HSE
Occupational Health & Safety
and Environmental Protection unit

Physiological effects of NIR exposure

NIR Seminar

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Overview of NIR induced voltages concerning frequencies able to enter the body

Electromagnetic Spectrum (Magnetic field part penetrating body)	Induced voltage in a 20cm Ø loop (size of the head) at 1µT field density
0 Hz (static and quasi-static magn. field)	0 (except you move through field lines)
50 Hz mains frequency	69.7 nV
1 kHz audio frequency	1.39 µV
1 MHz broadcast medium wave	1.39 mV (theoretical value, body starts to screen)
28 MHz short wave	body screens
100 MHz broadcast FM	|
900 MHz portable telephone	| For all induced voltages the limit
1.8 GHz portable telephone	| is 100µV, which can be reached
2.45 GHz WLAN and microwave oven	| either by increasing the field or by
6 THz infrared heat radiation	| increasing the frequency, or both.
385 THz visible light red	|
789 THz visible light blue	|
1 PHz UV radiation	|
300 Phz Röntgen ("X-ray")	|
300 Ehz Gamma-rays	|

Electromagnetic waves are transmitted by photons.

Electromagnetic Spectrum	Corresponding photon energy
50 Hz mains frequency	$3.3*10^{-32}$ J
1 kHz audio frequency	$6.6*10^{-31}$ J
1 MHz broadcast medium wave	$6.6*10^{-28}$ J
28 MHz short wave	$1.9*10^{-26}$ J
100 MHz broadcast FM	$6.6*10^{-26}$ J
900 MHz portable telephone	$5.95*10^{-25}$ J
1.8 GHz portable telephone	$1.2*10^{-24}$ J
2.45 GHz WLAN and microwave oven	$1.6*10^{-24}$ J
6 THz infrared heat radiation	$3.98*10^{-21}$ J
385 THz visible light red	$2.8*10^{-19}$ J
789 THz visible light blue	$4.96*10^{-19}$ J
1 PHz UV radiation	$6.6*10^{-19}$ J
300 Phz Röntgen ("X-ray")	$1.98*10^{-16}$ J
300 Ehz Gamma-rays	$1.98*10^{-13}$ J

Dissociation Energy for organic bindings

Type of Binding	Corresponding Energy
C-H	$6.72*10^{-19}$ J
C-C	$5.78*10^{-19}$ J
C=C	$1.02*10^{-18}$ J
C triple C	$1.39*10^{-18}$ J
C-O	$5.98*10^{-19}$ J
C=O	$1.34*10^{-18}$ J
O-H	$7.72*10^{-19}$ J

By definition NIR does not modify the DNA

The minimum energy required to break up a DNA molecule (which, due to this change, may provoke cancer), is the C-C binding at 5.78*10-19 Joule.	**Corresponding Frequency or quantum energy** **Starting at UV (i.e. about 1 PHz) the energy per quantum is sufficient to break up the DNA.** **Below the frequency range of the visible light a change of DNA caused by radiowaves is impossible.** **This fact is known for almost 100 years.** **It is also known that hard UV, Röntgen (engl. "X-ray") and gamma rays do cause cancer because they massively break up molecules inside our body.**

Thermal effects of NIR

Effects of medium to high frequency NIR happen mostly at the body surface, or close to it.

Physics knows a parameter called "skin depth".

It determines how far (parts of) a wave can penetrate into matter, depending on the wave's frequency and the consistency of matter.

Beneficial and malicious effects of NIR

NIR of low power density makes no effect onto the body because the thermal effect is very low compared to the body thermal turnover (in average around 100 Watts).

<u>Legislation limits the impact power to a tiny fraction of the body power.</u>

NIR of higher power density causes mainly heat effects.
Reminder: There are even medical applications when tissue or articulation heating becomes necessary.

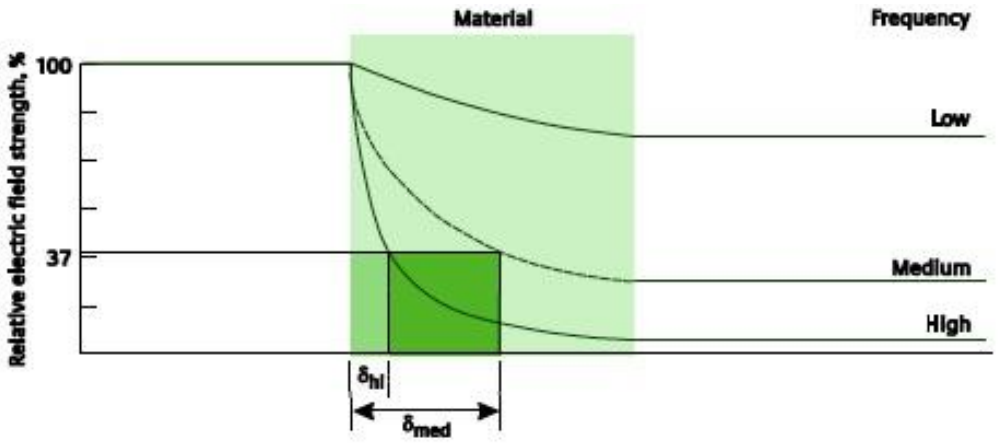
NIR of very high power density would burn or transform the skin, with all consequences attached to burns. The skin cannot keep high power NIR out of the body.

E.g., high power NIR into the unprotected eye damages or destroys the eye.

Skin depth versus frequency and tissue

$$\delta = \frac{1}{\omega}\left\{\left(\frac{\mu\varepsilon}{2}\right)\left[\left(1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2\right)^{1/2}-1\right]\right\}^{-1/2}$$

	Tissues with low water content				Tissues with high water content			
	Fat		Bone		Muscle		Skin	
Frequency	σ(S m^{-1})	δ(mm)	σ(S m^{-1})	δ(mm)	σ(S m^{-1})	δ(mm)	σ(S m^{-1})	δ(mm)
150 MHz	0.04	366.1	0.07	301.0	0.7	67.2	0.5	85.0
450 MHz	0.04	301.9	0.10	202.2	0.8	51.3	0.7	52.9
835 MHz	0.05	252.0	0.14	139.5	0.9	43.5	0.8	41.5
1.8 GHz	0.08	157.1	0.28	66.7	1.3	29.2	1.2	28.3
2.45 GHz	0.10	117.1	0.39	45.8	1.7	22.3	1.5	22.6
3 GHz	0.13	93.6	0.51	35.2	2.1	18.0	1.7	18.9
5 GHz	0.24	49.4	0.96	17.7	4.0	9.3	3.1	10.5
10 GHz	0.58	19.6	2.13	7.3	10.6	3.3	8.01	3.8



According to the Beer-Lambert law, the intensity of an electromagnetic wave inside a material falls off exponentially from the surface as

$$I(z) = I_0\, e^{-\alpha z}$$

Magnetic Induction at low frequencies

Static and low frequency magnetic flux goes unaltered through the human body.

The body is fully transparent to static and low frequency magnetic fields.

There no body defense against that.

Consequences onto the body

Static magnetic flux:

No immediate consequence except you move very fast.

Dynamic (alternating "ELF") magnetic flux:

Induction of voltages inside the body according to exciter frequency (in Hertz) and flux density (in Tesla).
BOTH PARAMETERS ARE REQUIRED FOR PROPER ASSESSMENT.

Most sensitive organs:

Brain (electrochemical organ)
Central nerve system
Liver
Basic limit: 100 µV into surface of head.

Pulsed Electromagnetic Fields

Pulsed electromagnetic fields have two major parameters:

a) Frequency f [MHz]
b) Repetition frequency f_r [MHz]
c) Field strength E [V/m]

For the human body the wave packets partially behave like a wave at lower frequency.
A bigger reach into areas beneath the skin is observed.

Pulsed fields are used

For cellphones

For accelerators

for RADAR's

for spread spectrum communications

for manufacturing processes

for X-ray

for NIR-weapons

Military RADAR personnel belongs to a group that showed dramatic health consequences believed to be caused by extremely powerful military RADAR's in the GW-range. Long term exposure to high power pulsed fields indeed has health consequences although DNA-break-up cannot have occurred and therefore cannot be the prime reason.

Brain Tumor from Cellphone Use?

Cellphones produce pulsed fields of low to medium intensity.

Cellphones are operated very close to the human brain. Their emissions are close to the legal limit.

Not so much the waves but the modulated current in the transmitter stage produces an alternating low frequency magnetic field that indeed enters the body.

Too much too long

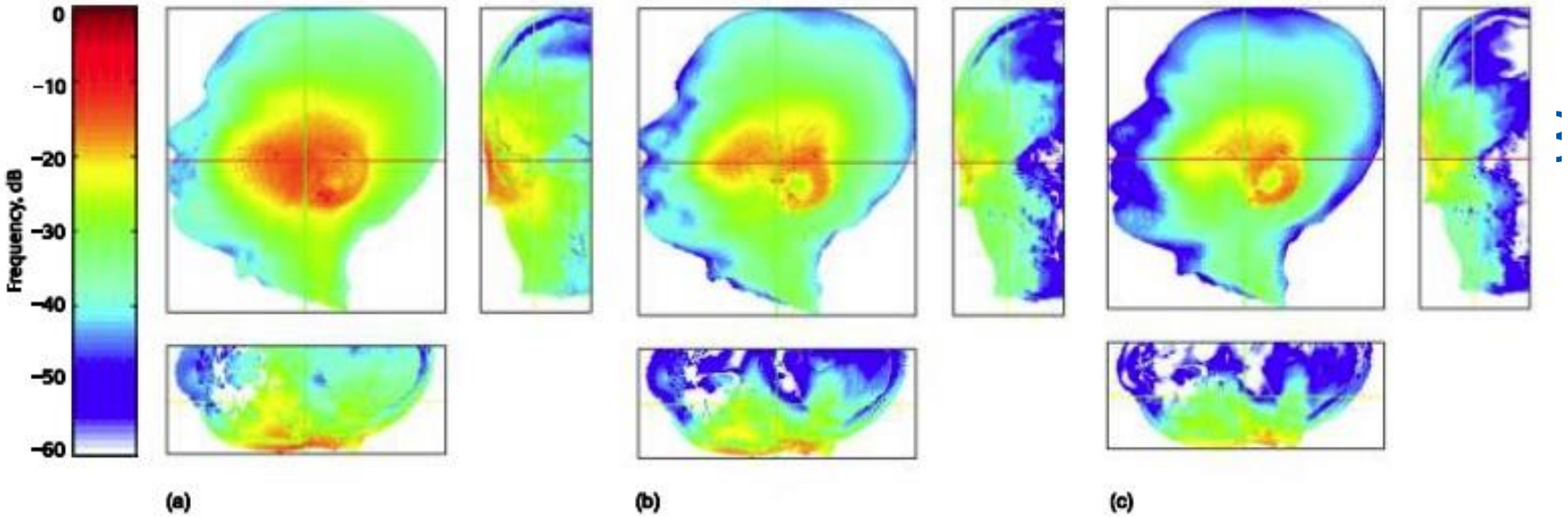
Several persons are known to have fallen ill by extensive cell phone use over years.
Brain tumors are the consequence of too much induction over longer periods.

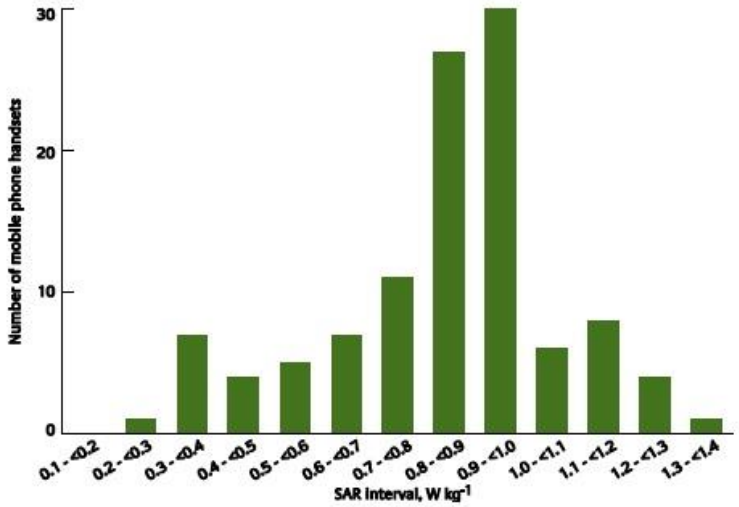
Not only a fraction of the transmitted wave enters the body. Also the the low frequency alternating current of the transmitter transistors inside the cellphone induces voltages deeply into the brain.

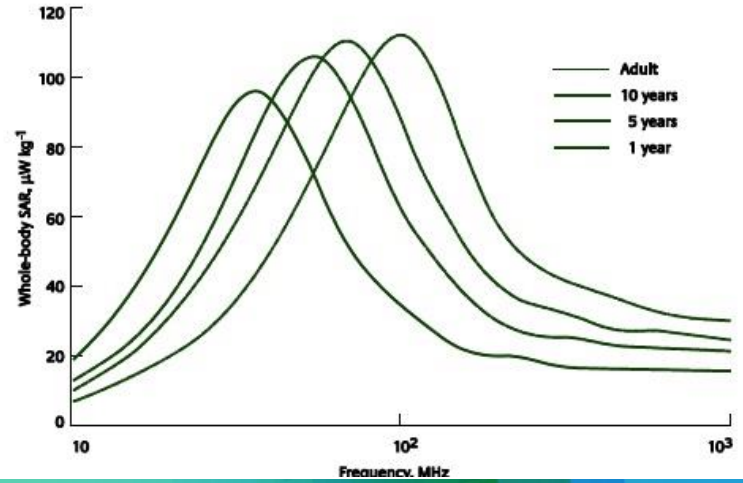
Above persons reportedly used the cellphone at their head for many hours during the day over several years.

Long term exposure may therefore cause malicious effects.

SAR facts – frequency and age dependence







Absorption of radio frequency energy into a child's head, depending on frequency.
a) 0.9 GHz
b) 1.8 GHz
c) 5.6 GHz
Right hand side:
SAR values from cellphones as communicated by producers
Absorption levels of a homogenous 1 V/m field for persons of different age (and height)

Summary of physiological influence onto the human body

How to influence human body:

Reminder:

The body itself emits 100W electromagnetic waves around 1 THz (infrared)

High frequency fields (waves):

The skin attenuates waves that impact on the body. The absorption causes the skin and underlying tissues to heat up.
Fields and waves therefore partially enter the body.
The lower the frequency the more the body will be penetrated. Indicative value: Few centimeters.

Low frequency fields:

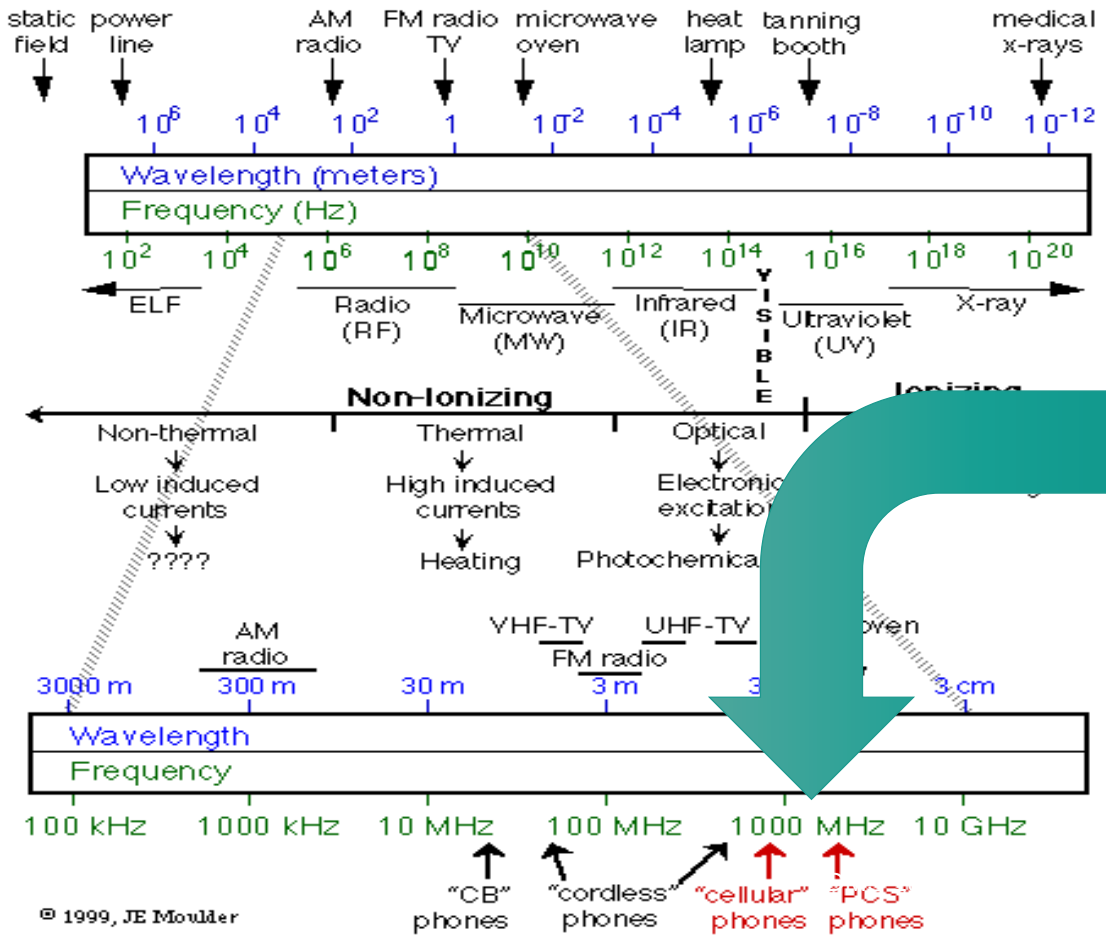
Body has no protection against magnetically induced voltages
Induction follows the equation U (voltage) = 4.44/A (surface) * f * n * B (magnetic flux density)
Induced voltages provoke an electrochemical reaction equivalent to the control functions of the brain, causing interference throughout the body. Medicine does not have any firm limit but experience shows that 100µV into the head's surface is the starting point for trouble.

Contact currents:

Nerves react to current flow, strongly depending on frequency and intensity (not treated in this talk).

Comparison of human body with WLAN

Reminder of body energyturnover:
Body emits electromagnetic waves around 1 THz (infrared) at a power level of 100W total



WLAN 2.5GHz worst case body exposure:
10-20mW/m2 at 100% duty cycle and 50cm distance
Duty cycle: typically 1%, can go up to 10%

ICNIRP (and EU Directive)
public exposure limit: 10W/m2

*WLAN: Sends and receives short packets at max. 100mW radiated **REGULATED power** into a large surface with an omnidirectional pattern.*

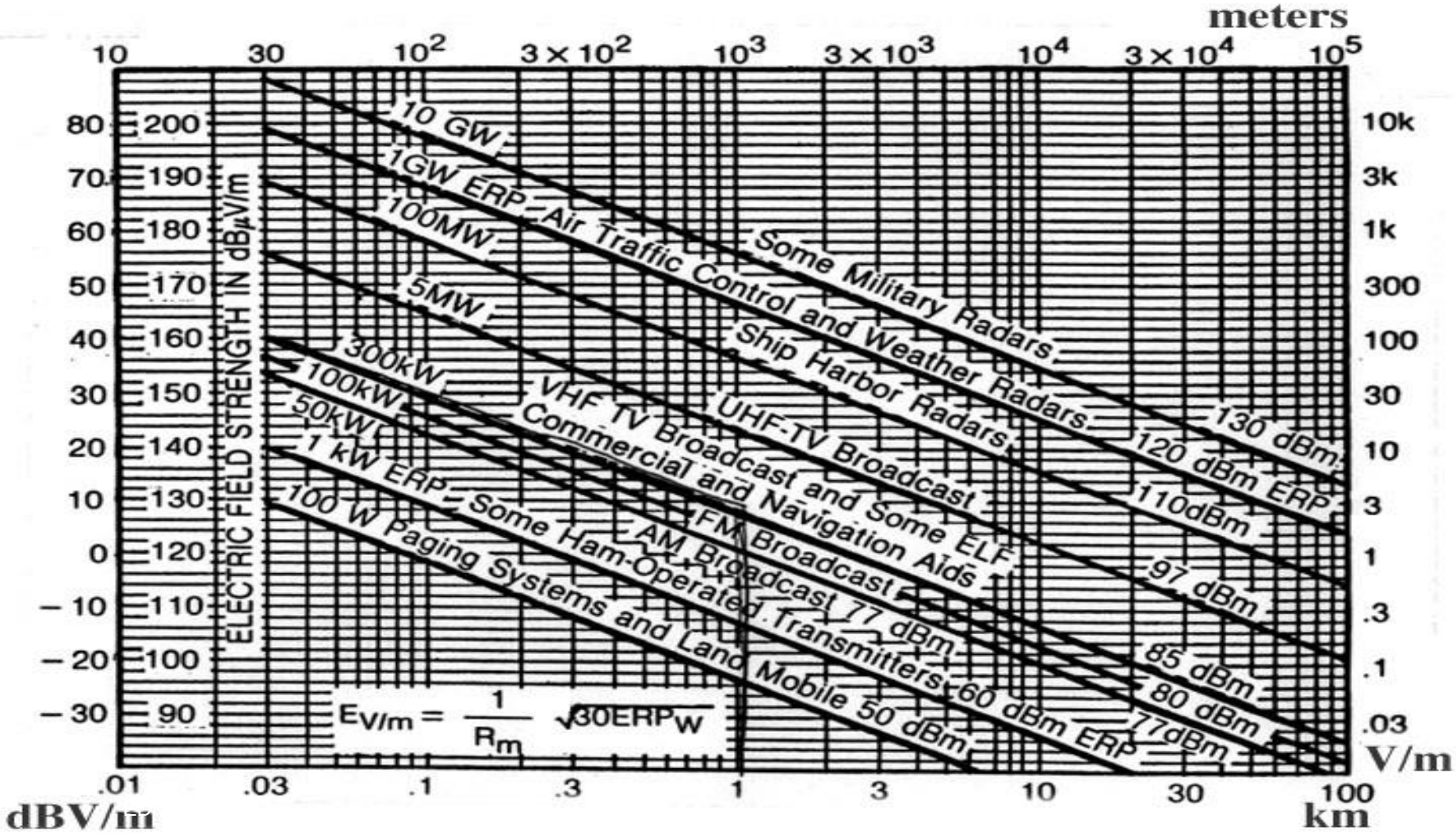
Conversion table
for field strength and power density:

Power density ($W\ m^{-2}$)	Electric field strength ($V\ m^{-1}$)	Magnetic field strength ($A\ m^{-1}$)
0.1	6.1	0.016
1.0	20	0.052
10	61	0.16
50	140	0.36
100	200	0.51

Intentional EM fields worldwide

ERP = effective radiated power [W]

WiFi (=WLAN) 2.5 GHz and 5.4 GHz is not mentioned. It would be situated in the lower left corner. Exposure of personnel is about 10000 times lower than PUBLIC exposure limits.

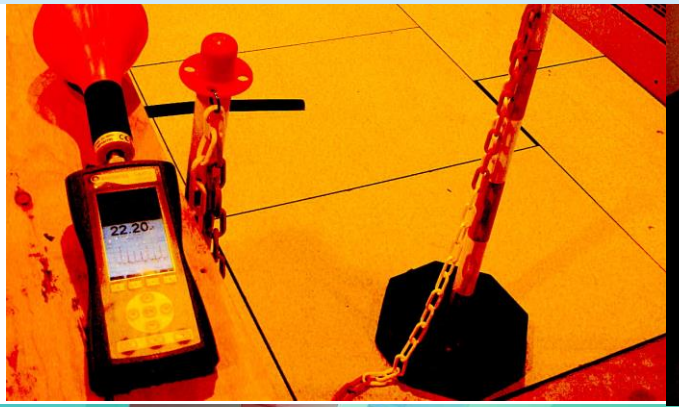


Electrical equipment radiation – example CAST (SR8)

Left:
Stray field of asynchronous motor fed by a VSD

Attention!
In all cases the meter shows the peak flux density in µT. This value needs to be weighed against the frequency contents of the field, which shows plenty of harmonics.
The induced voltage in a person's head needs to be summed up correctly:
10µT@500Hz induces the same voltage as 100µT@50Hz

Right:
Stray field at position of CAST guest book (!!) and at rectifier ventilation 1.5 metres away



Latest NIR concerns

Recent NIR concerns as presented in Dresden on the **NIR2018** conference

Electric car operation – exposure of passengers to magnetic stray fields in close vicinity (mainly on rear seats)

Electric car operation – high power chargers

Electric bus operation – contact-less overhead (or street mounted) magnetically coupled high power chargers (you can inspect such stations already at Geneva airport)

Increased requirements for power transfer because of wind power – public actions against new HV-lines

And: No mention of cell phone base stations and WLAN because for the experts these are not the issue...

Conclusion

WLAN (WiFi) exposure, or radiation from cell phone base stations, are not a hazard in any way. Any physiological consequence has purely psychological origins.

Many charlatans are making money with suggestions that indeed there are hazards. The web is full of bogus offers.

In city dwellings we have an exposure much higher than at CERN. Also inside airplanes, on board of ships or closer to broadcast transmitters (e.g. in Gex). Enormous amount of statistics worldwide underlines the fact that low level fields are no hazard at all.

Field paranoïa at CERN should be treated collectively by the CERN psychologist. Neither from cell phone base stations nor from WLAN there is any health hazard.

It violates the Code of conduct to put into doubt the work of colleagues, agencies and science. CERN should not allow people to mention WLAN (WiFi) as a "hazard" on the OHS-form.

www.cern.ch