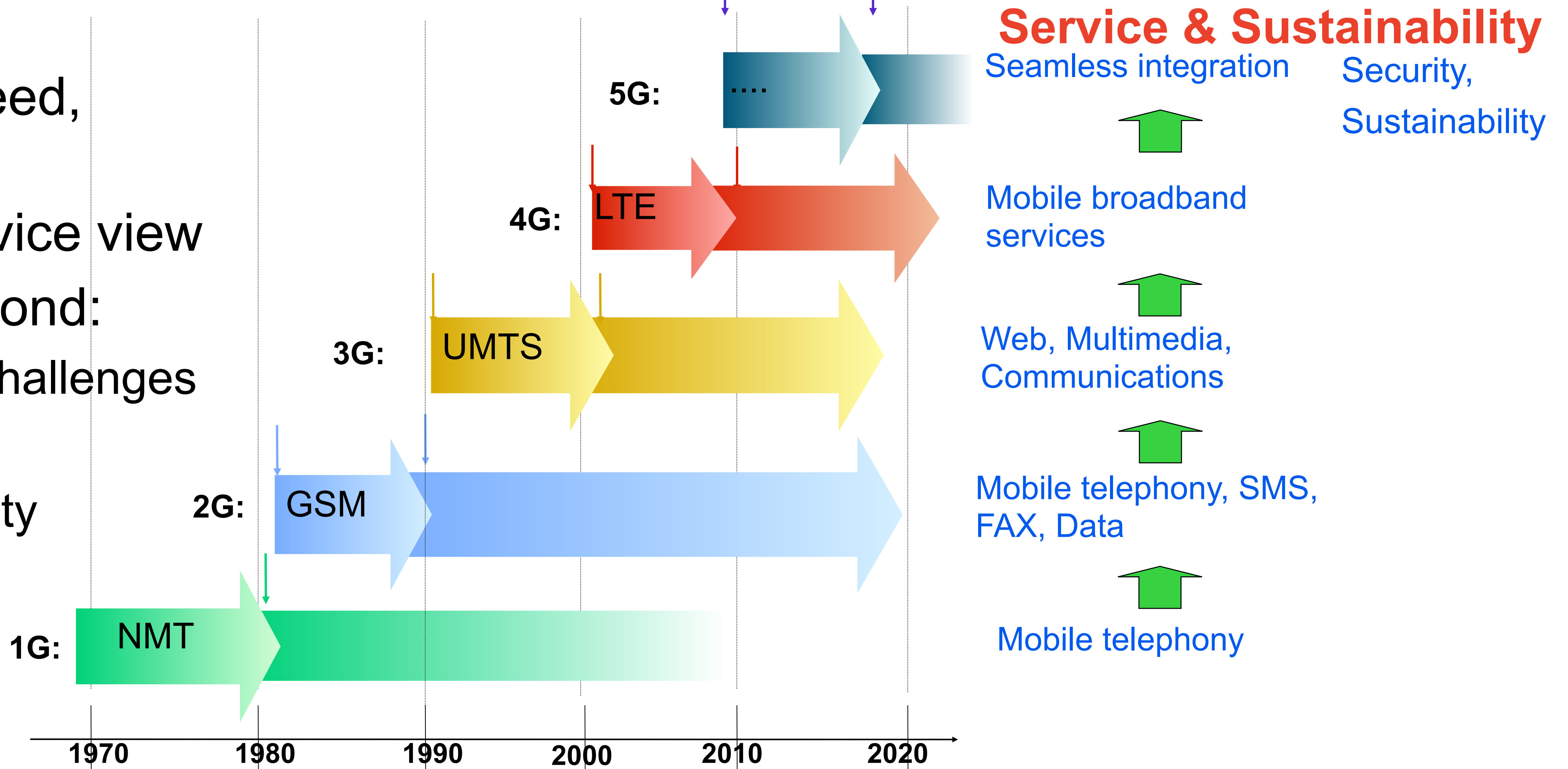


Fig. 7.26. Ray tracing in indoor environment



5G: Speed, Bandwidth, latency and **much more**

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

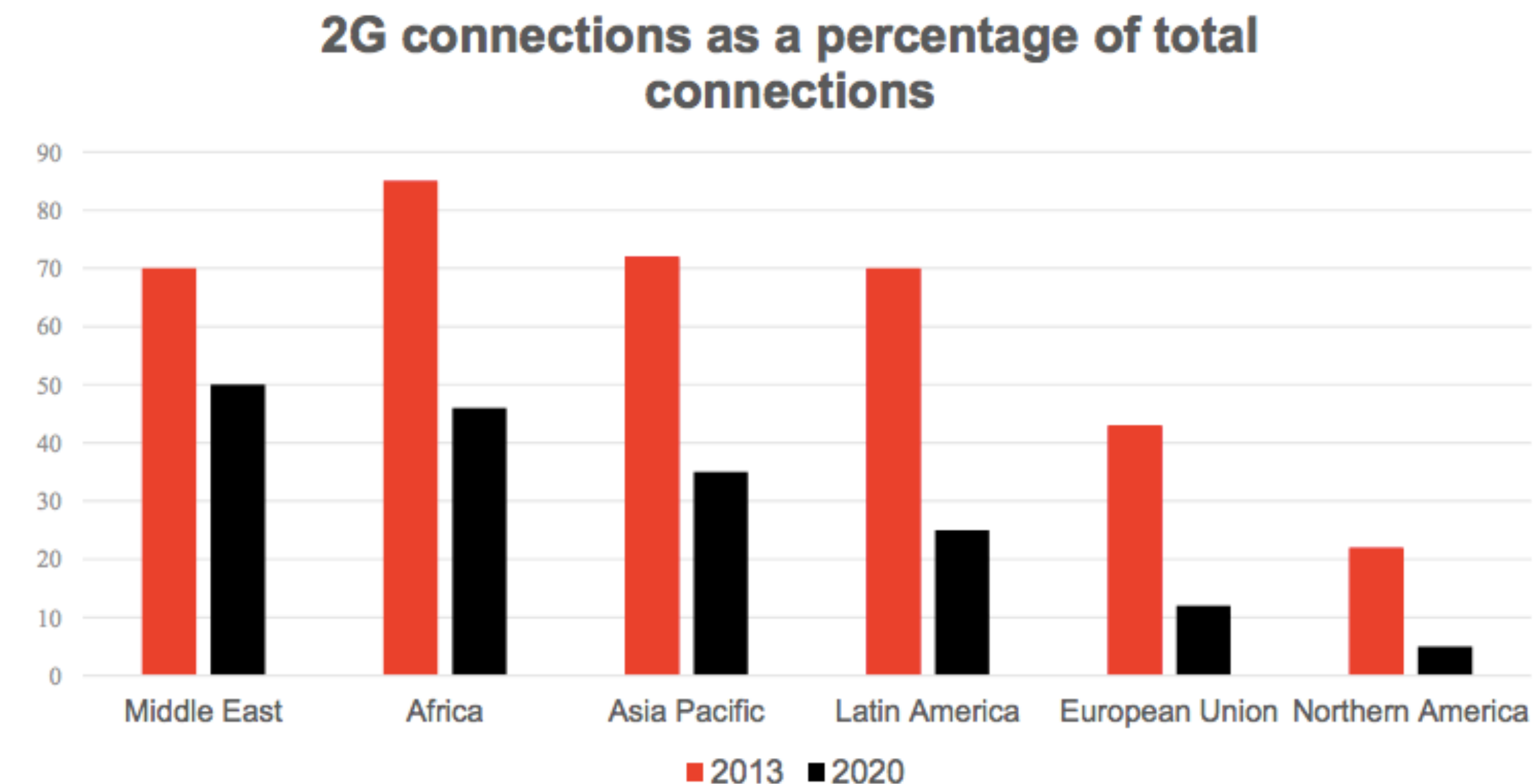


[adapted from Per Hjalmar Lehne, Telenor, 2000]



The challenge of area coverage

- Land area Norway, 385.178 km² - 7500 basestasjons
 - <http://www.mynewsdesk.com/no/telenor/pressreleases/sjekk-naar-du-faar-4g-der-du-bor-1399662>
- Tanzania 947,303 km² = 3 x Norway,
- Mali 1.240.000 km² = 4 x Norway
- DR Congo 2.345.000 km² = 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:

- Date for presentation: **20Oct2018**
- Prepare questions to your papers http://its-wiki.no/wiki/TEK5110/List_of_papers

