ElectroMagnetic Radiation Exposure of the Human Body

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- Background:
  - electromagnetic theory, radiation, antennas, computational electromagnetics, bio-electromagnetics, nano-electromagnetics, EMC, …
    - with measurements

Questions

- Who has no mobile phone?
- Who is living close to a high voltage power distribution line?

Goal of the lecture

- providing objective information, scientific facts, that allow any one of us to draw own conclusions
  - in my experience, in many cases the media tend to give a “colored” picture of the problem, (slightly?) biased by the opinion of the reporter, making it impossible for the layman to assess the situation correctly

- introduce a “pragmatic” view on the problem:

ALATA

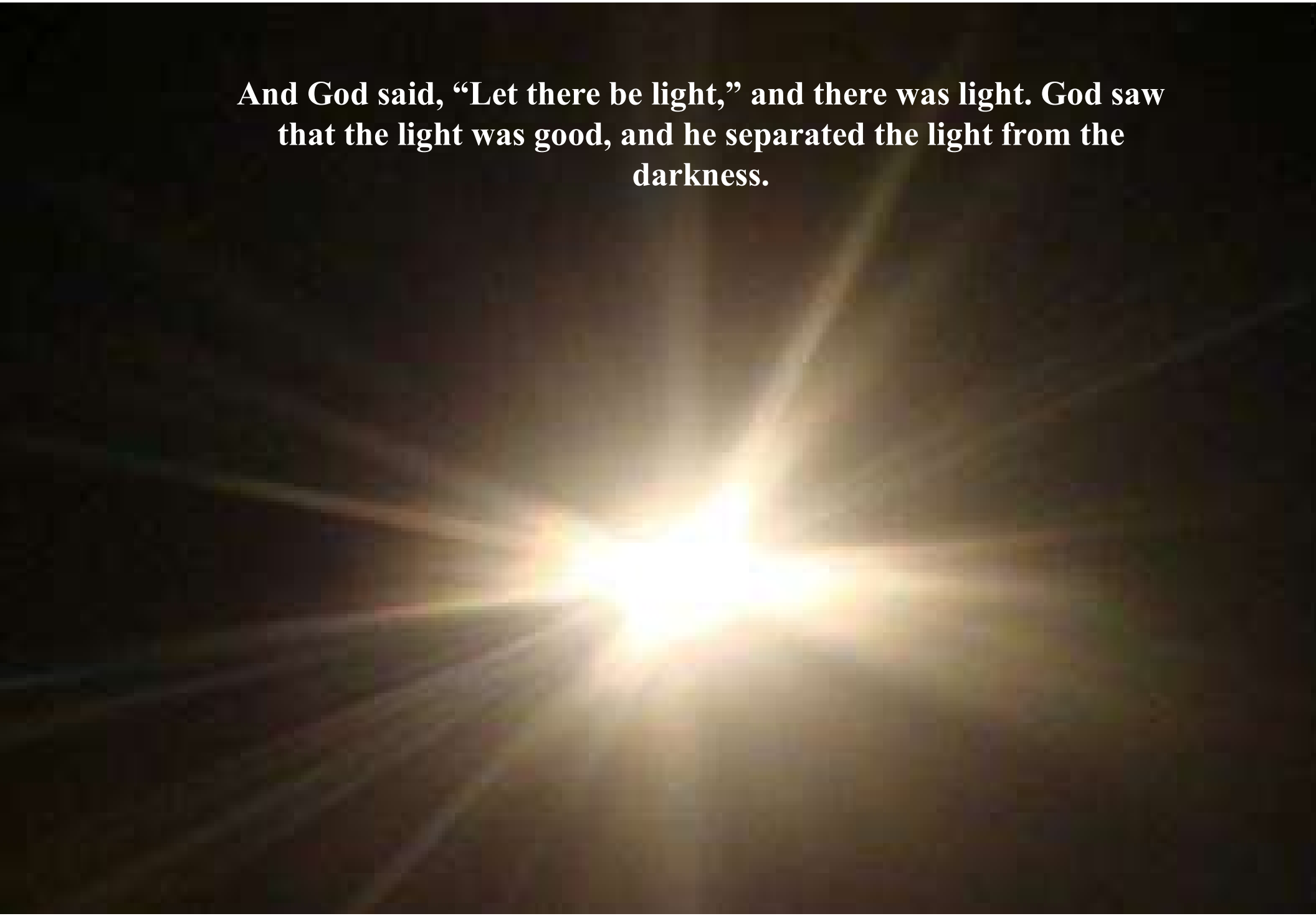
Overview

- What does physics say
- Electrical Engineering
- Why radiation
- What is important in this radiation
- Two forms of radiation
  - telecom
  - electricity distribution
- Effect on human body
- Conclusions

Physics says

- Every electrical current causes electromagnetic fields and radiation

- The crucial question is … HOW MUCH

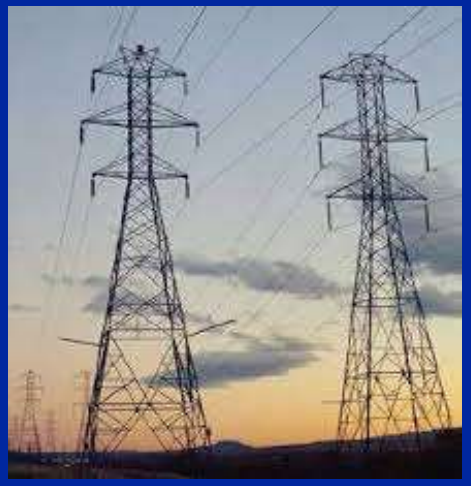

And God said, “Let there be light,” and there was light. God saw that the light was good, and he separated the light from the darkness.

Distinction EM field - radiation

- Radiation = propagating electromagnetic field
  - in many applications the field is only locally present, i.e. in the immediate neighborhood of the source (for example high voltage power distribution network)

Electrical Engineering

- **transfer energy**
  - cables
    - EM fields locally “high”
    - radiation “low”



- **transfer information**
  - cables
  - wireless
    - radiation “high”

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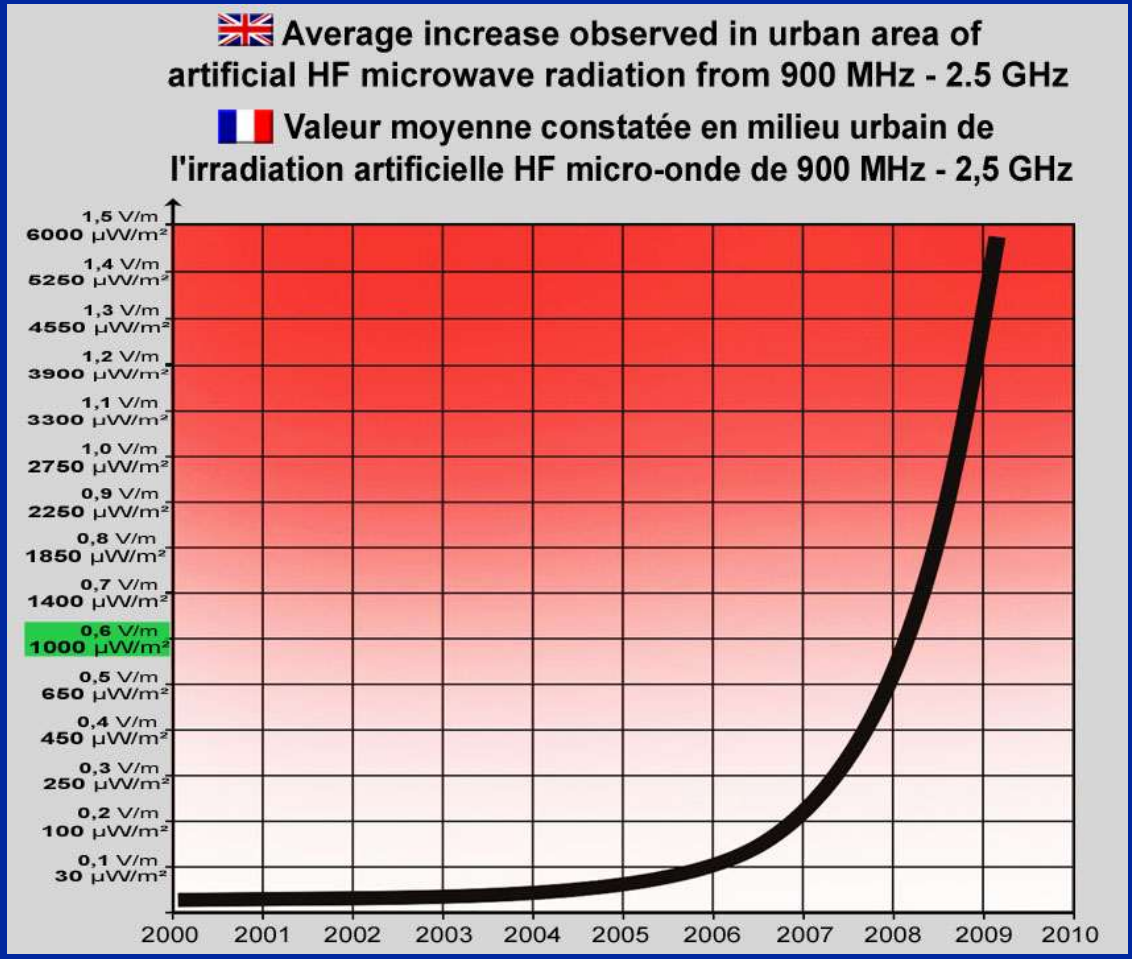
THE PROBLEM
The invisible rise of EM radiation …



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Should we look at the matter like this …

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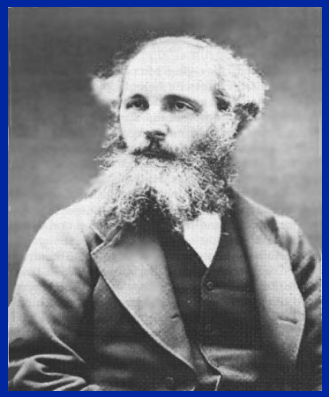
or like this …

ELECTROSMOG

sensoryperspective

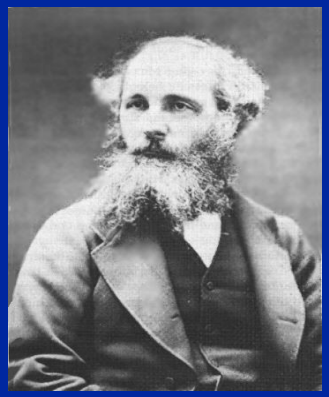
Why radiation ?



J. C. Maxwell
1831-1879

- Radiation = propagating electromagnetic field
  - 300.000 km/s
- Radiation "contains" the information (audio, images, data, …)
  - compare with sound waves
- Radiation is **essential** for wireless communication, it is no side effect

Why magnetic fields ?



J. C. Maxwell
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- "Radiation" = quasi-static magnetic field
- is a **side effect** of the inevitable electric currents that are necessary to transfer the electric power

Telecom radiation …

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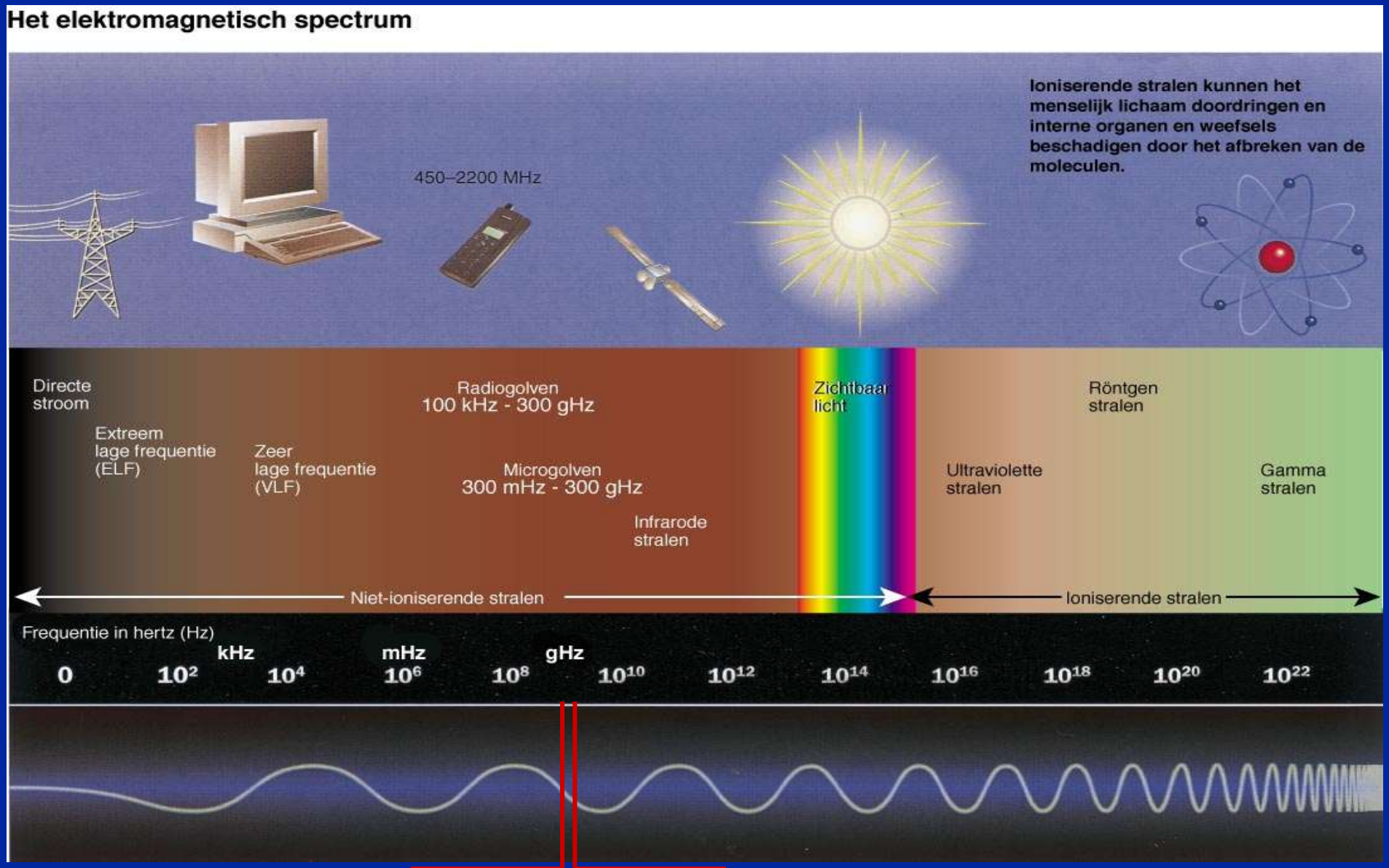
Characteristation of radiation

- (1) frequency
- (2) power
- (3) distance
- (4) the way the information is “embedded” within the radiation
  - –“pulsed radiation”

(1) spectrum



GSM / DCS / GPRS / UMTS

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(2) radiated power

- energy radiated per second (see further),
  - for GSM mobile: max. 2 W (1/8 of time)
  - for GSM base stattion: typically 10s to 100s of W

= 100 W

(3) distance

- Intensity decreases as $1/r^2$

  this means:

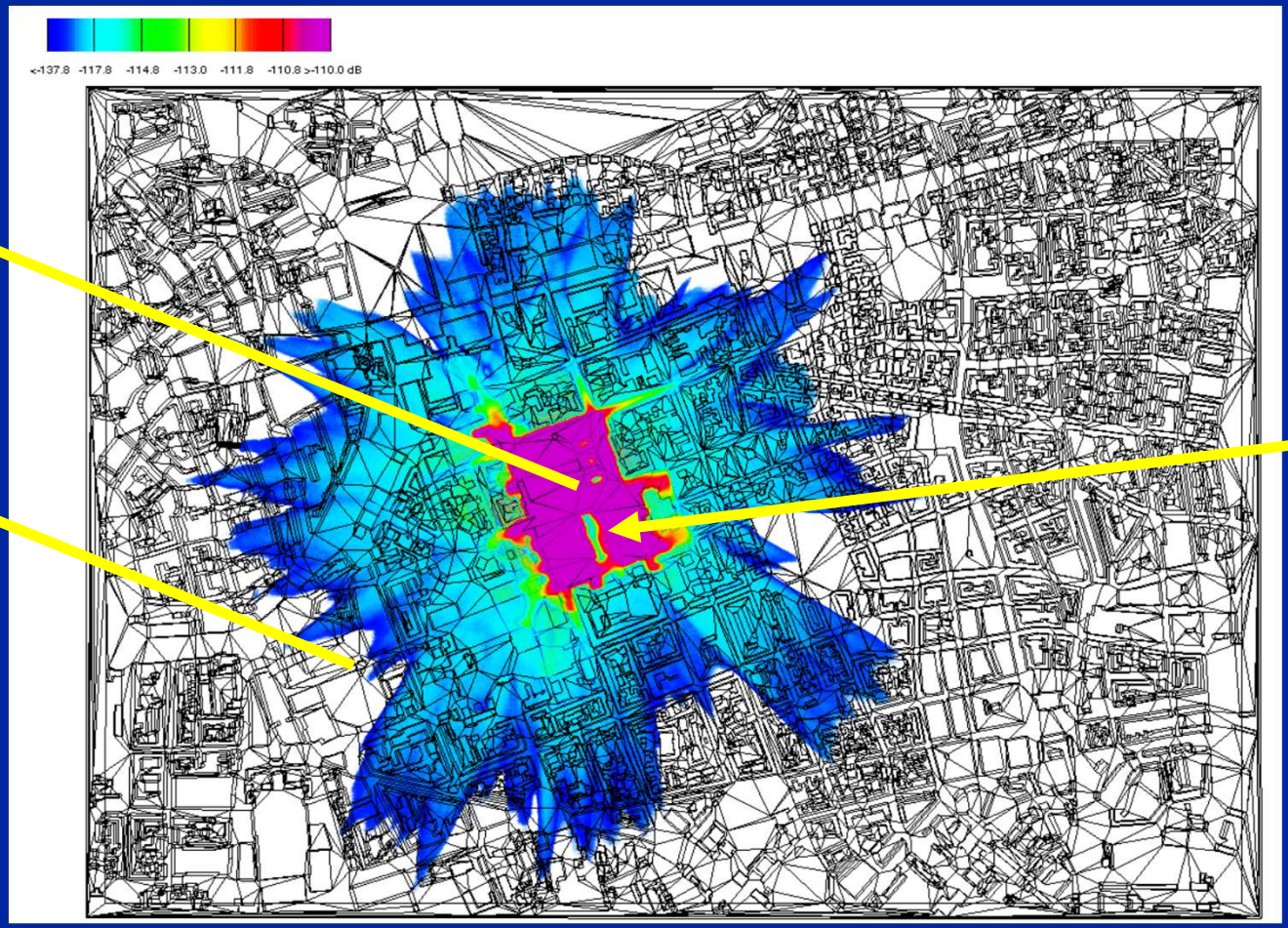
  distance x 10 = intensity /100

- **distance is hugely important**

propagation: result

GSM BS
Now: 3 V/m
Future: 0.6 V/m

Cell edge
1 – 10 mV/m



“weak spot”

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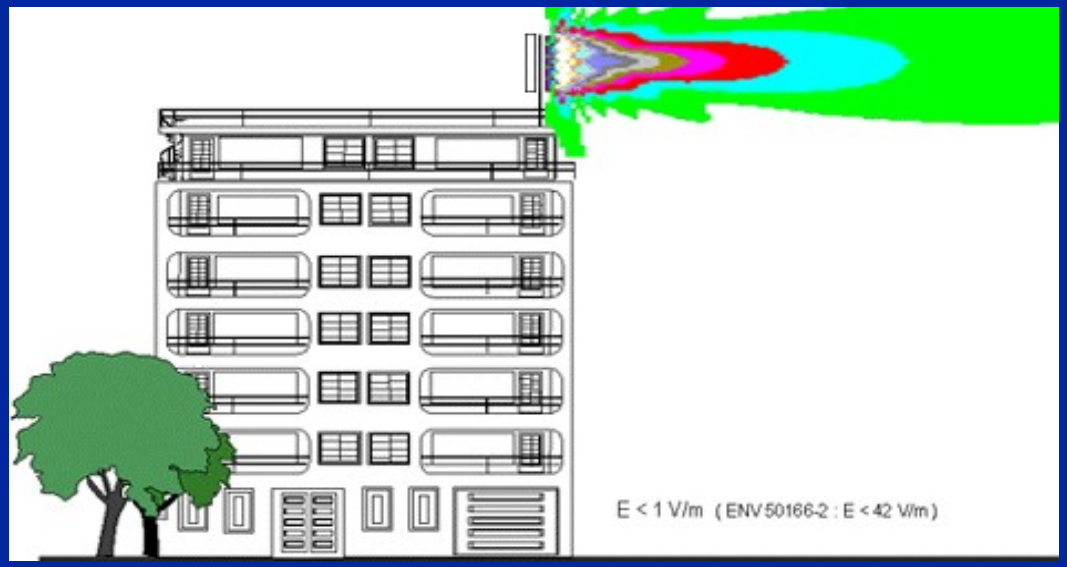
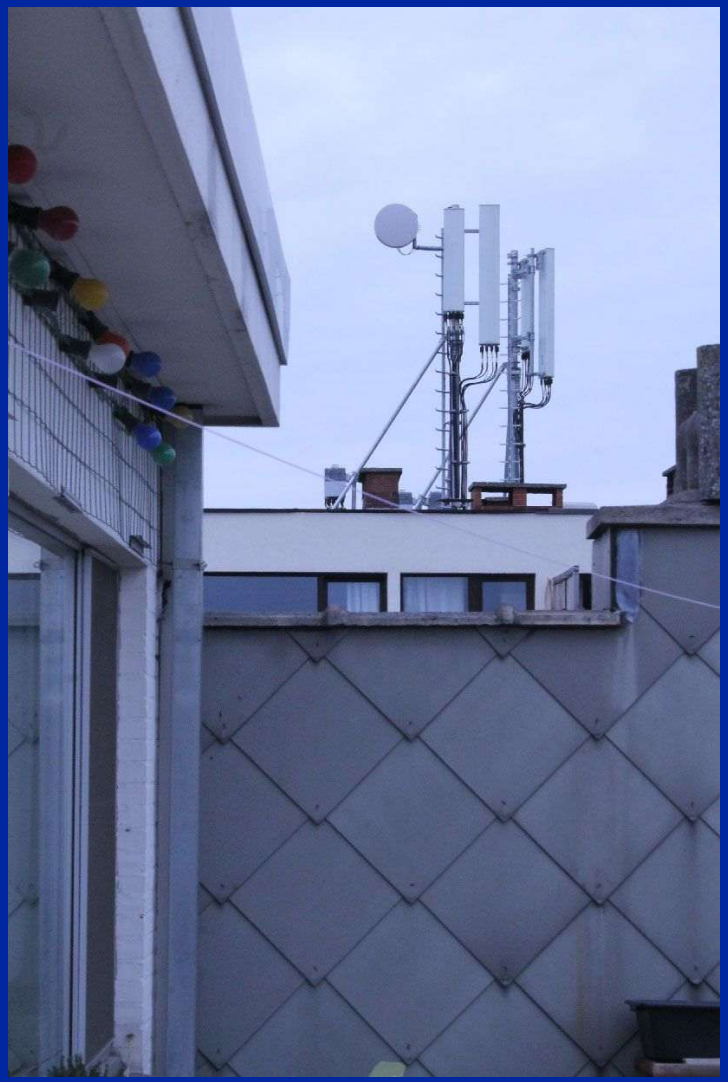
Antenna radiation pattern



very low radiation on and in building



“worst case” scenario

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Power, distance, and intensity

Source	Frequency	Power	Distance	Intensity
Radio/TV	kHz – MHz	**up to 100 kW**	1000 m	0.016 W/m^2
GSM BS	0.9 - 1.8 GHz	20 – 100 W	10 m 100 m	3.2 W/m^2 **0.032 W/m^2**
GSM handset	0.9 -1.8 GHz	20 mW - 2 W (1/8 time)	1 – 2 cm 1 m	**2 - 200 W/m^2** 0.0002 – 0.02 W/m^2
DECT (phone)	1.9 GHz	250 mW peak	1 m	0.02 W/m^2
WLAN,WIFI (internet)	2.4 GHz	100 mW max	1 m 10 m	0.008 W/m^2 **0.00008 W/m^2**
Bluetooth	2.4 GHz	1-10 mW	1 – 2 cm	0.8 - 8 W/m^2
UMTS handset	0.85 – 1.7 – 1.9 – 2.1 GHz	max. 125-250 mW	1 – 2 cm	max. 12.5-25 W/m^2
Sun	broad spectrum ionising !			1400 W/m^2

worst case: 14 s phone call = day at 100 m from mast

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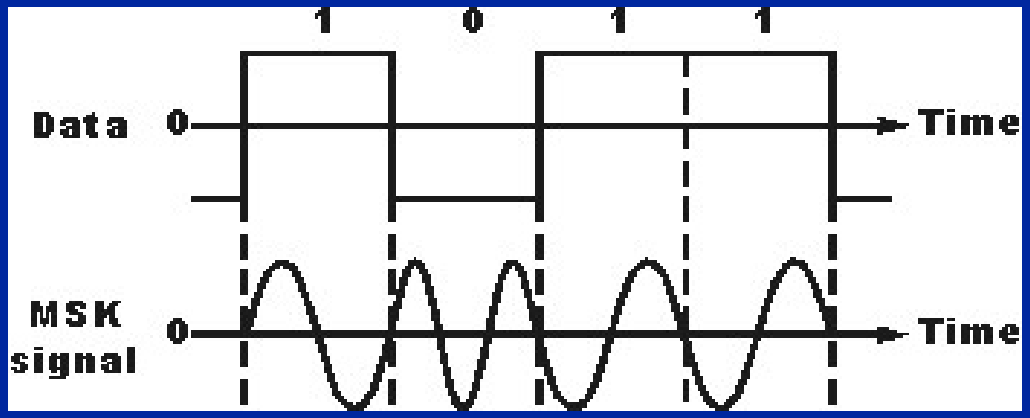
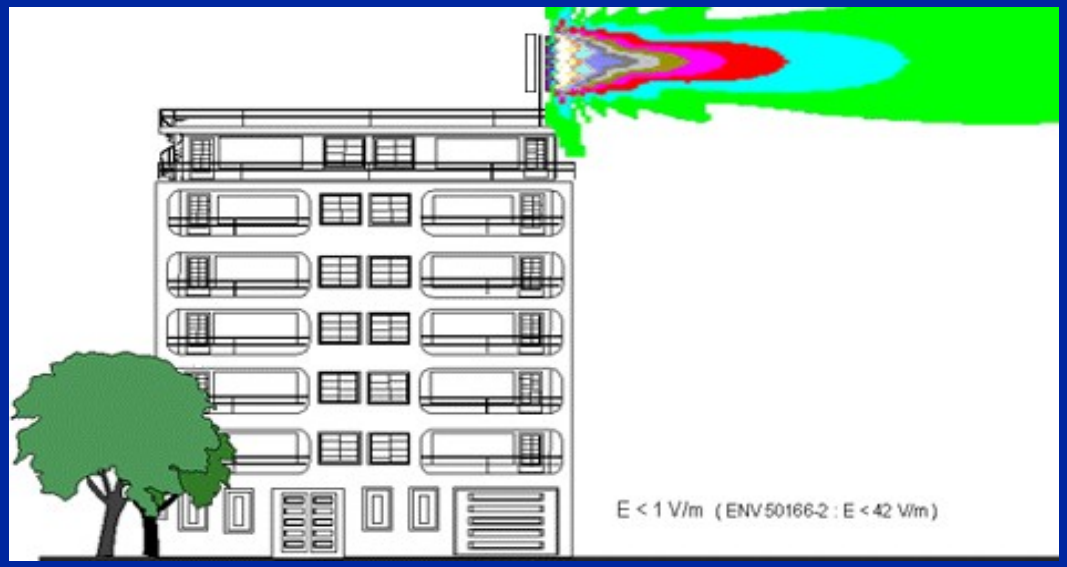
(4) Enting of information onto radiation

- radiation = “carrier” at a certain frequency
- info = slightly modifying the carrier, the modification contains the information
  - simplest form
    - bit 1 = carrier is radiated
    - bit 0 = carrier is not radiated
  - GSM: Gaussian-filtered Minimum Shift Keying (GMSK)



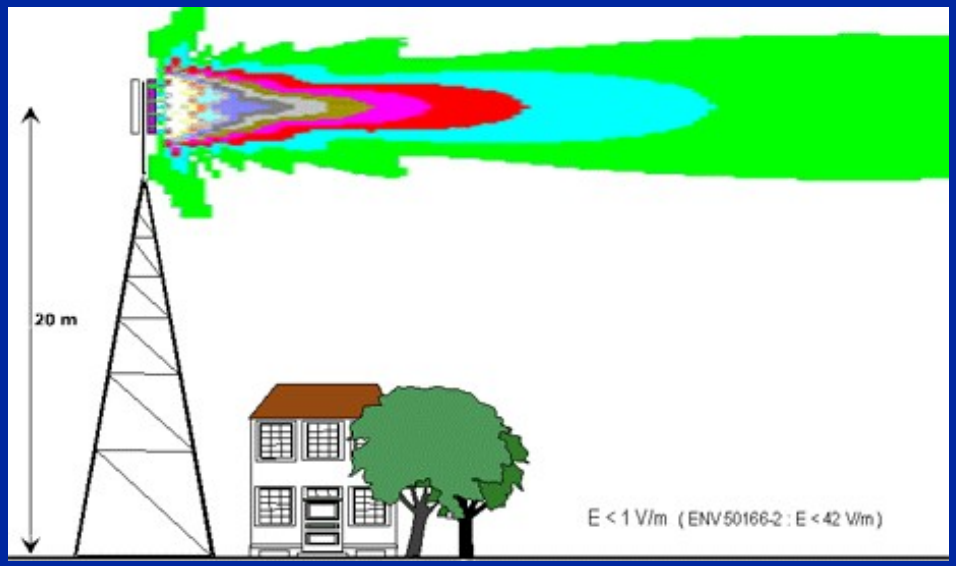
All of this is the same for 4G, 5G, … whatever G !

Effect of position base station



very low radiation in building

very low radiation on house



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So ... it is a fact that ...

- In 5G more cells with a central antenna are able to REDUCE the exposure … due to the smaller radiated power
- In 5G beam steered antennas are able to REDUCE the exposure … due to their spatial selectivity
- 5G satellites only induce a NEGLIGIBLE exposure … due to the large distance
- …

Effects on the body

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Effects on the body

- ~~Ionizing effects~~
- ~~Thermic effects~~
- Biological effects (+ and -) ?
  - SAR: Specific Absorption Ratio
  - real proof has to be consistent !!!

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Biological research

- headache, insomnia, concentration loss, ear buzzing, slower reaction time, …
- effect on de blodd/brain barrier in rats (Salford et al, 1994)
- cancer (Repacholi et al, 1997, Interphone study, …)
- DNA-damage in rat brains (Lai and Singh, 1995, 1996)
- increased effect of carcinogens (Maes et al, 1996)
- …

Types of research (1)

- epidemiologic: on groups of people
  - group has to be large enough, with control group
  - problems:
    - almost impossible to control all factors, so that other factors inevitably could play a serious role, which is difficult to filter out
      - e.g. other type of pollution, eating habits, …
    - this generates a lot of "selectivity" and consequently discussions in the scientific community
    - ***my vision: real cristal clear convincing consistency and causality are missing***

Types of research (2)

- in vivo: on animals
  - group has to be large enough, with control group, better control of most factors
  - problems:
    - still, some influencing factors can be missed …
    - **representative radiation intensity, duration, etc. ?**
    - **how representative for humans ?**
    - **my vision: in lots of research that suggests adverse effects the radiation intensities are really high, not representative for levels in society**

Types of research (3)

- in vitro: on tissue
  - "relatively easy" to control all factors
  - effects have been clearly proven
  - problems:
    - representative for a full body, with all its complex interactions ?
    - what do these effects on tissue mean for a human body ?
      - e.g. effect of jogging

So, what to do now ?

Requirements for radiation ?

- different frequencies really have to be considered as different
  - regulation depending on frequency
  - examples
    - at f=0
      - normal 120 V/m
      - thunder storm: up to 40.000 V/m
      - ESD: up to 20.000 V on human body

limit : 4 W/kg = **proven risks THERMIC**

employees
- ⇨ limited in time
- ⇨ educated
- ⇨ safety equipment

/ 10

0.4 W/kg

general public
- ⇨ permanent exposure (24u/24)

/ 50

/ 200

/ 5

0.08 W/kg = 42 V/m → **WHO**

0.02 W/kg = 21 V/m → **Belgium**
now: 3 … 9 V/m → **Flanders**
future: 0.6 V/m ?

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Electricity distribution “radiation”

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Magnetic field exposure

Source	Magn. field (μT) at 30 cm	Magn. field (μT) at 90 cm
computer monitor	0.02 - **13.00**	0.001 - 0.9
color TV	0.02 – 1.20	0.007 – 0.11
scanner	0.20 - 2.60	0.009 – 0.3
electric drill	0.02 – 3.3	0.003 – 0.80
dish washer	0.50 - 0.80	0.08 – 0.16
microwave oven	0.05 – 5.00	0.011 – 0.45
transfo to 230 V	up to typical 10-tal **μT**	
high voltage lines	**totally depending on currents**	

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Requirements for magnetic field

- Preferably < 0.4 **μT**
- Intervention > 20 **μT**

Proven statistic correlation between long term exposure to magnetic fields above 0.4 µT and leukemia in very young children
causality is not proven

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Proposed alternative strategy: ALATA

- precautionary principle:
  - strategy from risk management in case of scientific uncertainty
  - basis of environmental legislation in Europa
  - *Take action against potential risk without waiting for the results of scientific research*
- ALARA: As Low As Reasonably Achievable
- ALATA: As Low As Technically Achievable

Step 1

- The society as a whole substantially benefits from the availability of wireless communications / electricity
  - e.g. Search and Rescue: many lifes have been saved
- There is absolutely no democratic majority to stop wireless communications / use of electricity

→ Systems ***HAVE*** to function

Step 2

- With the technology available at a certain moment in time there is an exposure level below which the systems do not function satisfactory any more, and this is thus not acceptable

→ What is this level ?

Note: Telecom system

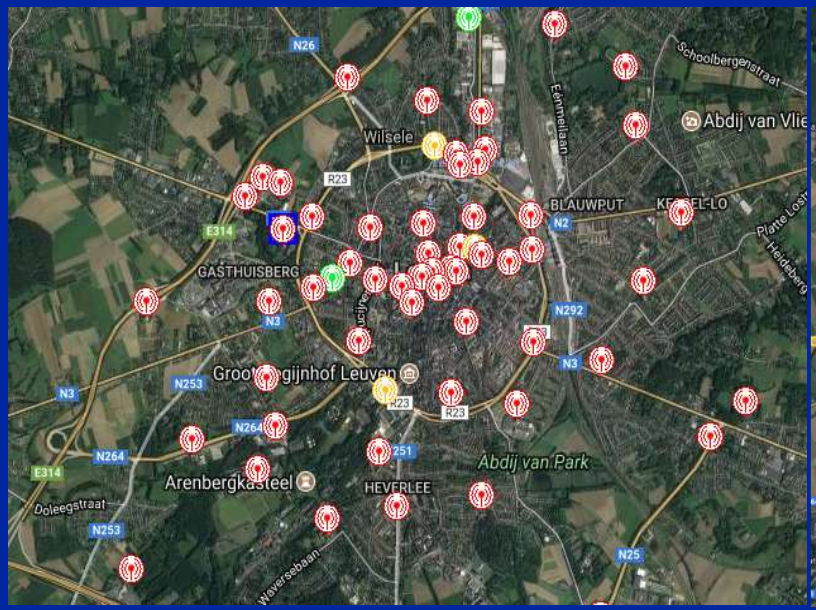
- quality directly depending on "**signal over noise ratio**"
  - compare to conversation in a quit room or a loud discotheque
  - signal = radiation
  - noise: a.o. "noise" of other wireless applications, "random" radiation in neighborhood (lightning, welding, …)
- signal: 20 V/m to 3 V/m

  ⇒ S decreases by factor 44,4 (= "to speak 44,4 x more quiet")
- signal: 20 V/m to 0.06 V/m

  ⇒ S decreases by factor 100.000 (= "to speak 100.000 x more quiet")

Step 3

- Measurement campaigns, Leuven, system works properly



1) R. Iyare, V. Volski, and G. A. E. Vandenbosch, "Study of the Correlation between Outdoor and Indoor Electromagnetic Exposure near Cellular Base Stations in Leuven, Belgium", Environmental Research, Vol. 168, pp. 428-438, 2018

2) R. Iyare, V. Volski, and G. A. E. Vandenbosch, "Study of the Electromagnetic Exposure from Mobile Phones in a City Like Environment: the Case Study of Leuven, Belgium", Environmental Research, Vol. 175, pp. 402-413, 2019

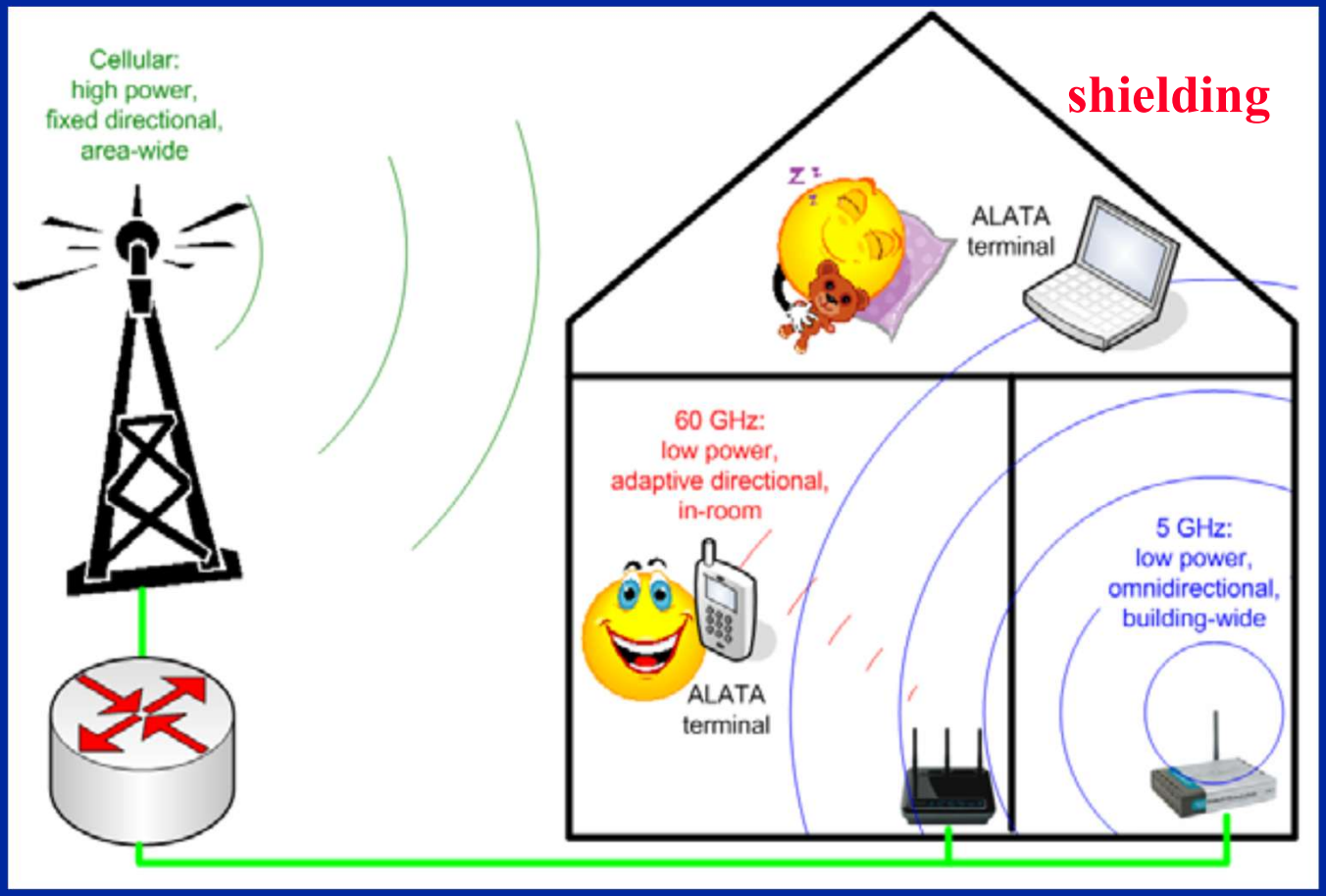
Step 3

- Exposure due to cell phone towers
  - to the average, GSM is by far the biggest contributor
  - maximum outdoors is about 1 V/m
  - maximum indoors is about 0.5 V/m
- Exposure due to your own smart phone

  –up to 30 V/m

- ALATA level for base stations “seems to be” ca. 1 V/m at 900 MHz)

How to reduce exposure: separate indoors - outdoors



0.6 V/m and even much lower becomes very feasible

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Electricity distribution:

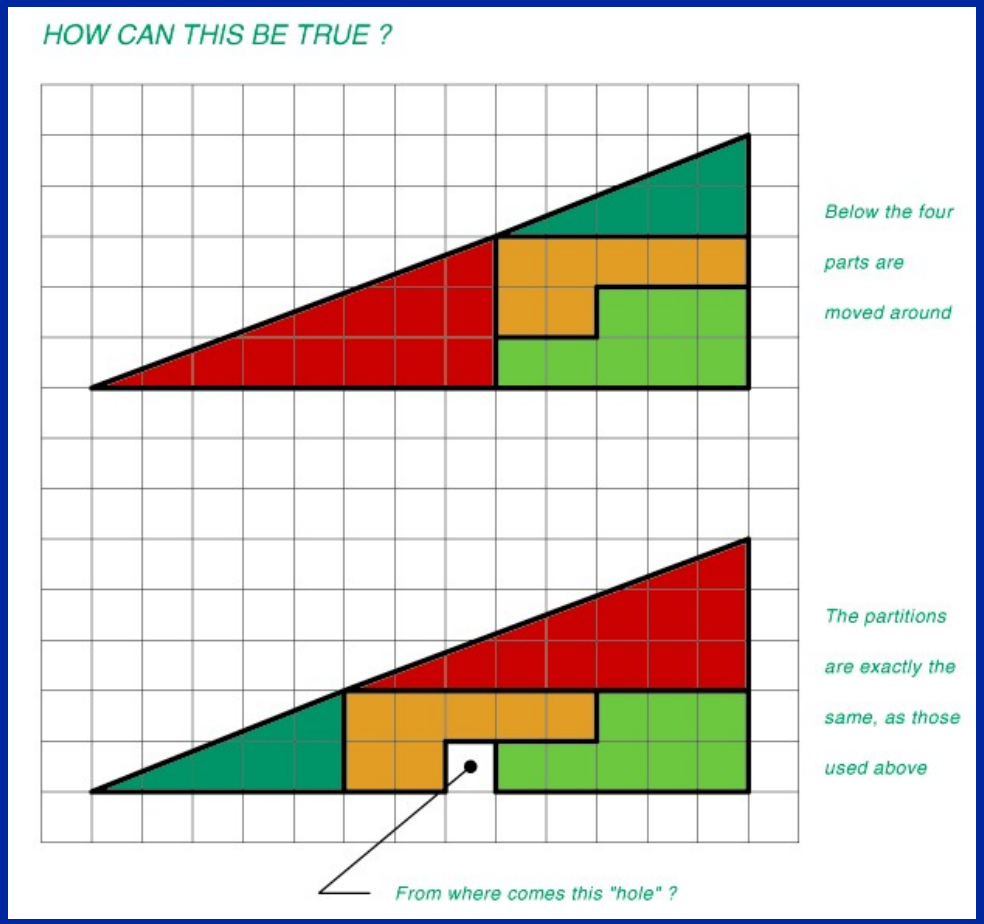
- reduction necessary power
- optimal designs, e.g. high voltage lines and trafo buildings
- highest magnetic fields only where no people are present

Conclusions

- It is ethically not correct to assume that EM radiation has no adverse health effects on humans
- These effects probably will be (very ?) small and, and will manifest themselves only in the **long term over larger populations** (the long term effect is the real major unknown in the debate)
- Society as a whole hugely benefits from wireless technology

- ***Solution: ALATA: As Low As Technically Achievable***, based on a consensus within society about our "connectivity"

Things are not always what they seem to be



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