Telenor 7.500 base stations ~ 4.5 B NOK

Africa

Revenue 2 US$/month

Tanzania 3x
Mali 4x
DRC Congo 8x

f
BW
noise/interference

) range
capacity

$E, H \sim \frac{1}{r}$ $r = \text{distance}$

$\vec{P} = \vec{E} \times \vec{H} \sim \frac{1}{r^2}$

$$c = f\lambda \qquad c = 3E8\ m/s$$

## Wave propagation and absorption mechanism

| Band | Frequency | Wavelength | Propagation via |
|---|---|---|---|
| Very low frequency, VLF | 3-30 kHz | 100 - 10 km | Guided between the earth and the ionosphere. |
| Low frequency, LF | 30 - 300 kHz | 10 - 1 km | Guided between the earth and the D layer of the ionosphere. Surfac |
| Medium frequency, MF | 300 - 3000 kHz | 1000 - 100 m | Surface waves.E, F layer ionospheric refraction at night, when D laye |
| High frequency, HF (short wave) | 3-30 MHz | 100-10 m | E layer ionospheric refraction. F1, F2 layer ionospheric refraction. |
| Very high frequency, VHF | 30-300 MHz | 10-1 m | Sporadic E propagation Extremely rare F1,F2 layer ionospheric refra activity up to 80 MHz. Generally direct wave. |
| Ultra high frequency, UHF | 300-3000 MHz | 100-10 cm | Line-of-sight propagation. Sometimes tropospheric ducting. |
| Super high frequency, SHF | 3-30 GHz | 10-1 cm | Direct wave. |
| Extremely high frequency, EHF | 30-300 GHz | 10-1 mm | Direct wave limited by absorption. |

The frequencies which we use for mobile communications are ranging from 450 MHz (ICE), the old TV bands, 800-900 MHz (G MHz (UMTS), 2400 MHz (Wifi), 2650 MHz (LTE), and 5100 MHz (IEEE802.11a..). While previously frequency band were used *refarming* started in 2012 to open for communication technologies in other bands. Examples of such refarming are $LTE_{1800}$ ind the 1800 band. Back in 2013 Apple *surprised* the European operators, as the iPhone came with LTE only in the 1800 band, and ı 2600 band.

(Source:http://en.wikipedia.org/wiki/Radio_propagation)

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

$\lambda \sim 10$ cm

| | $\lambda$ | |
|---|---|---|
| 1 GHz (800-900 MHz) | 30 cm | trunk, branches |
| 2 GHz | 15 cm ... | |
| 5 GHz | 6 cm | |


$e^{-\alpha x}$ ↑ thickness
↑ atten. coeff.

~ 20-30 dB

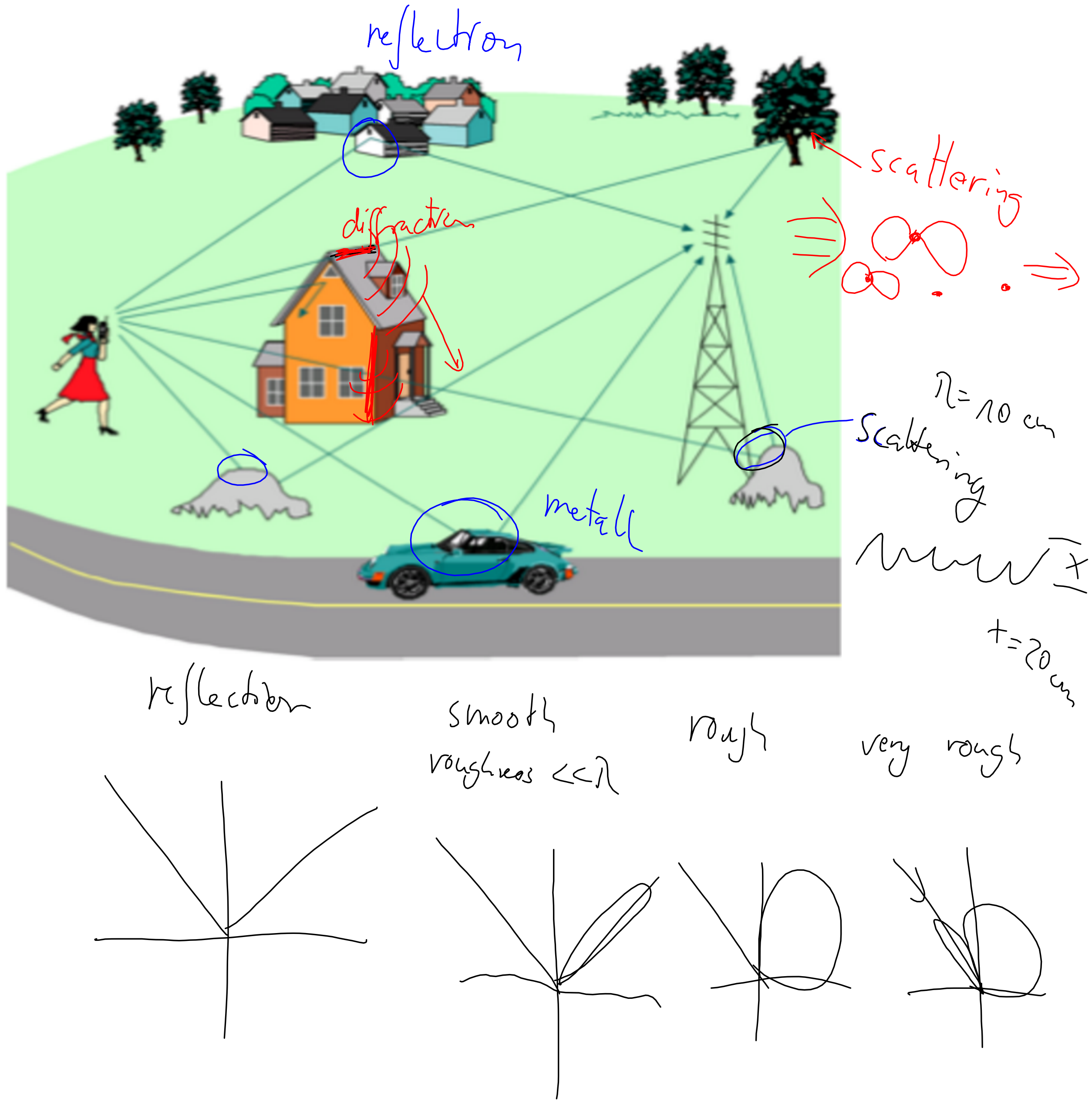
$\frac{\lambda}{r^2}$

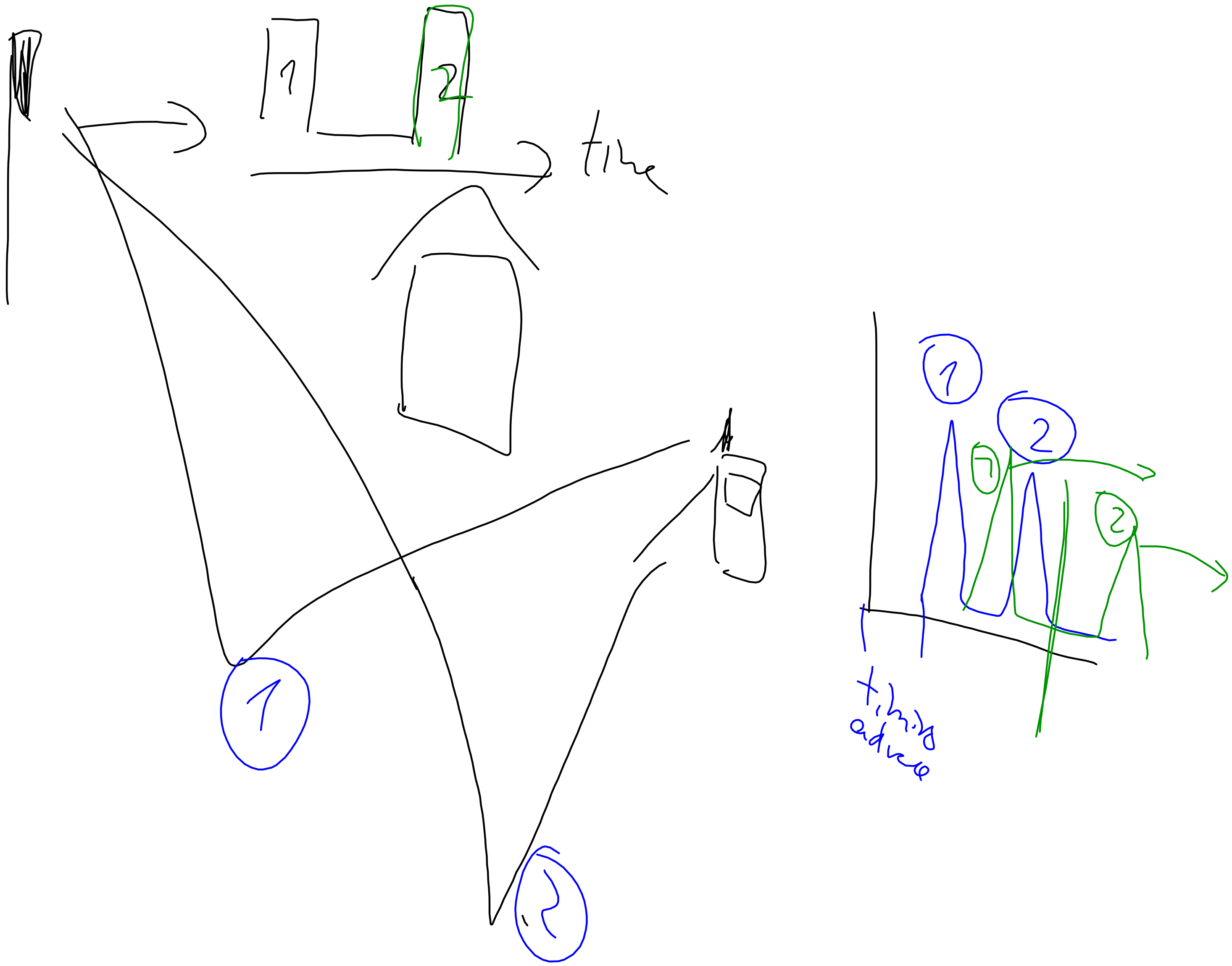
Objects:

✓ $\frac{\lambda}{10}$ < 1 cm

$\frac{\lambda}{2}$ $\lambda$ ... $2\lambda$ — 10 cm, resonance antennas

$> 2\lambda$ shadow


reflection
scattering
diffraction
λ = 10 cm
Scattering
metall
t = 20 cm
reflection
smooth
roughness << λ
rough
very rough


1
2
time
timing advance

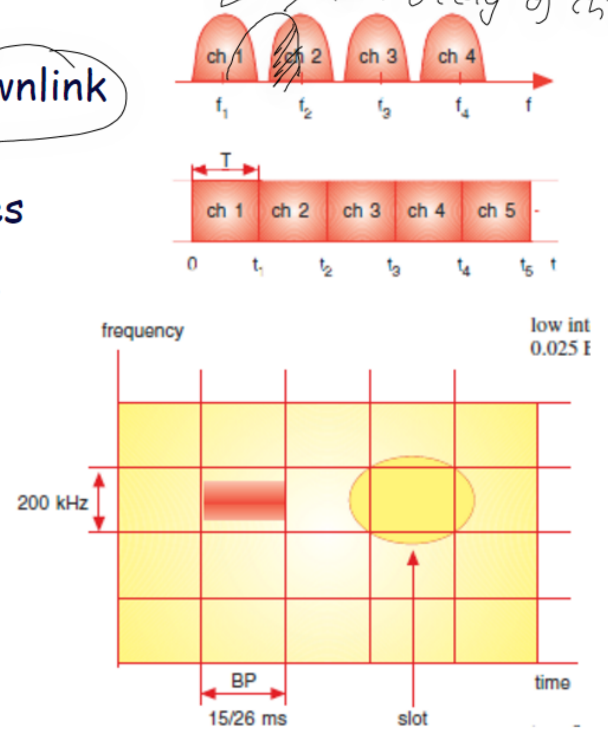
cwi.unik.no/index.php?title=Basics_of_Communication&action=slide

# Frequency And Time Division Multiplexing

- Time domain, e.g. 8 slots in GSM
- Frequency domain, e.g. up- and downlink in specific bands FDMA / FDD
- Code division (CDM), specific codes "language"

[Source:K.E. Walter, Basics of Mobile Communications]

Multipath — time delay of ch1

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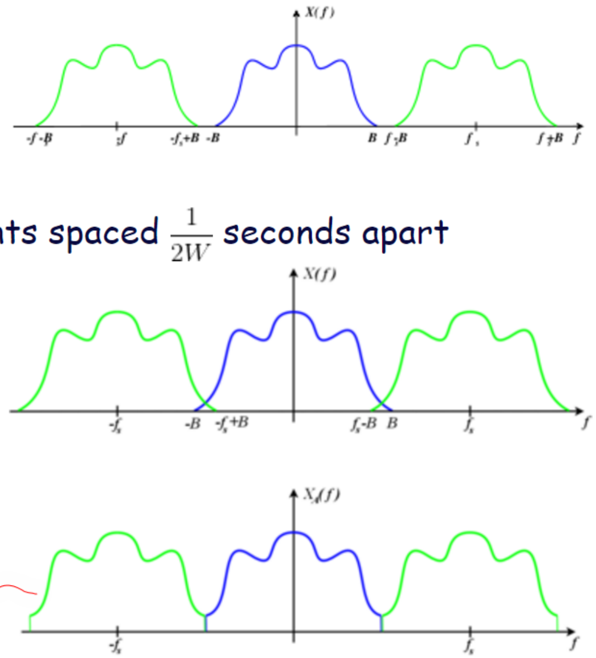
# Nyquist Theorem

- 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]



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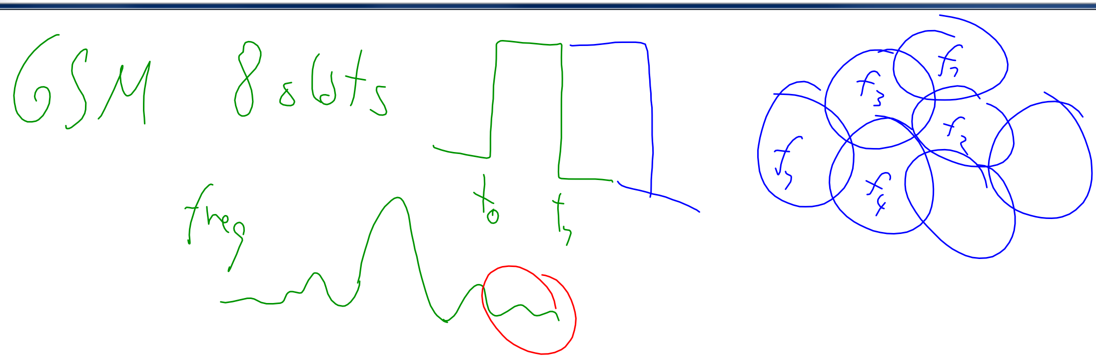

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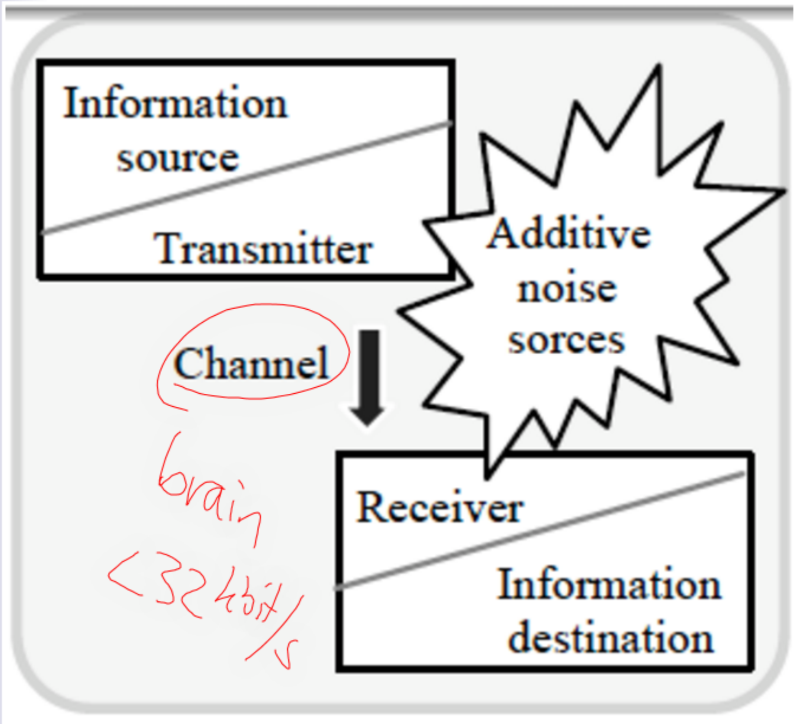
# Electromagnetic Channel

mp3 64 kbit/s
bad video 192 kbit/s
digital TV 2 Mbit/s




The radio channel is always affected by noise, which restricts the information flow to the receiver

[Source:Neelakanta et. al., Fig1.2]

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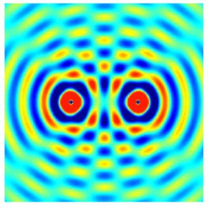
# Sources Of Noise



* Electronic parts of transmitter and receiver (components)
- Spurious electromagnetics (lines radiating on the chip)
- Fluctuations in power (switching CMOS circuits)

Radio

- In-band interference
- out-of band interference, e.g. GSM/NMT interference
- radio channel, e.g. scattering, multi-path

[Source: Wikipedia, "interference"]

Noise floor in receiver

N = Boltzmann × Bandwith × Temperatur [K]

GSM 200 kHz

UMTS 3800 kHz

802.11b 20.000 kHz

- further explanations: Telektronikk 4/95, Rækken and Løvnes, Multipath propagation

$P_{sens.} = -95\ dB_m$ WiFi

$= -106\ dB_m$ GSM

quality / price → $= -114\ dB_m$ UMTS

Noise floor in WiFi 100x in GSM

$0^\circ C = 273\ K$

293 K, 313 K – 20 °C, 40

20dB → $10^2$

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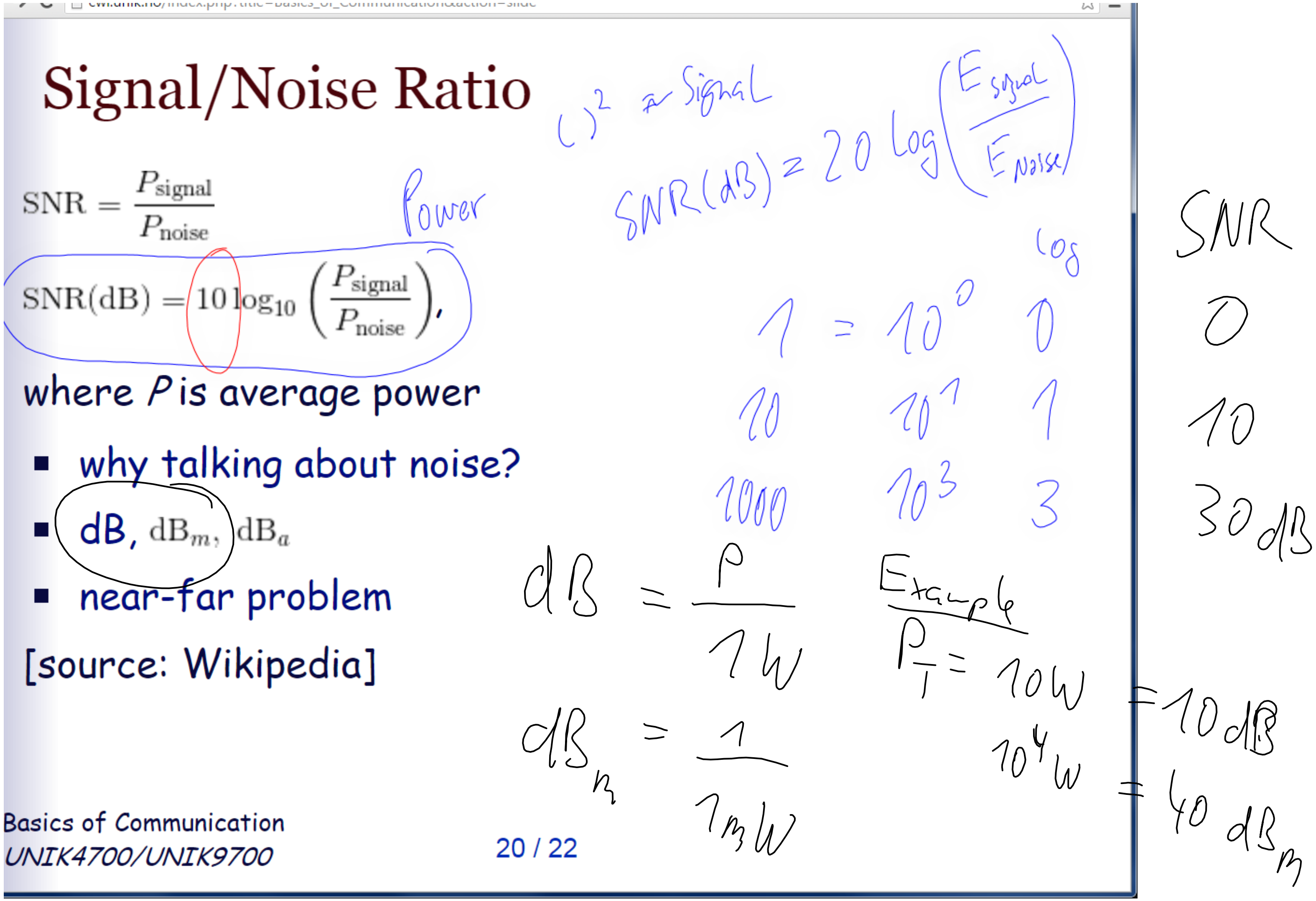


P Watt/mW

Wi-Fi 100 mW

EIRP

20 Sep Shazad Mobile Comm Dependencies

20 Sep ~~12 W~~ Zaid freq, range & type of wireless comm

Topics

- Interference
- 12Sep2014 - Wave Propagation
- 19Sep2014 - Radiation equation, Antennas
- 26Sep2014 - Propagation models: Yun Ai
- 26Sep2014 - Frequency rande and type of wireless co
- GSM and UMTS (cell breathing)
- 17Oct2014 - LTE - Solomon
- 17Oct2014 -Voice in LTE - Mikhail Yakubovich
- 10Oct2014 - WiFi long lange standards - Mohsen
- 10Oct2014 - WiMAX - Qihaoli
- 10Oct2014 - Security in NFC - Seraj

Part II assignments

13 Sep Maghsoud "5G Security"

13 Sep Simon 1G → 5G

f, BW, noise → range, cap.

Part I

**History, Now and Future**
- History
- Pioneers: Maxwell, Hertz,...
- 1G, 2G,... 5G networks
- Frequencies and Standards
- Future Challenges

**A-Basics of Communication**
- Electromagnetic Signals
- Radio Communication Principles
- Digital communication: Signal/Noise Ratio
- Signal strength and Capacity: Shannon

**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)

**D-System Comparison**