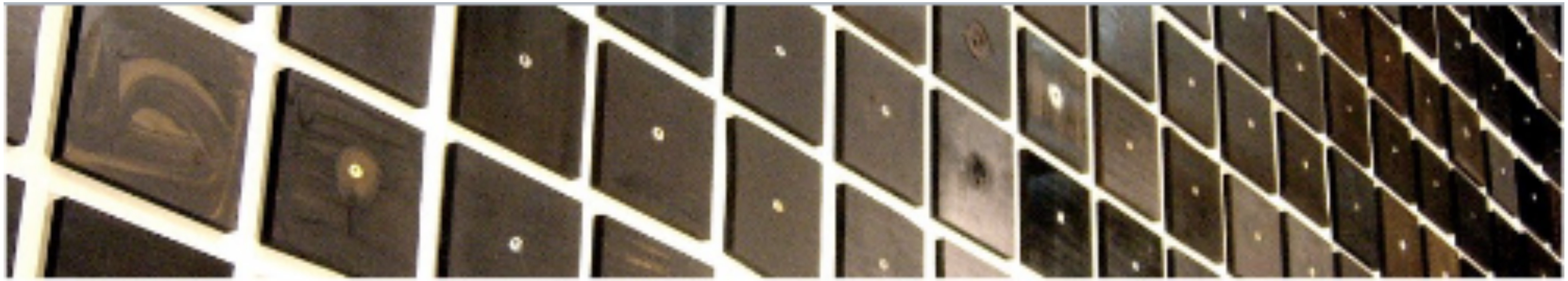

UiO : Universitetet i Oslo

TEK5110

L3 Propagation Characteristics

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Current	Basic Internet Foundation, University Graduate Studies (UNIK), University of Oslo (UiO), Movation AS
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| 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?

Lecture plan is detailed on:
its-wiki.no/wiki/TEK5110

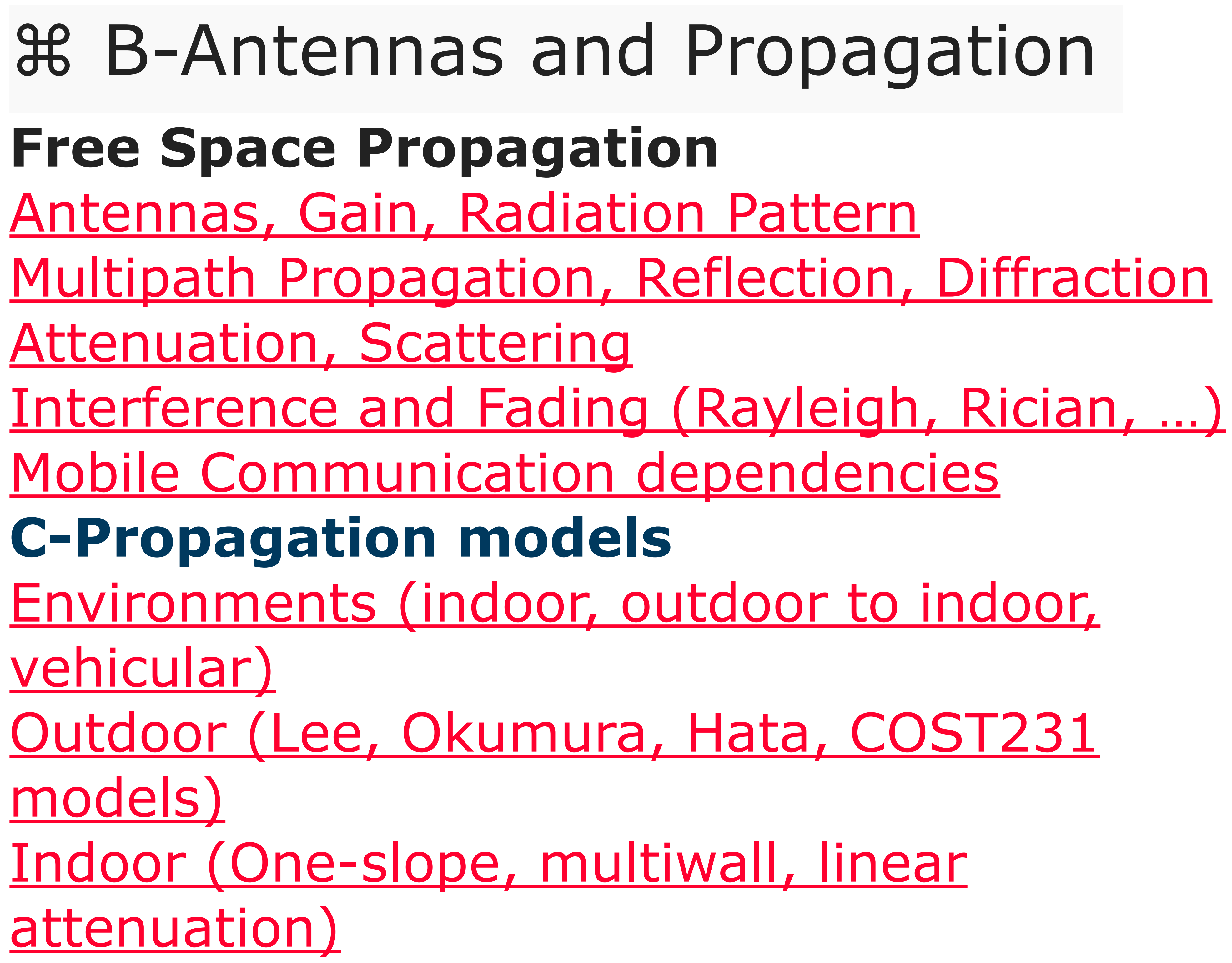
TEK5110 - Lecture Plan

- 28Aug - L1 Intro
- 4Sep - L2 Radio
- 11Sep - L3 Propagation Characteristics
- 18Sep - L4 Real time monitoring
- 25Sep - no lecture presenation preparation
- 2Oct - Presentations
- 9Oct - Maghsoud (Josef travel)
- 16Oct - Group work (Josef/ Maghsoud travel)
- 23Oct
- 30Oct
- 6Nov
- 13Nov
- 20Nov
- 27Nov
- 4Dec
- 11Dec Exam

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

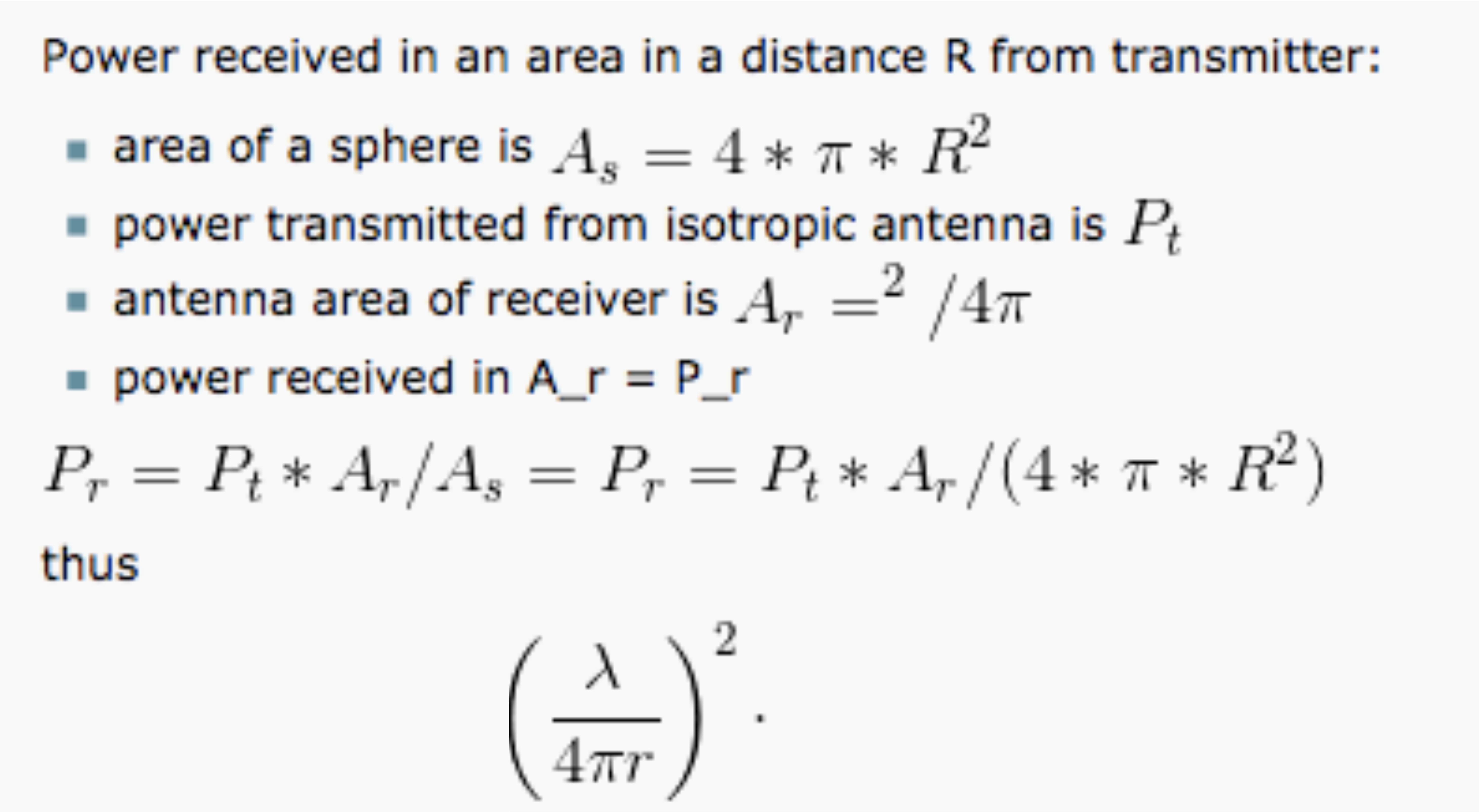
C-Propagation models

Environments (indoor, outdoor to indoor, vehicular)
Outdoor (Lee, Okumura, Hata, COST231 models)
Indoor (One-slope, multiwall, linear attenuation)

Free Space Propagation Equation

Free space propagation

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



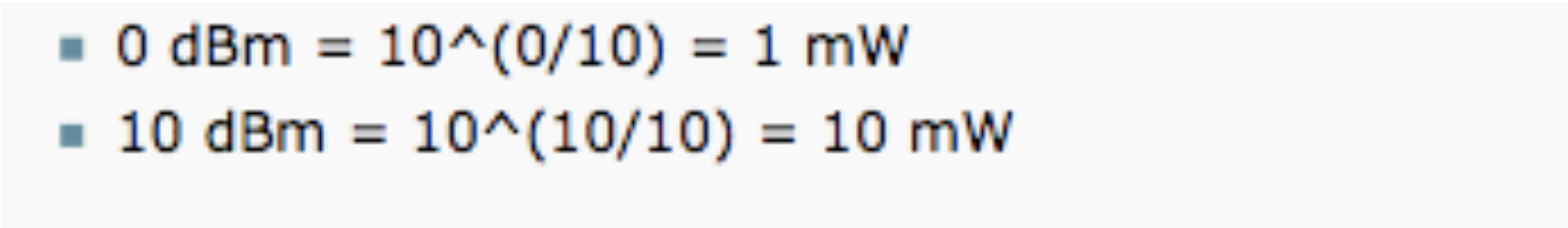
Power received in an area in a distance R from transmitter:

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

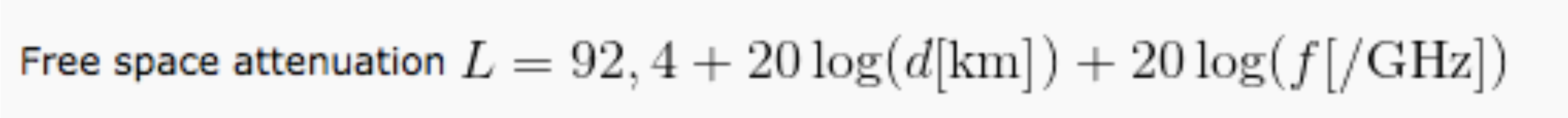
$$P_r = P_t * A_r / A_s = P_r = P_t * A_r / (4 * \pi * R^2)$$

thus

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



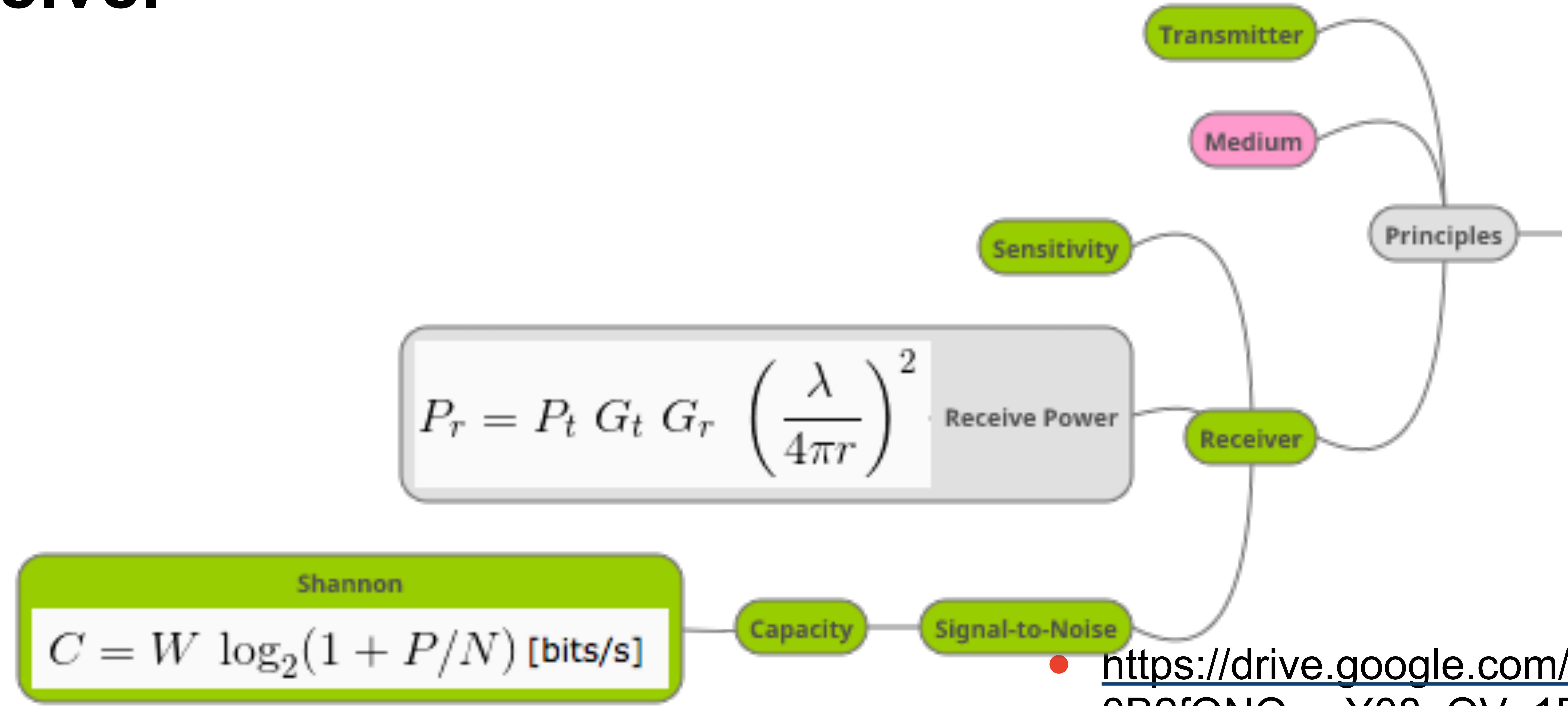
- 0 dBm = 10^(0/10) = 1 mW
- 10 dBm = 10^(10/10) = 10 mW



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)

Receiver



Transmitter

Medium

Principles

Sensitivity

Receive Power

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

Receiver

Shannon

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

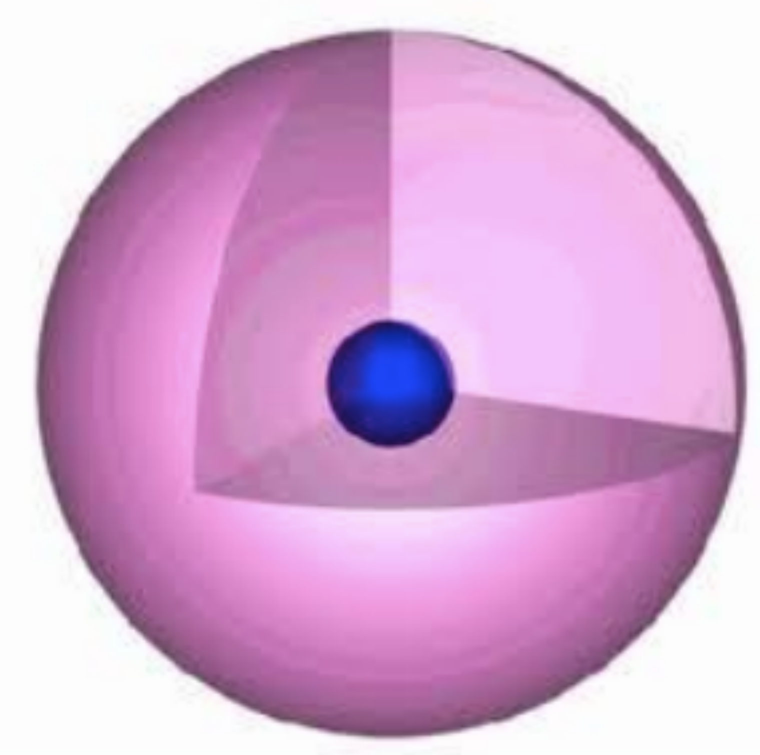
Capacity

Signal-to-Noise

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

Antennas

B2-Antenna Basics



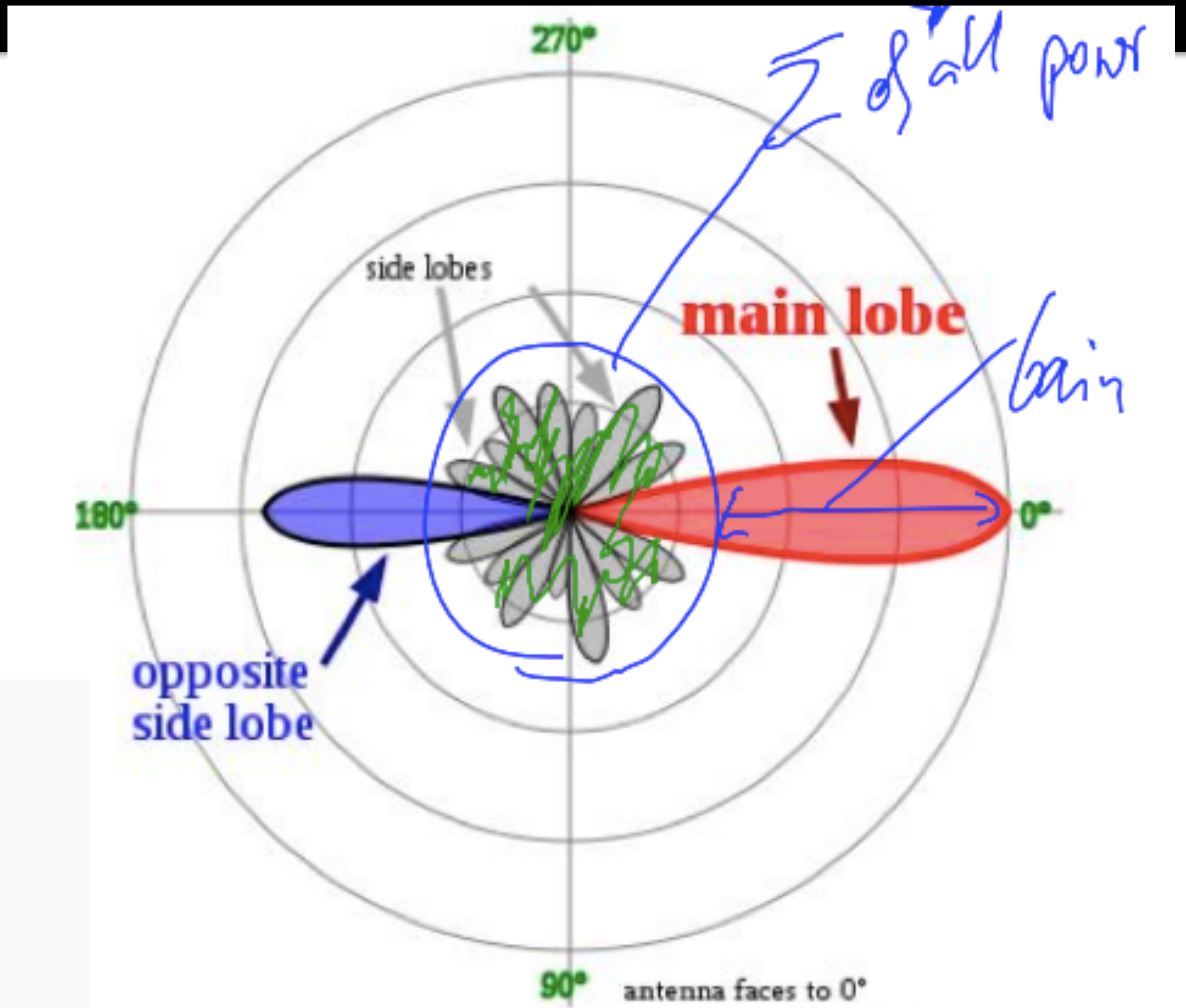
- The gain is the radiation intensity of an antenna into the main direction as compared to an isotropic antenna (omnidirectional).
- For a perfect antenna without any losses, the gain *G* will be identical to the directivity *D*.

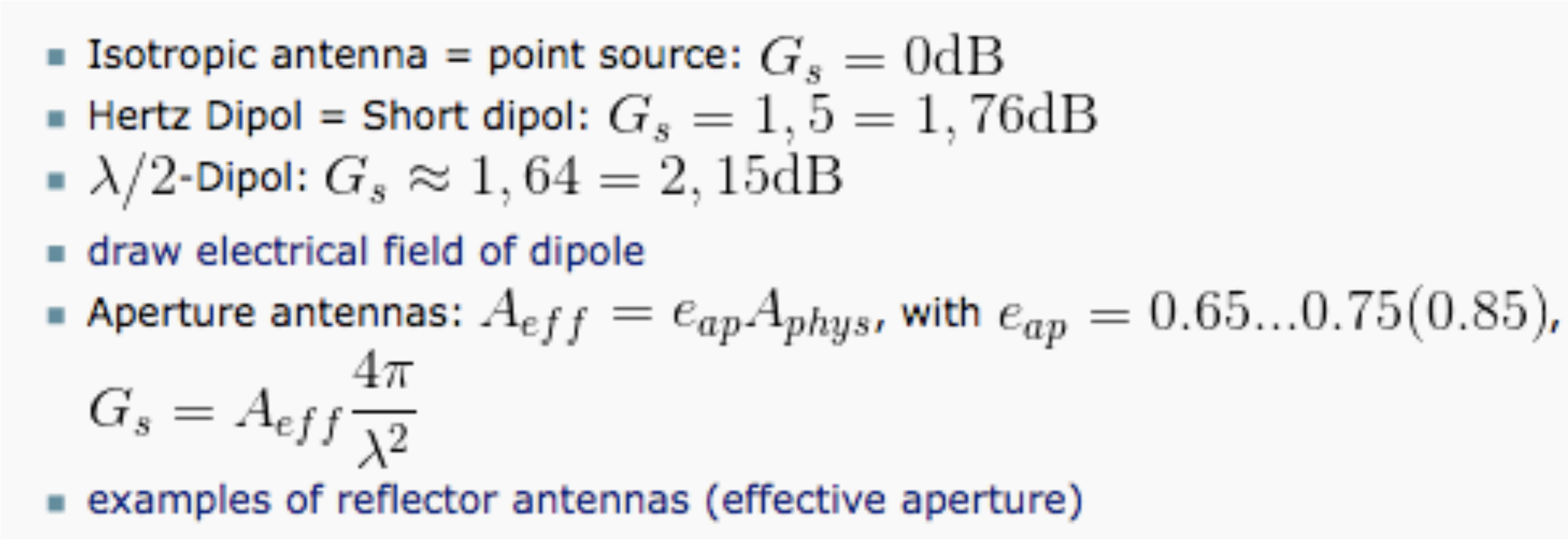
$$D = D_{main}/D_{isotropic}$$

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

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 $e_{ap} = 0.65...0.75(0.85)$,

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

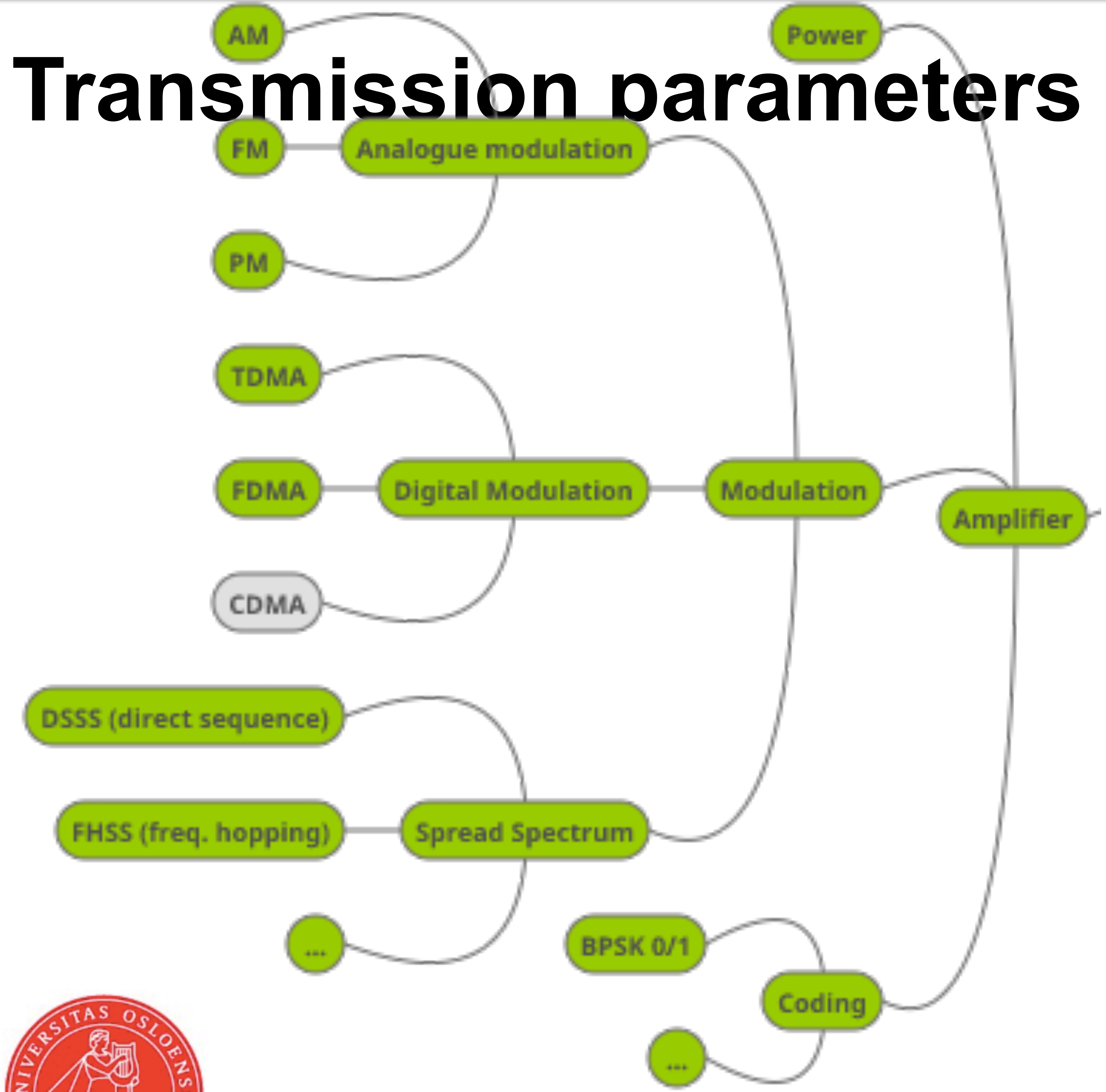
- examples of reflector antennas (effective aperture)

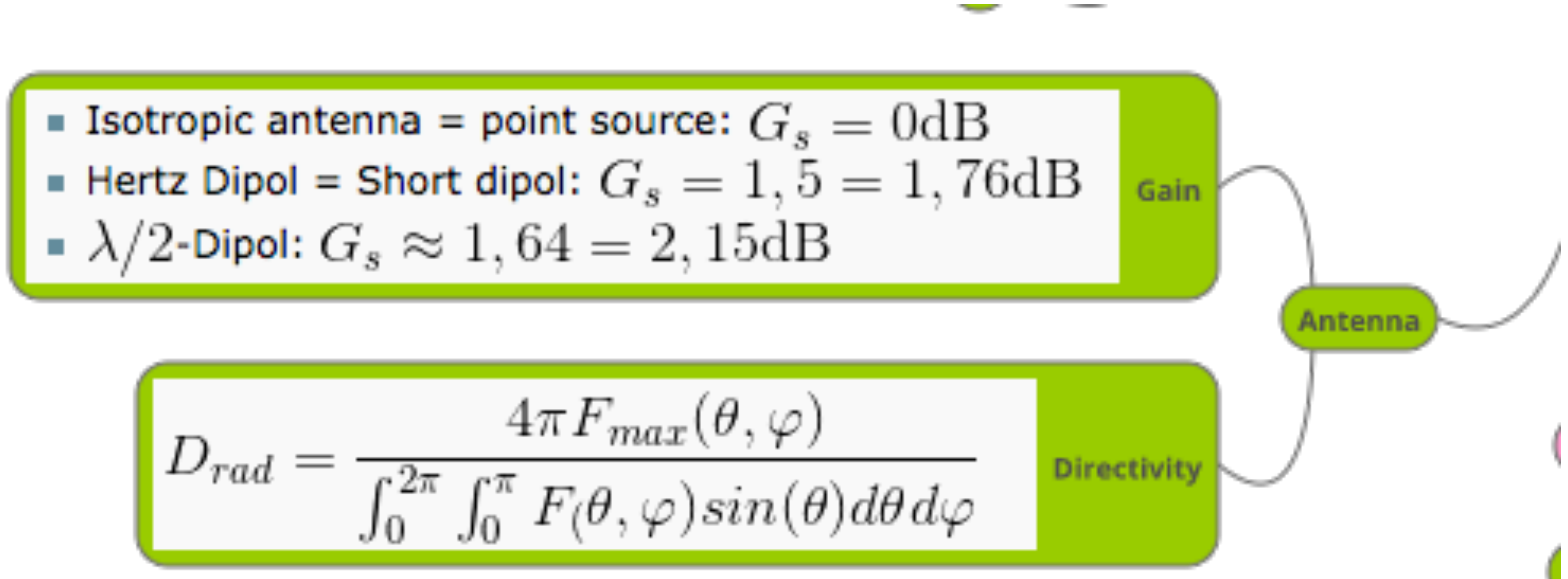
For more info, see intro course: http://www.cv.nrao.edu/course/astr534/AntennaTheory.html

- Media:Antennas_for_communications_Haavard.pdf (by Håvard Austad)

Transmission parameters

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





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

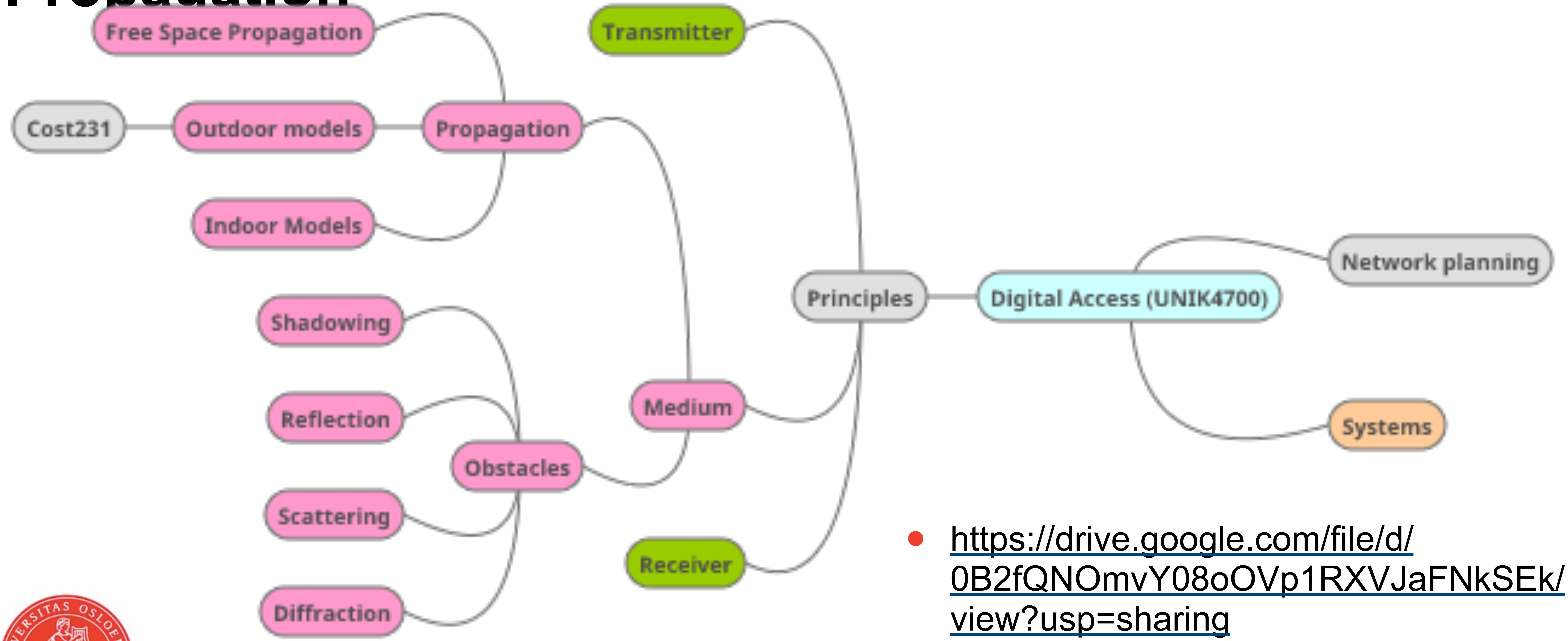
Antenna Questions

- 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

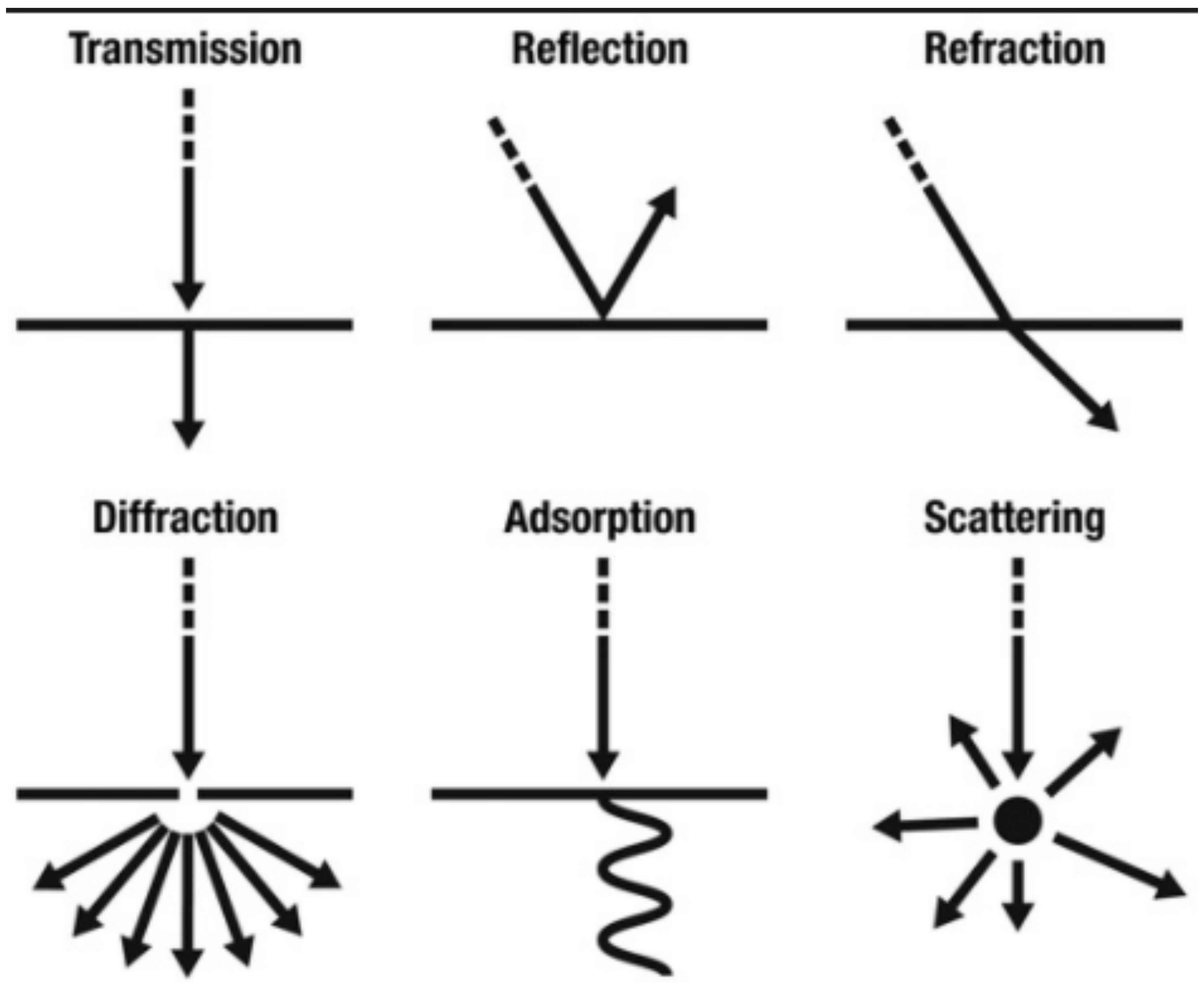
Propagation



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

Scattering, Reflection, Diffraction

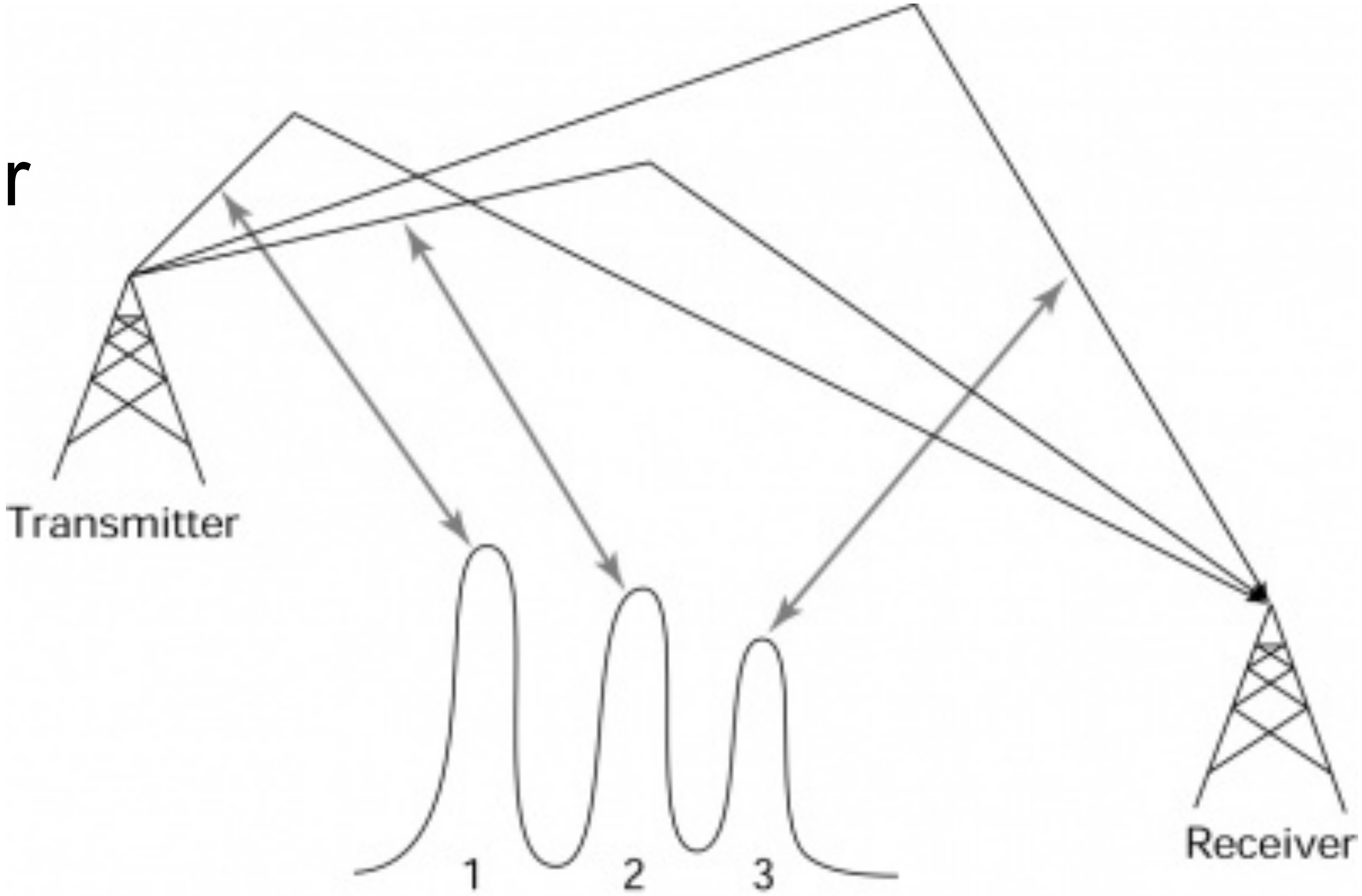
- Reflection
  - wave hits smooth surface
  - dimension >> lambda
  - typical: buildings, walls, water
  - “ideal” reflection: mirror
- Diffraction
  - dimension ~ lambda, or
  - edges (roof top)
  - bending wave
- Scattering
  - dimension << lambda
  - spread out energy



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

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

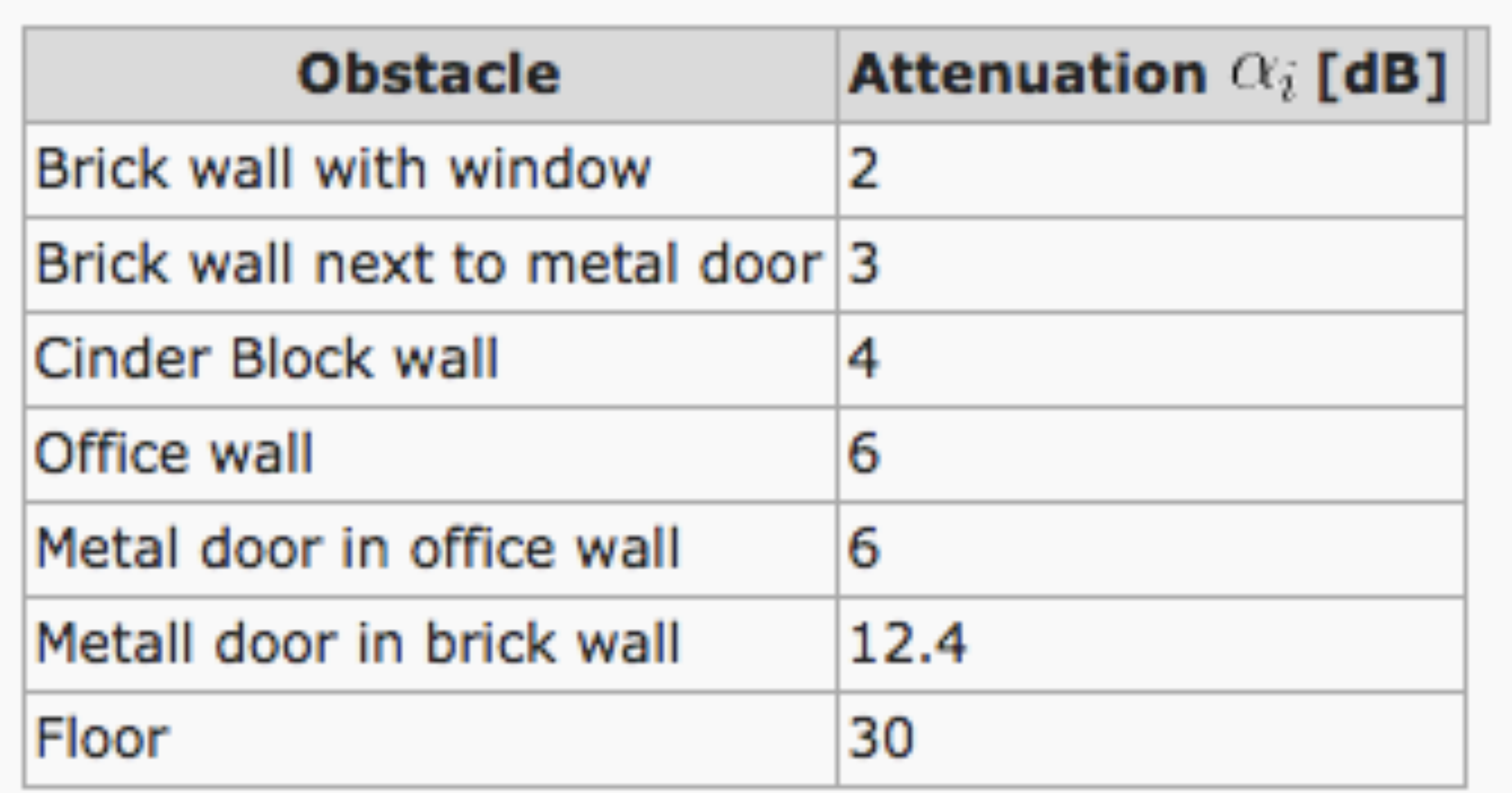
Attenuation

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

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

- Q: Relation between fading margin and receiver sensitivity?

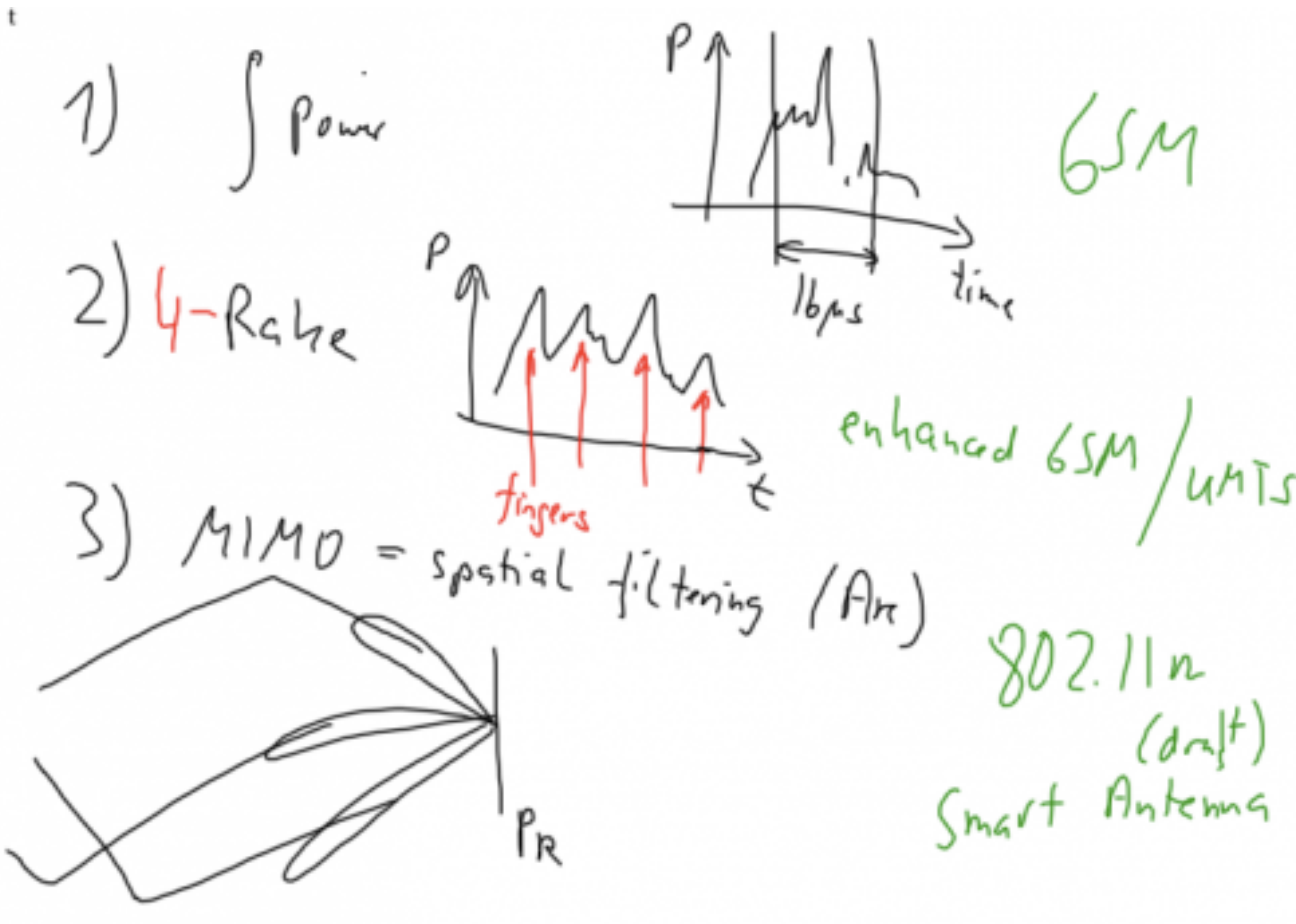
2.4 GHz attenuation, source: Hydra Deliverable D5.4



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

Receiver characteristics - impulse responses

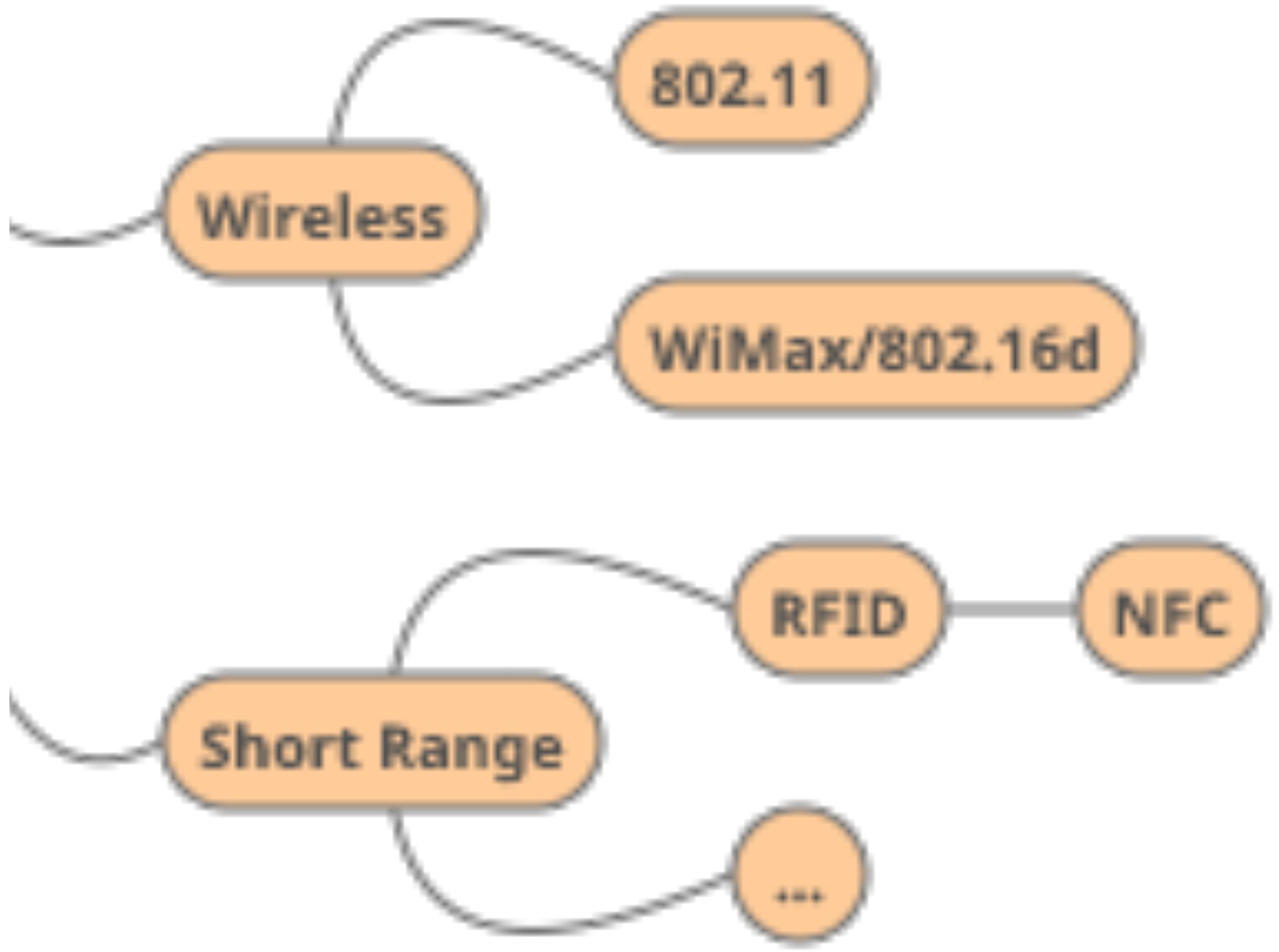
- Sliding 16 mu s window and integration of power in this window (typical GSM)
- Rake receiver, where each finger of the receiver points to one reflection (typical enhanced GSM, UMTS)
- MIMO (Multiple input, multiple output) or smart antenna arrays. Spatial filtering, with radiation from different directions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

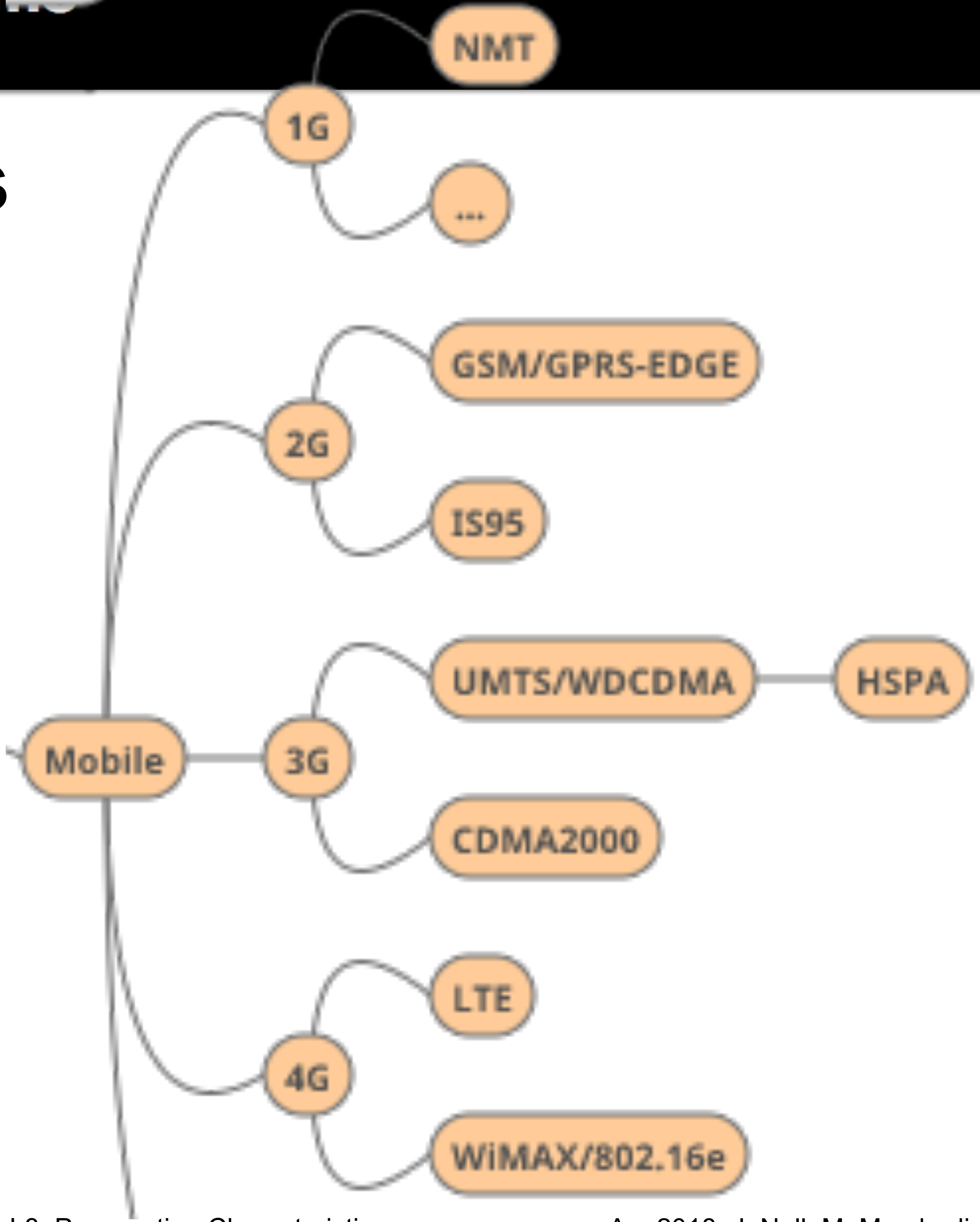


Mobile Systems and Propagation Characteristics

Mobile and Wireless Systems

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





ITU-R propagation scenarios

- indoor, outdoor to indoor, vehicular

Typical Propagation parameters

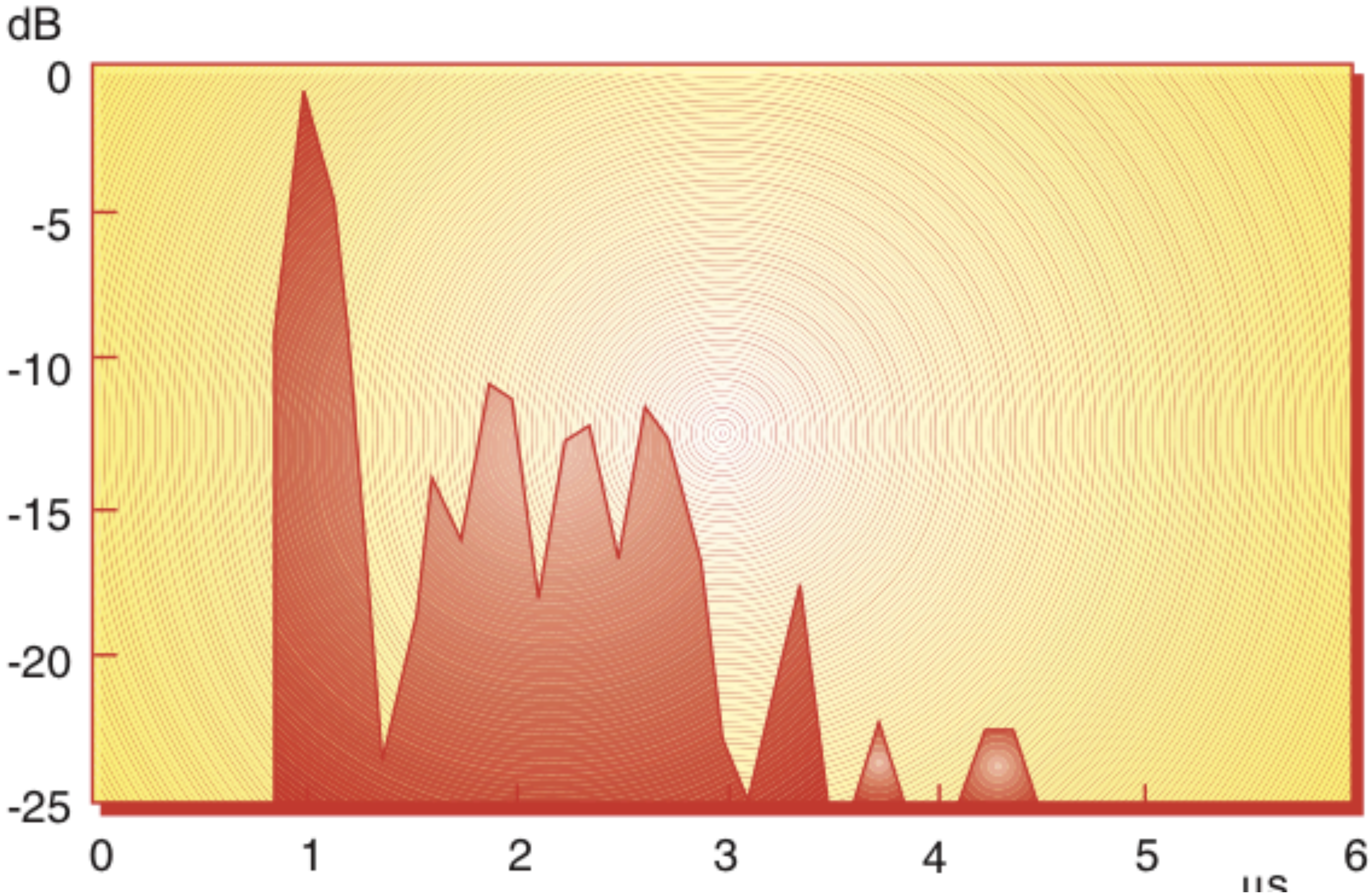
	Radio coverage [km^2]	Distance [km]	speed of mobile [km/h]	type of cell
Indoor office environment	0.01	0.1	3	picocell in open space environment
Pedestrian mode	4	2	3	Microcell
Vehicle	150	13	120	Macrocell

- 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
  -

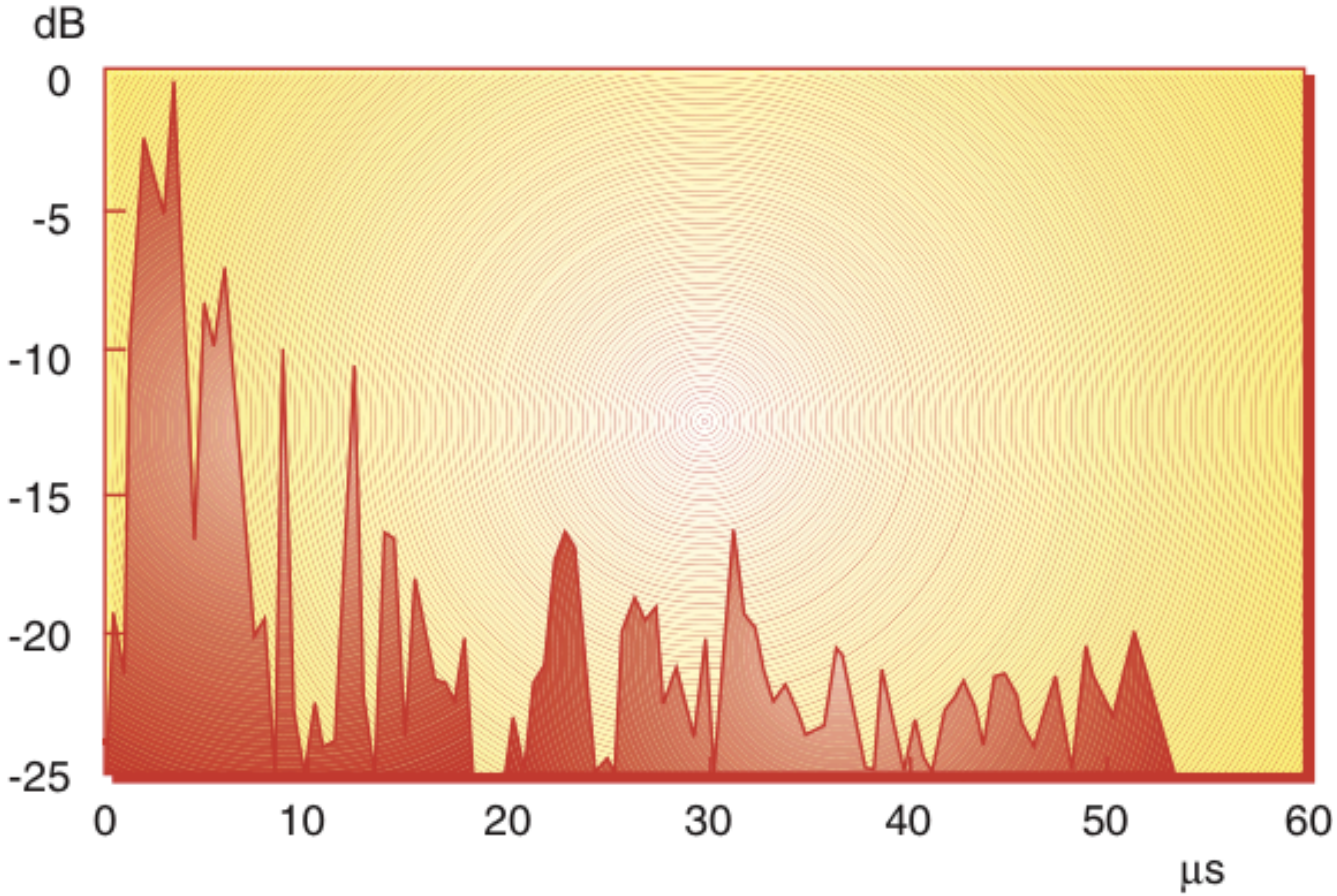


[Source:R Rækken, G. Løvnes, Telektronikk]

Impulse Response, rural farmland

- 953MHz.
- Total received power was <93dBm

- Q (all impulse responses):
  - describe characteristics of reflection
  - from delay, calculate reflection factor and free space attenuation
  -

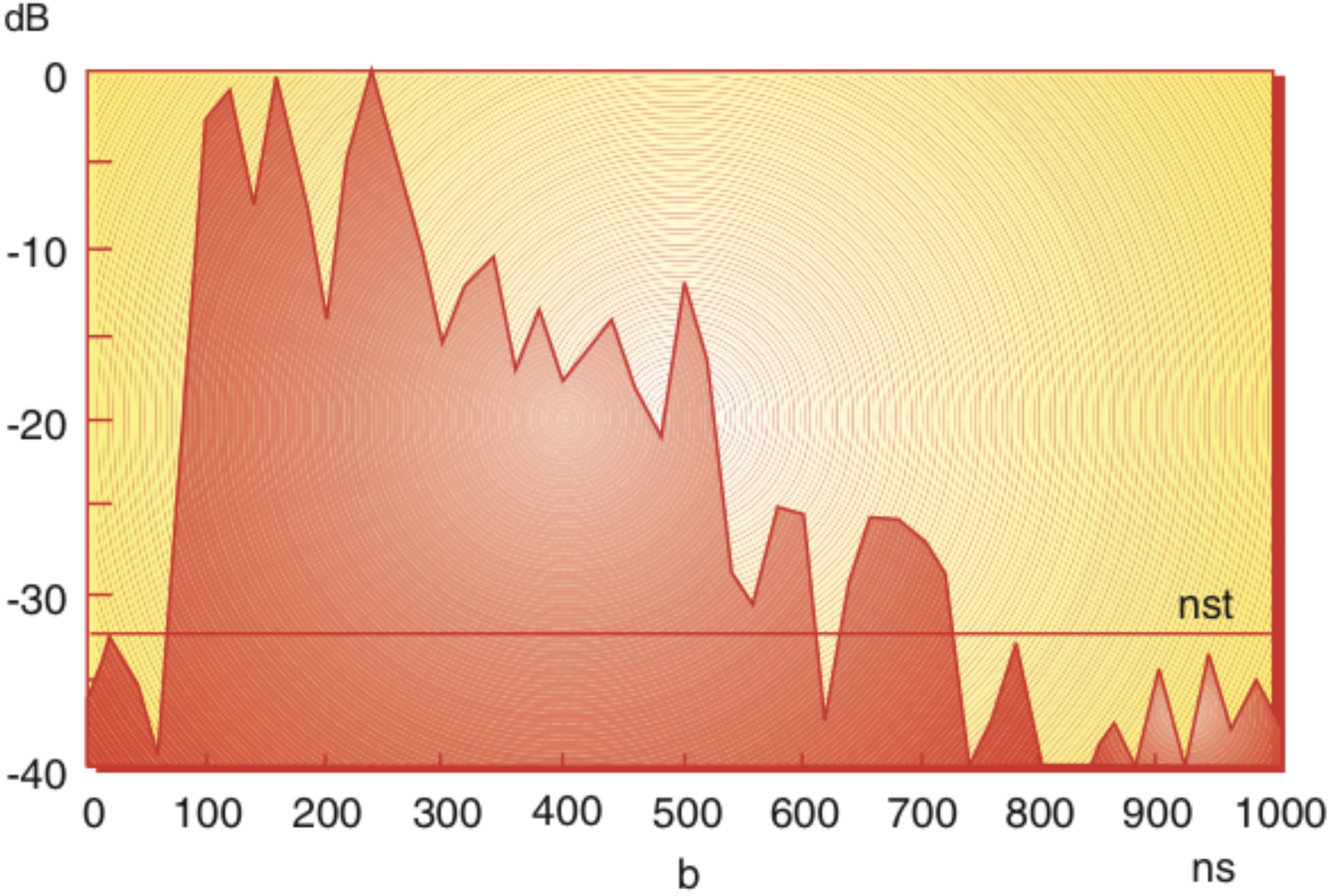


[Source:R Rækken, G. Løvnes, Telektronikk]

Impulse Response, U

- 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

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

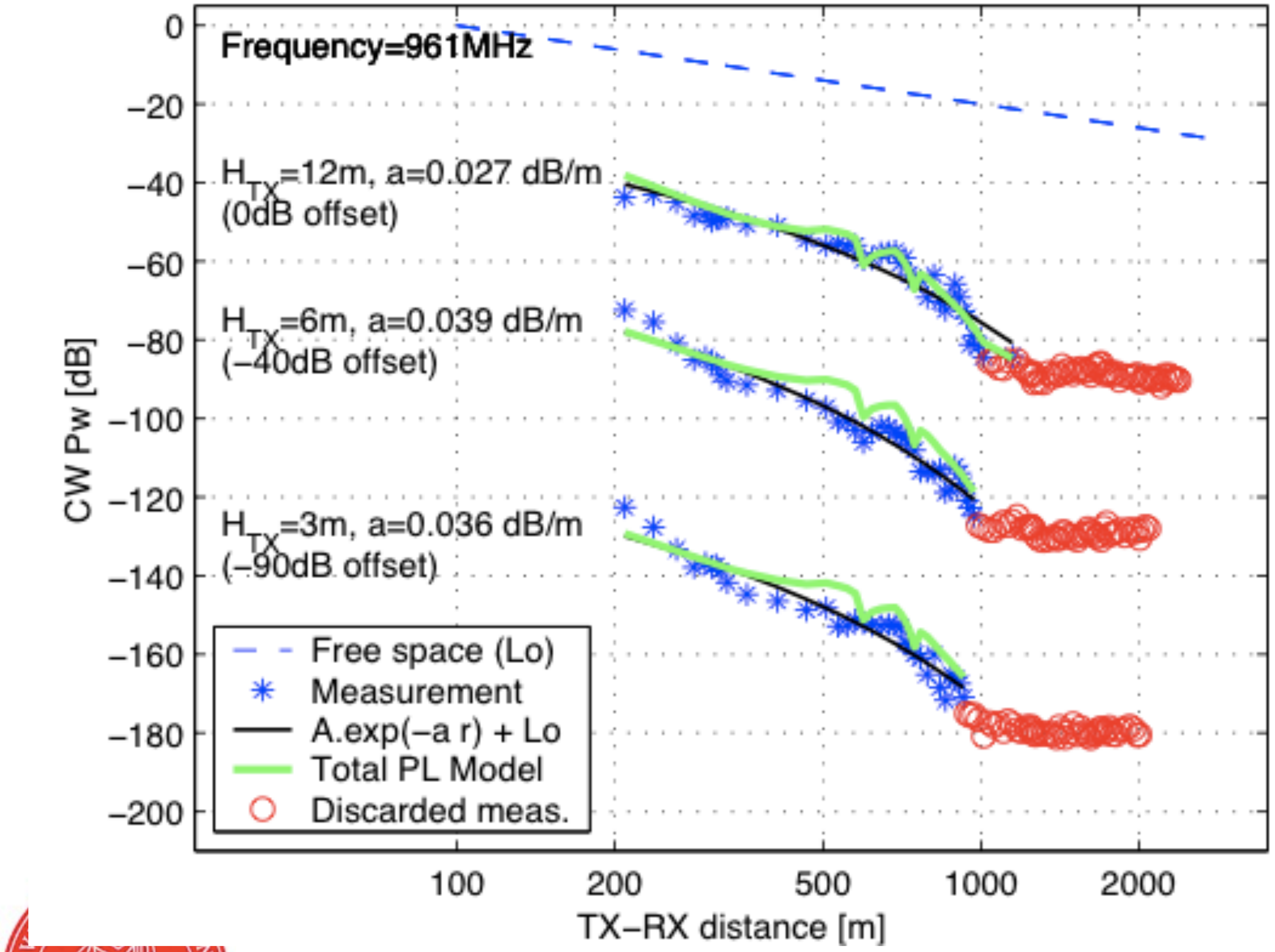
- propagation over roof tops
- assumes antennas below roof top

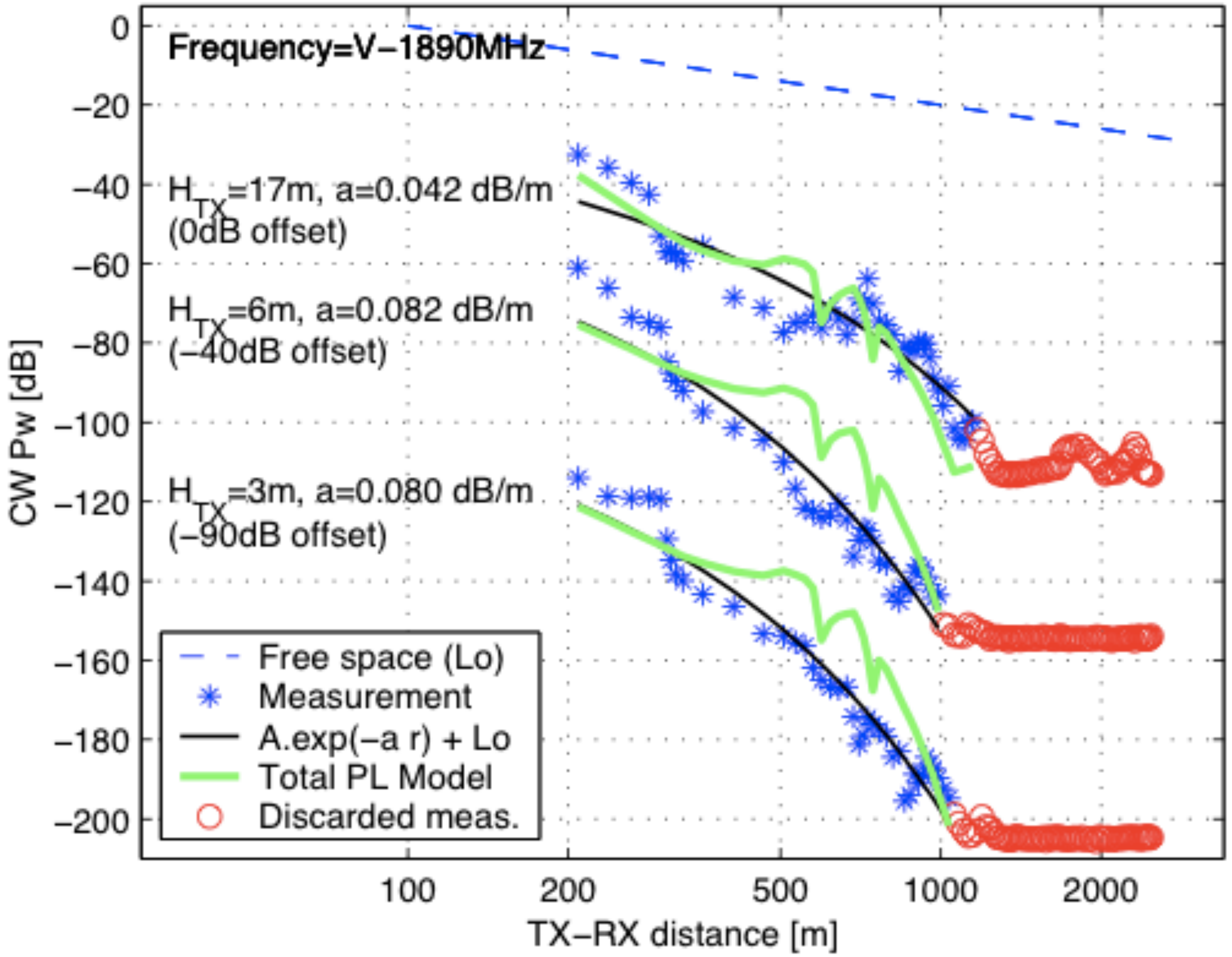
ETSI vehicular

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

- 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, 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… 3000 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

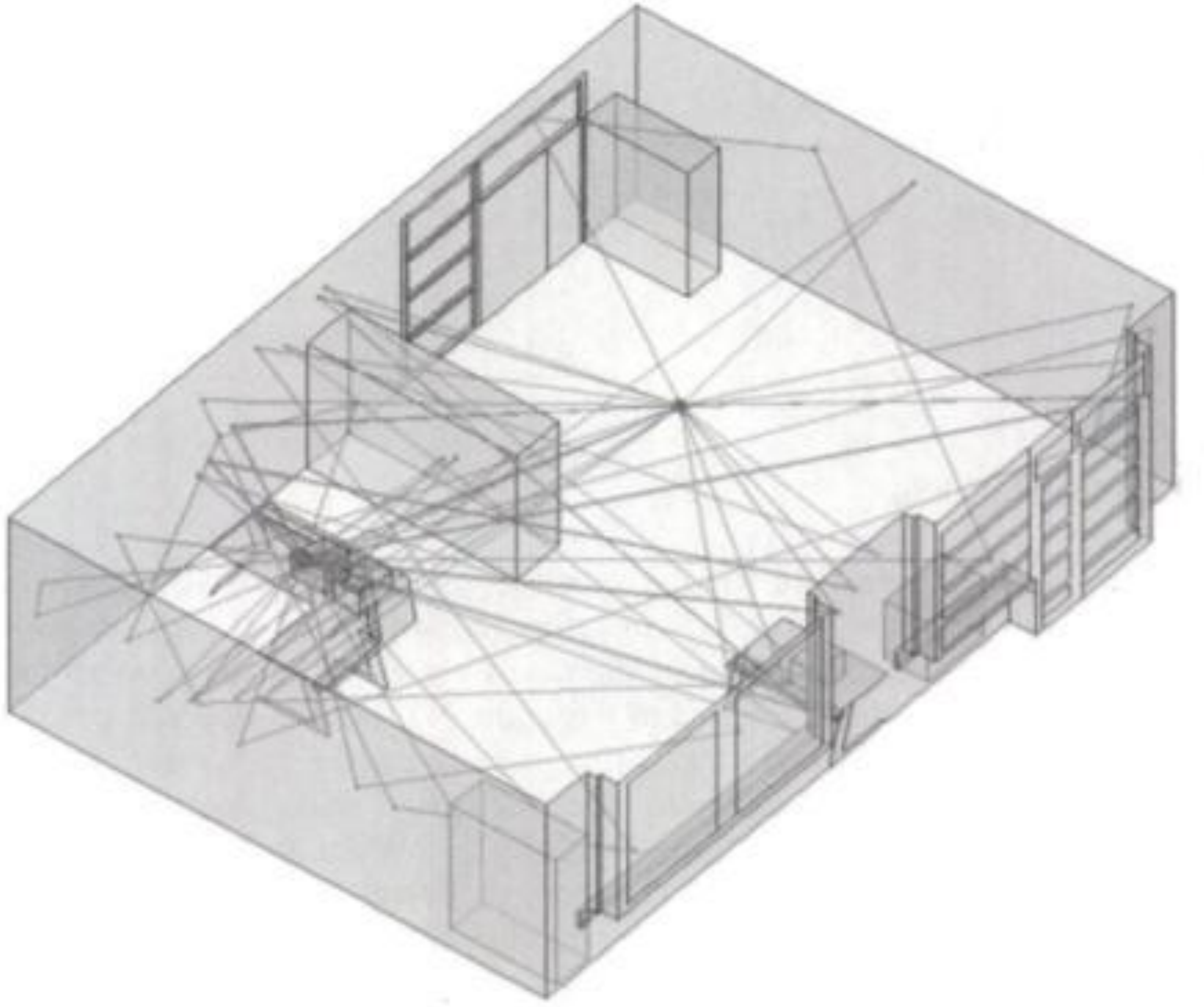
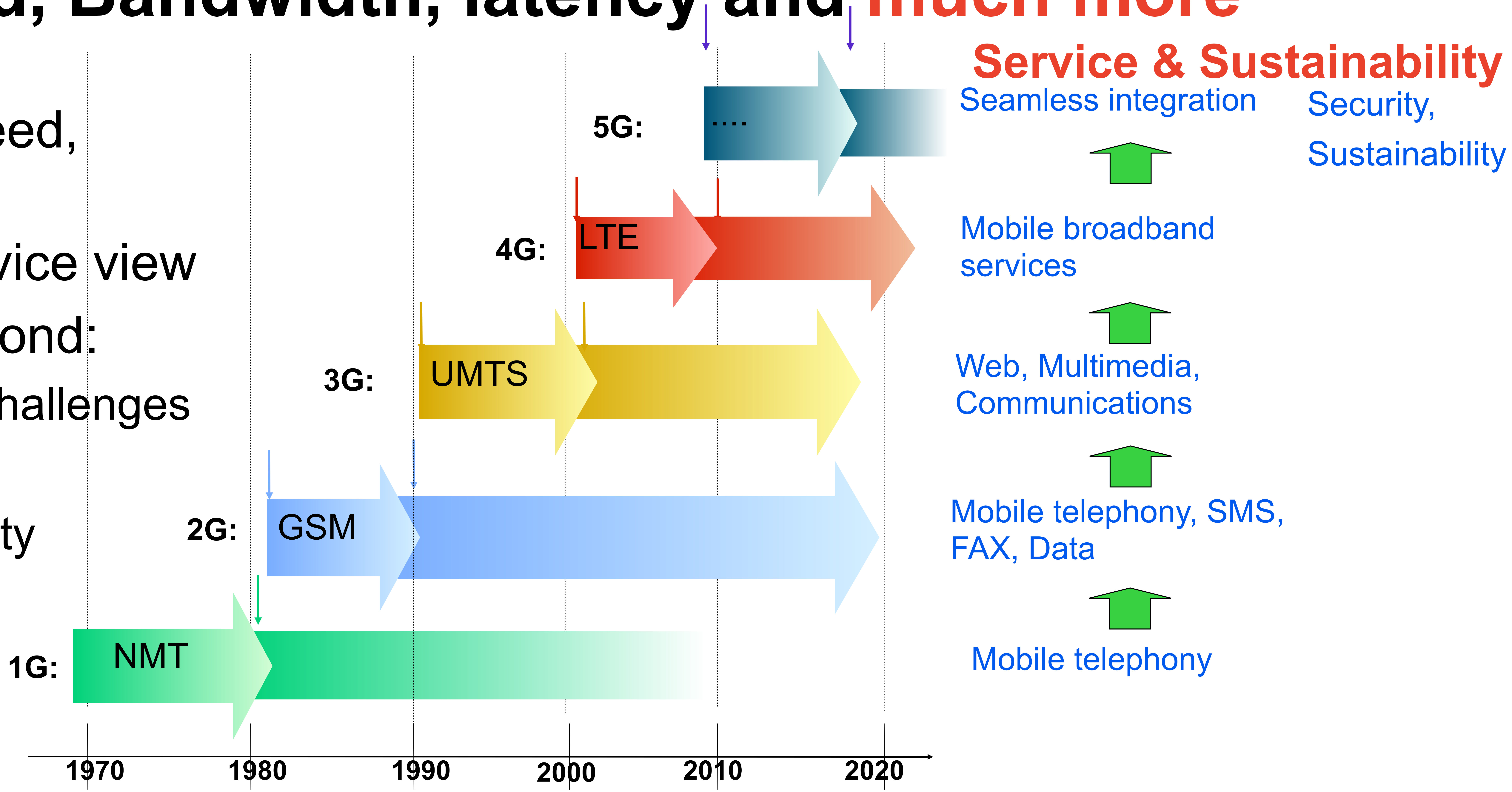


Fig. 7.26. Ray tracing in indoor environment

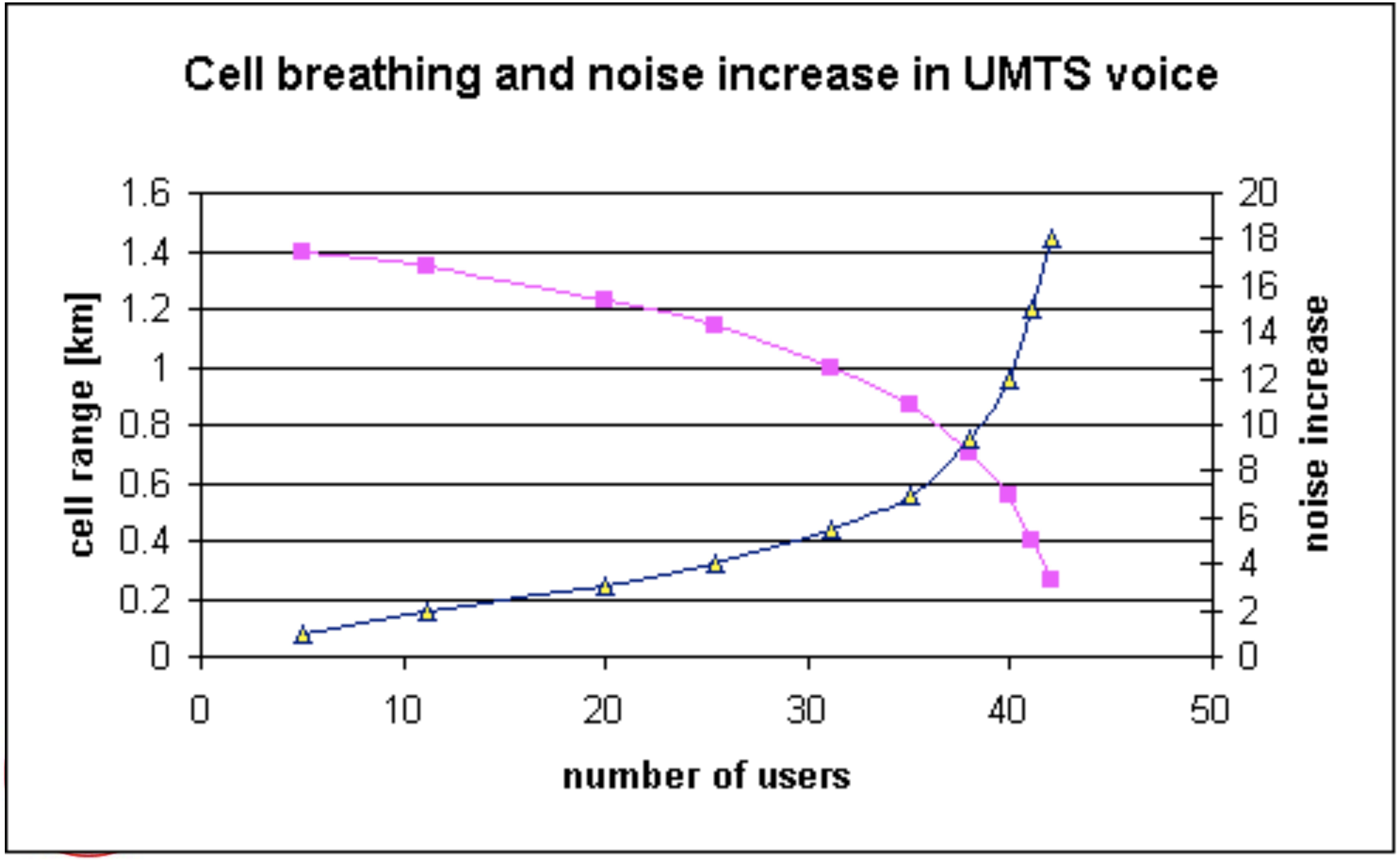
5G: Speed, Bandwidth, latency and much more

- 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 3G - “Cell breathing”



(Source: Eurescom P921, D2)

Network refarming

- Mobile frequencies
- GSM bands in 800 – 900 MHz and 1800 – 1900 MHz
- UMTS bands are typically within the 1900/2100 MHz frequencies;
- LTE is found at (450)/700/1900/2100/2400/2650 MHz in the spectrum.

- Refarming: new frequency distribution for 2G, 3G, 4G
  - ➡ What is the optimum combination?

Refarming case study (Sweden 1800 MHz)

- 2x10MHz renewed for each incumbent to ensure service continuity of 2G GSM service;
  - ➡ Restructured the band into 5MHz blocks, making it fit for UMTS and
  - ➡ other technologies that could co-exist with GSM & UMTS;
- Vacant spectrum was auctioned, technology & service neutral;
- A newly formed joint-venture by several incumbents to consolidate their spectrum assets and operation in the band.

- Full case study can be found here: http://www.gsma.com/spectrum/wpcontent/uploads/2012/07/refarmingcasestudysweden900mhz20111129.pdf/

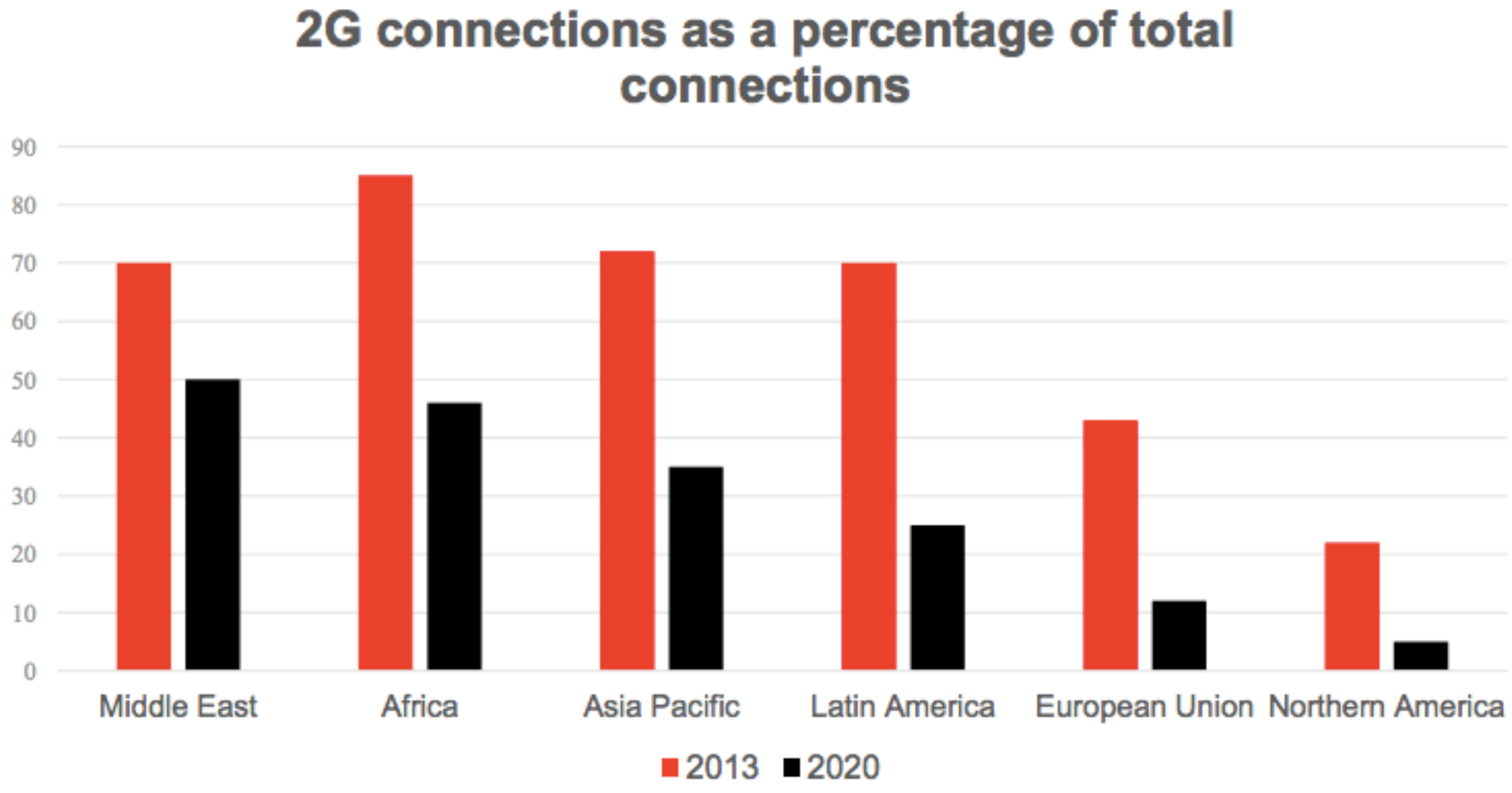
[Source: Shola Sanni, GSMA]

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:

- Date for presentation: **2Oct2018**
- Prepare questions to your papers http://its-wiki.no/wiki/TEK5110/List_of_papers