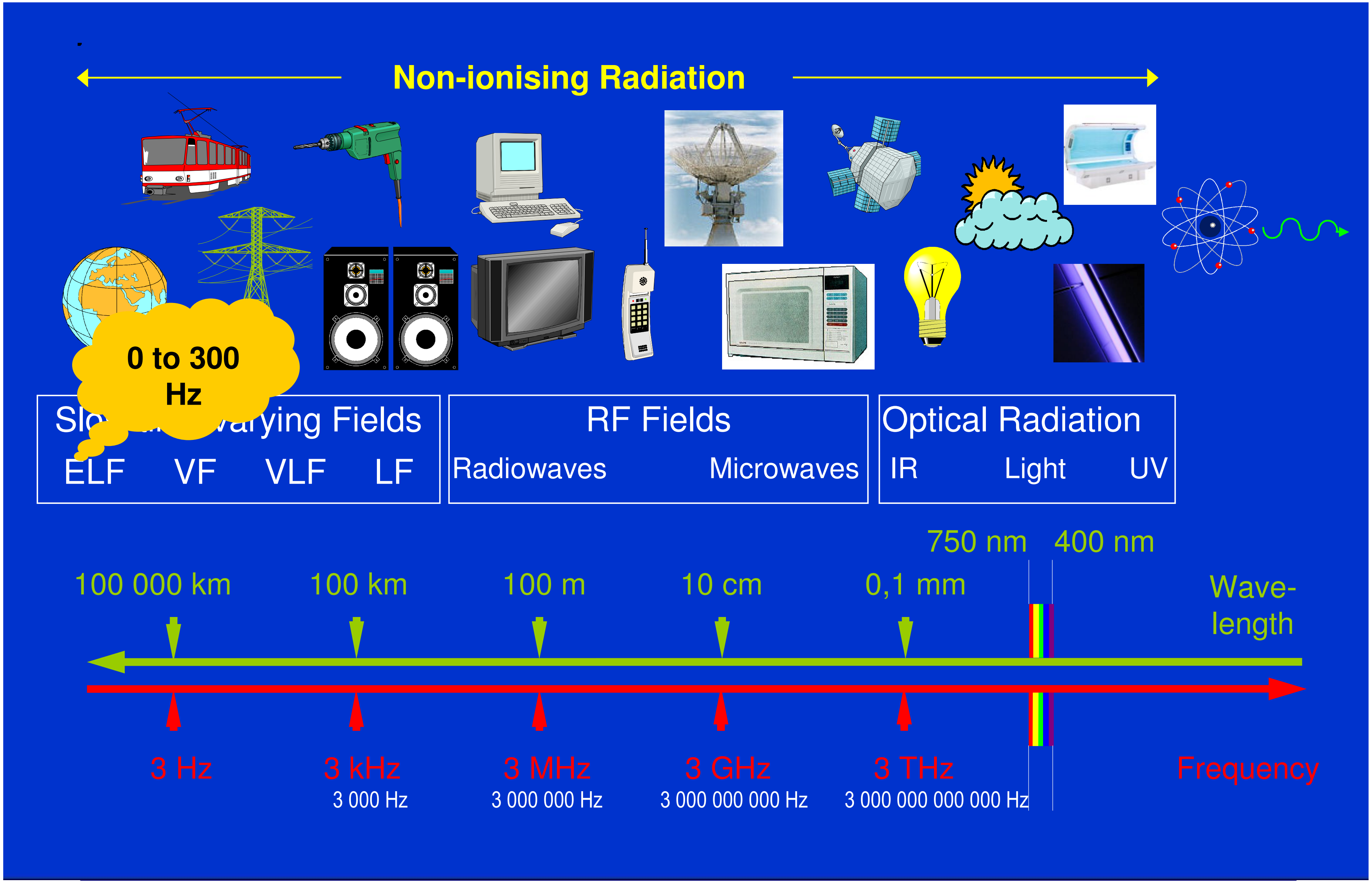
Static and ELF sources
- MRI, power lines, etc

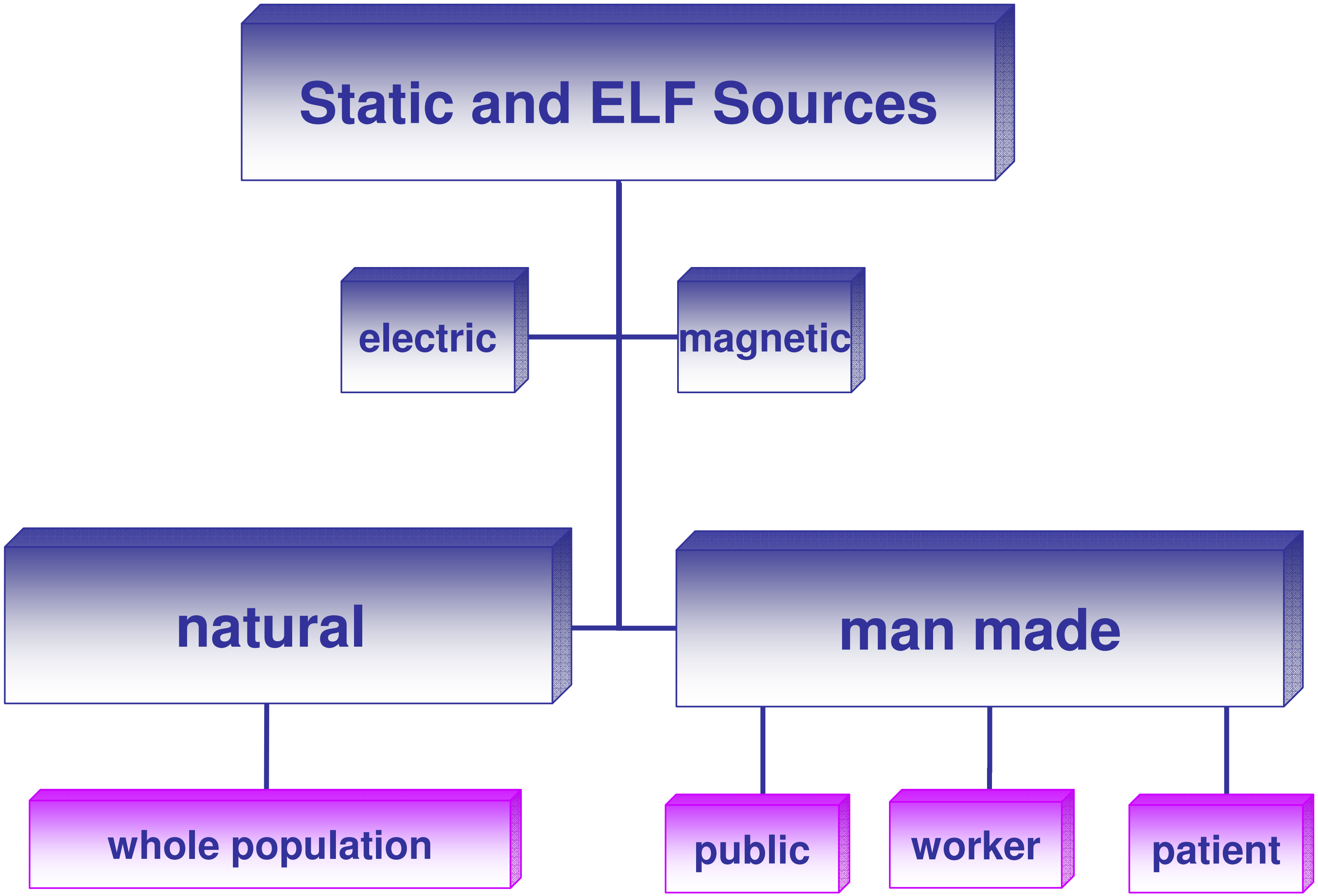
Rüdiger Matthes
Federal Office for Radiation Protection
Germany



6th International NIR Workshop
October 14th to 17th, 2008, Rio de Janeiro, Brazil

ICNIRP – International Commission on Non-Ionizing Radiation Protection

Bundesamt für Strahlenschutz

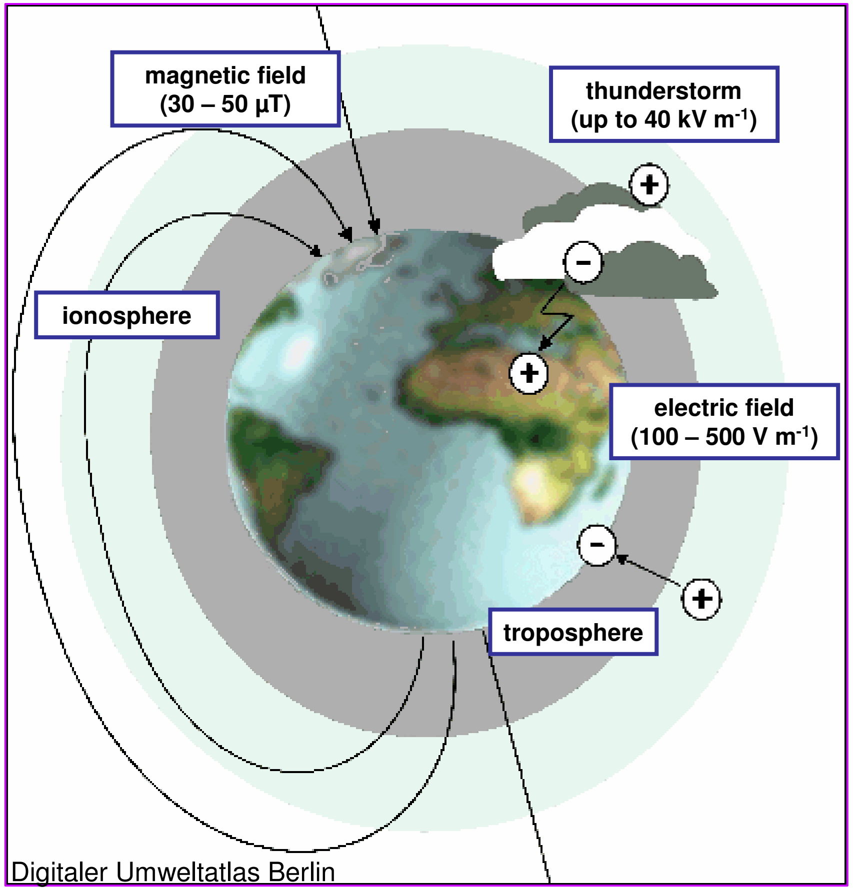

Static and ELF Sources
electric
magnetic
natural
man made
whole population
public
worker
patient

Characterising sources / exposures

- Electric field strength V m^{-1}; magnetic field strength A m^{-1}; magnetic flux density T; frequency Hz
- Fields are vector quantities (polarisation)
- Fields may have a complex time course (harmonics, transients)

- Fields decline with distance to the source
- Fields depend on actual operation conditions of the source
- Fields from different sources sum up in a complex way
- Fields depend on geometrical arrangements/design (e.g. power lines)
- Fields can be disturbed by the environment (especially E-fields)

Natural sources



Nature/origin	Frequency (Hz)	Amplitude (µT)	Comment
Regular solar and lunar variations	10^{-5}	0.03-0.05 0.005-0.006	Increases in energy during summer and towards the equator
Irregular disturbances, e.g. magnetic storms	Wide range	0.8 – 2.4	27 day period (sun rotation)
Geomagnetic pulsations	0,002 - 5	$2 \cdot 10^{-5}$ - $8 \cdot 10^{-2}$	For moderate activities at mid latitudes
Cavity resonances	5 - 50	$2 \cdot 10^{-5}$ - $5 \cdot 10^{-5}$	Schumann resonance / lightning
Atmospherics	1-2 kHz	$5 \cdot 10^{-5}$	Lightning discharges, energy peak 100-200 Hz

Man made sources

Static electric fields

- Charge separation as result of friction
- Use of DC electric power

Walking on carpet	10 - 500 kV m^{-1}	near the body
VDU	100 – 300 kV m^{-1}	5 cm from screen
Treatment of plastics	several hundred kV m^{-1}	near the body
HVDC line (500 kV)	20 kV m^{-1}	below; 2 kV m^{-1} in 400m
Electric train systems		
600 V systems	30 V m^{-1}	5m from line
1 – 6 kV systems	300 V m^{-1}	inside train

Man made sources

Static magnetic fields

fridge magnet

dental implant

necklace fastener

Permanent magnets 1-2 T

- Mechanical hazards
- Electromagnetic interference

magnetic bracelet

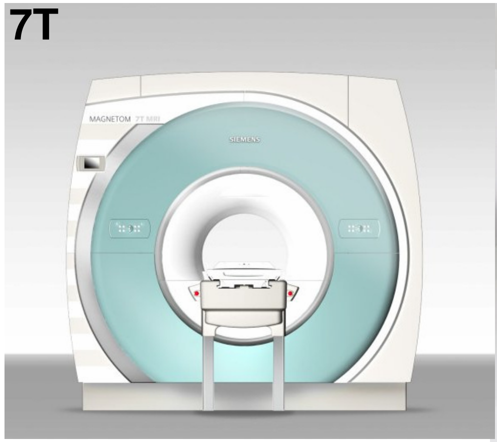
* Magnetic blankets up to 50 mT at surface

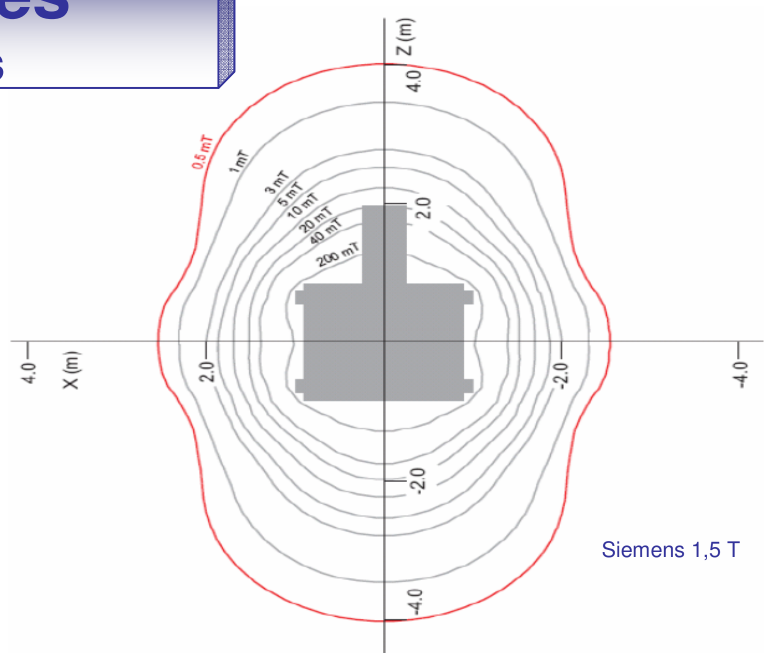
Exposed:

- General public exposure → high but only local (e.g. hands)
- Occupational exposure → depending on the process
- Medical → high, local (anywhere inside the body)

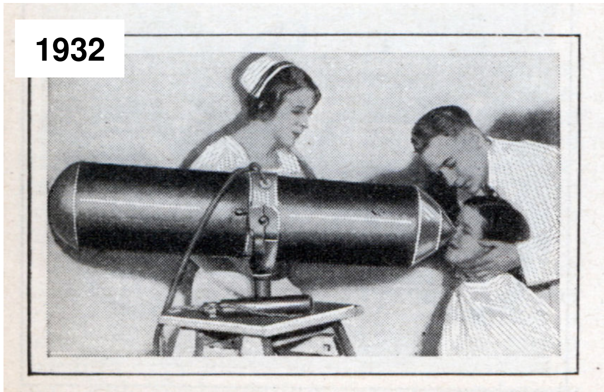
Man made sources

Static magnetic fields





Most systems 1.5 T and less
Increasing routine use of 3T
Experimental systems up to 11.7 T



Exposed:

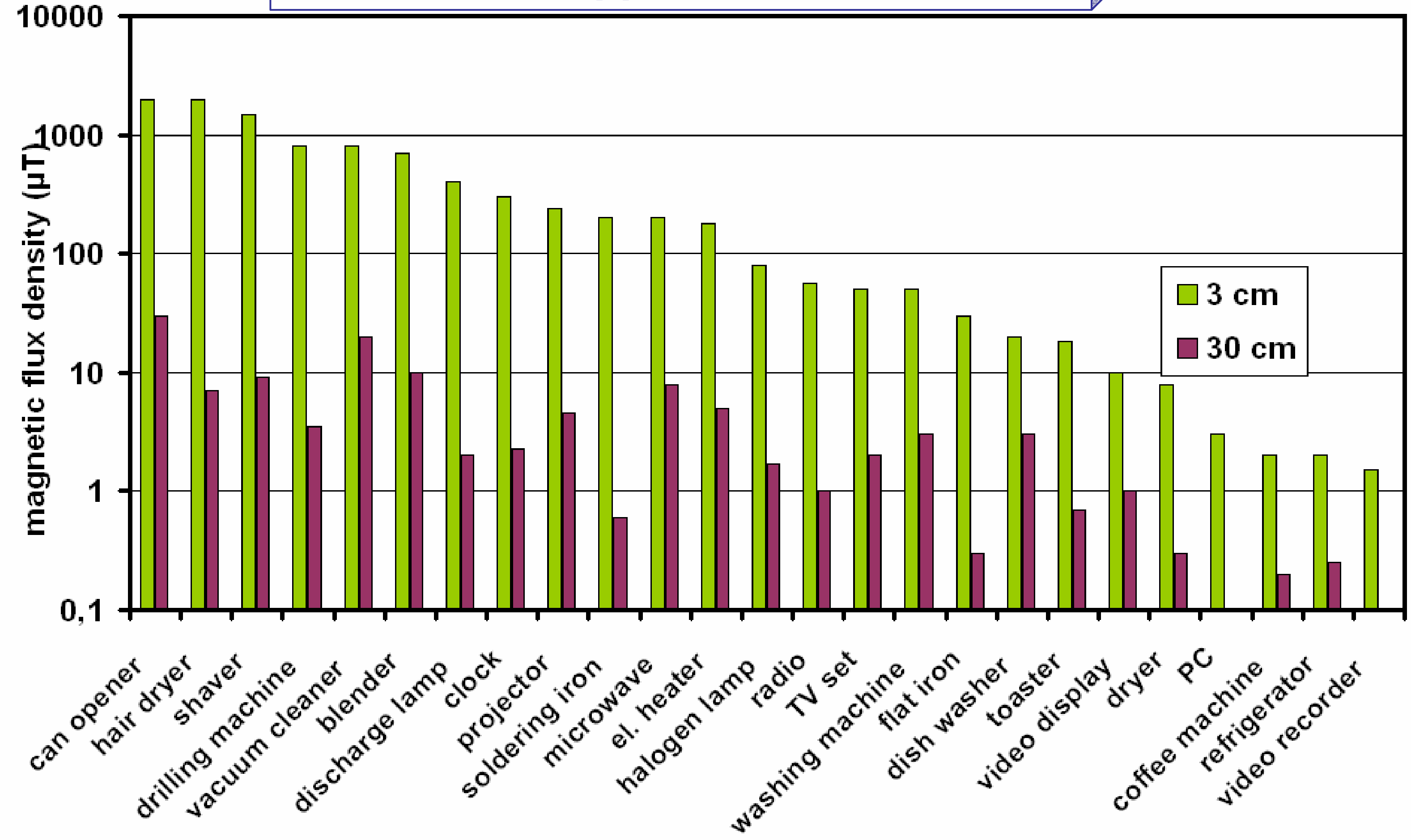
- **General public exposure → rarely**
- **Occupational exposure → up to 2 T**
  several hundred mT in general
- **Medical (patient) → magnet field strength**

Man made sources

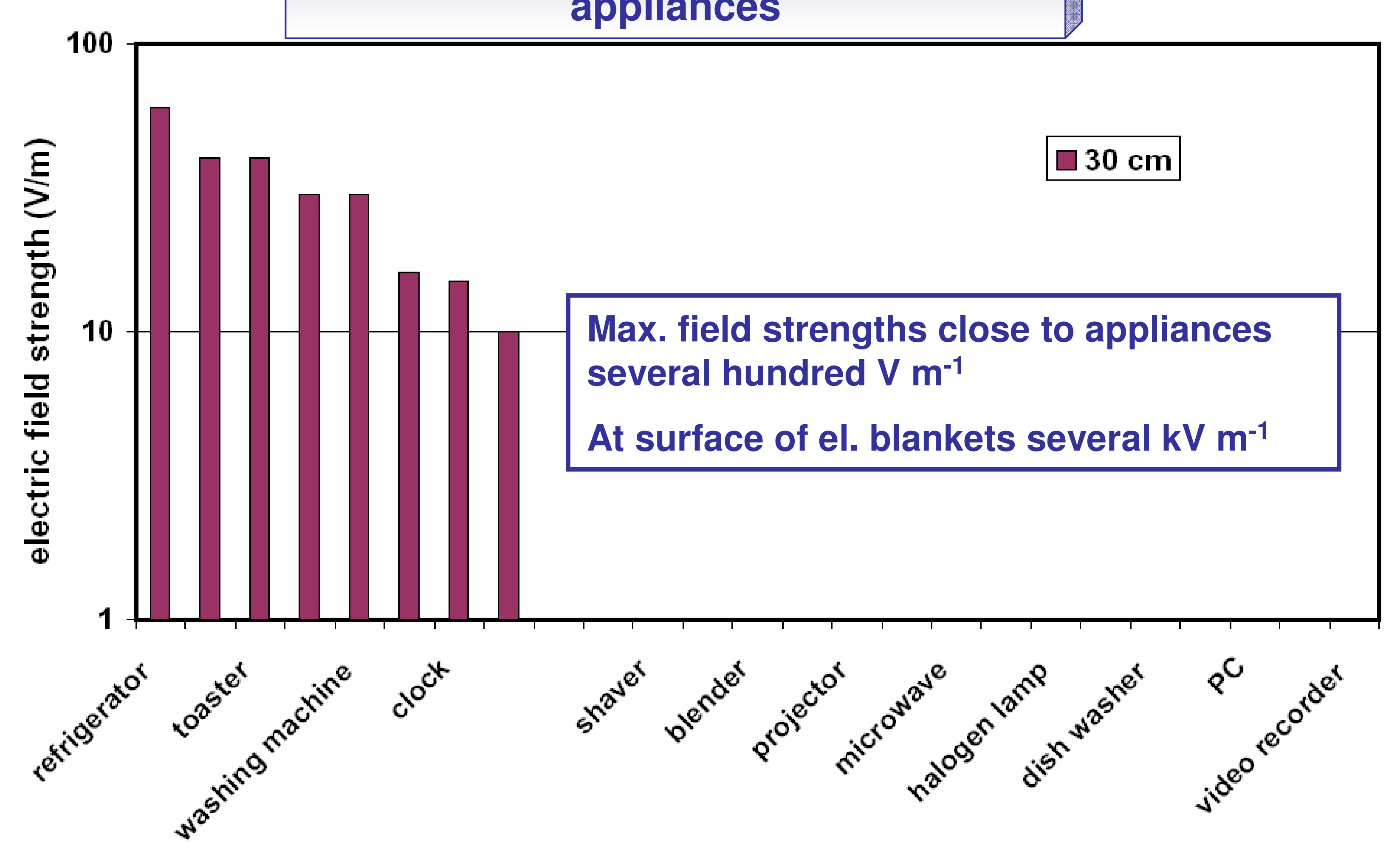
Static magnetic fields

	Industry		Transport	Energy distribution
General public	(hobby)	few mT	Maglev 0,05 – 1000 mT Trains 0,1 – 1 mT Tram 0,01 – 0,4 mT	few tens of µT
Occupational	Aluminium Chlor-alkali Welding Heavy	< 60 mT < 20 mT < 5 mT < 0,2 mT	0,1 – 15 mT	50 mT

ELF sources
appliances



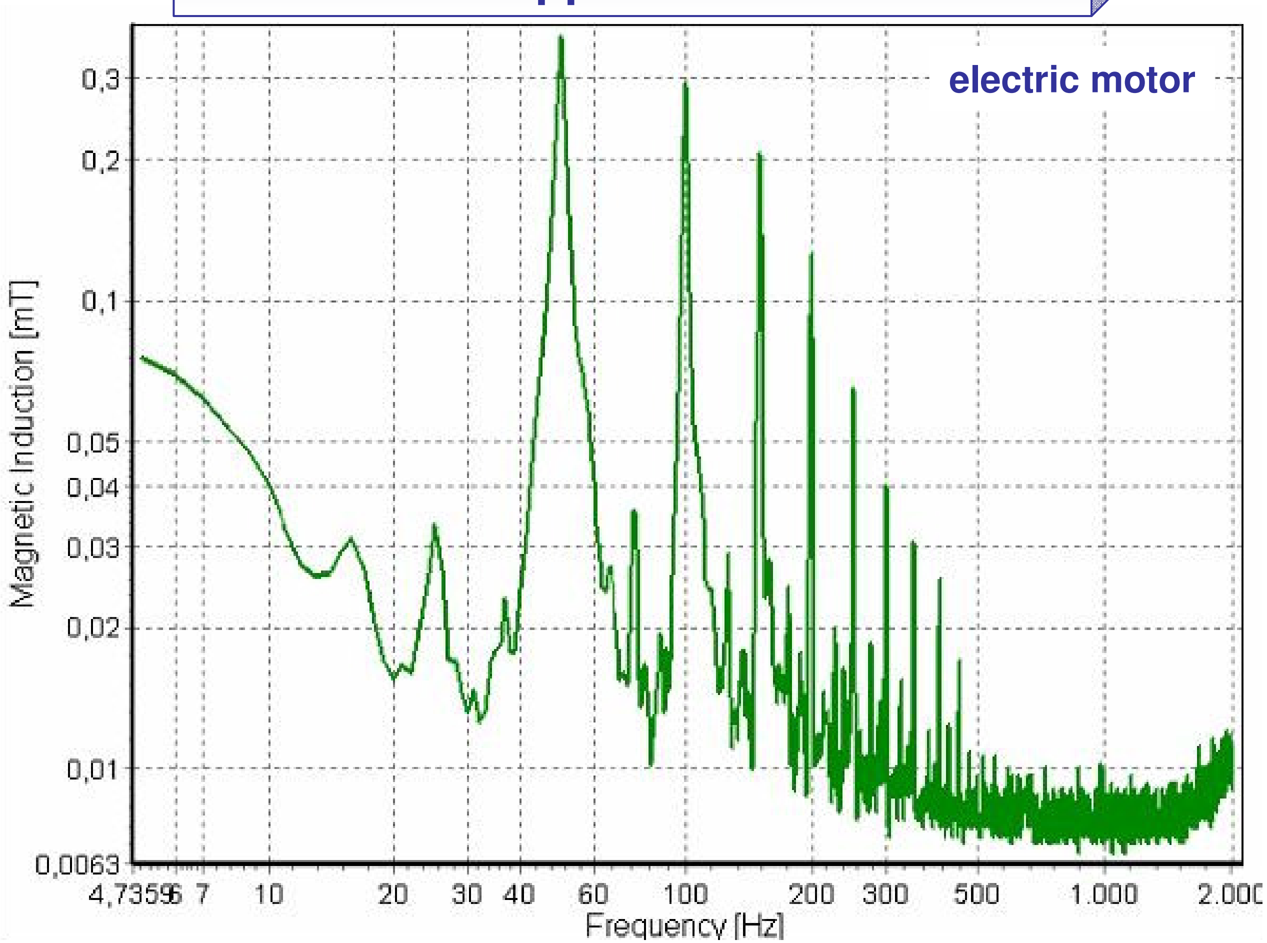
ELF sources
appliances



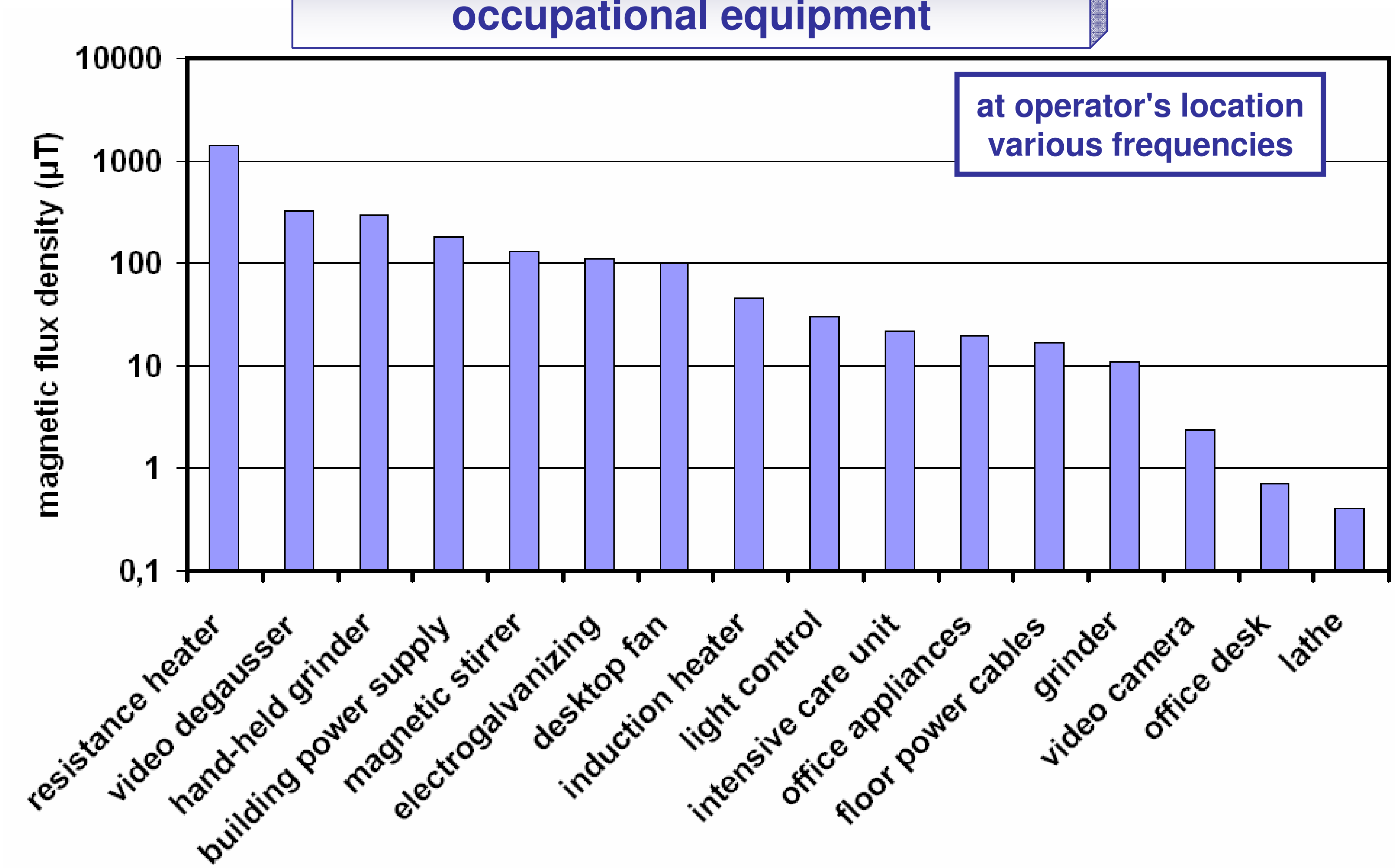
Max. field strengths close to appliances several hundred V m^{-1}

At surface of el. blankets several kV m^{-1}

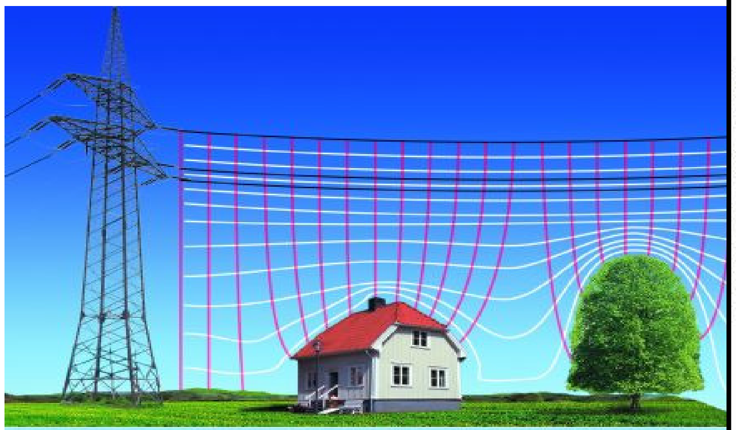
ELF sources
appliances

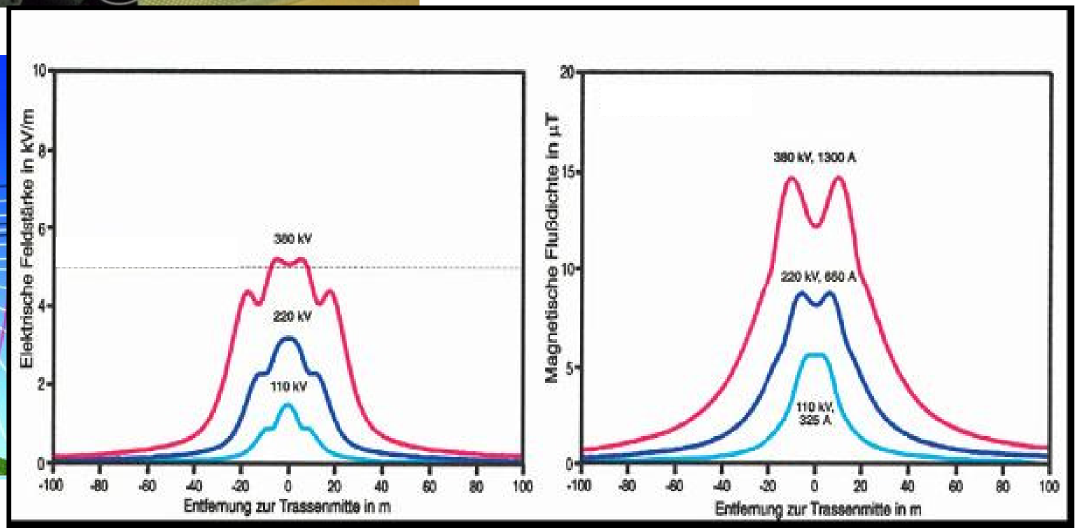


ELF sources
occupational equipment



ELF sources
electric power distribution





ELF sources
electric power distribution

Source	Typical electric field strength (Vm^{-1})	Comment
Overhead power lines	1 000 – 10 000	High exposure only outdoors below the line
	up to 30 000	Occupational (e.g. climbing a tower)
Underground cables	0	Usually screened
Substations	~ 0	Usually housed or fenced
House wiring	< 100	On average; very inhomogeneous
Outlet	700	On surface, 60V/m in 10 cm
Electro cable (2wire)	40	On surface of isolation

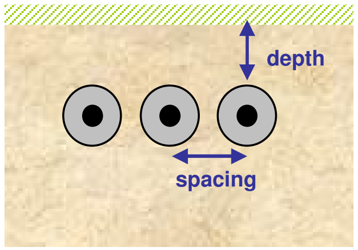
ELF sources

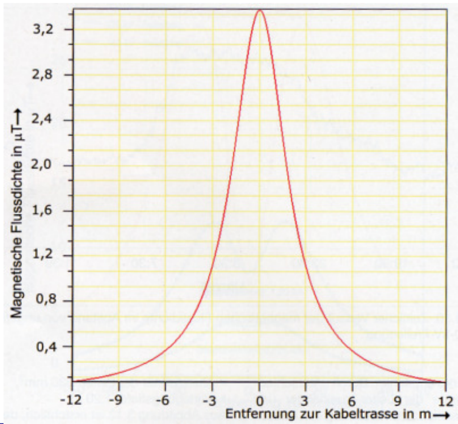
electric power distribution

Source	Magnetic flux density (µT)	Comment
UK overhead transmission line		
400 kV (2 kA)	40 (8)	beneath line (25 m lateral displacement)
275 kV (1 kA)	22 (4)	
overhead distribution lines		
132 – 11 kV	7	
415 V	1	
US overhead transmission line		
500 kV	18,3 (2,7)	beneath line (25 m lateral displacement)
230 kV	11,8 (1,5)	
115 kV	6,3 (0,4)	
Substation		
275 and 400 kV	10	at perimeter fence
11 kV	1,6	

ELF sources
electric power distribution

Voltage	Geometry of underground cable system	Typical magnetic flux densities 1 m above ground (µT)			
		0 m	5 m	10 m	20 m
400 / 275 kV	0.5 m spacing;0.9 m depth	96	13	3.6	1
132 kV	0.3 m spacing;1 m depth	9.6	1.3	0.36	0.1
132 kV	1 m depth	5	1.8	0.94	0.47
33 kV	0.5 m depth	1	0.29	0.15	0.07
400 V	0.5 m depth	0.5	0.14	0.07	0.04

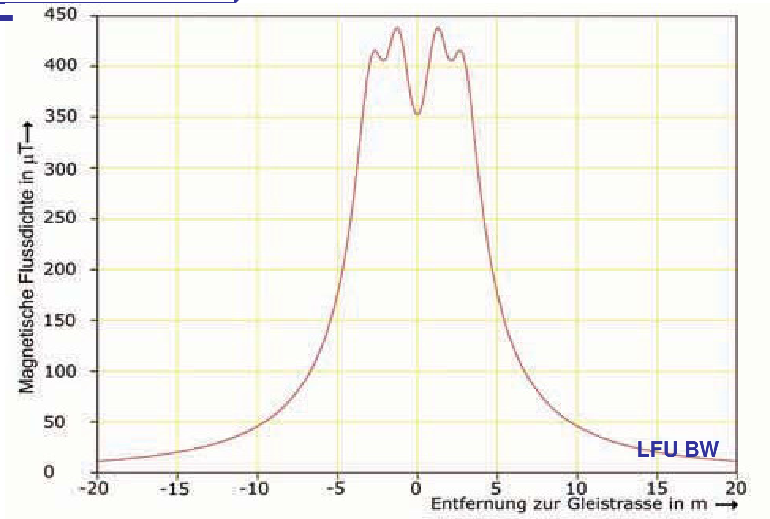




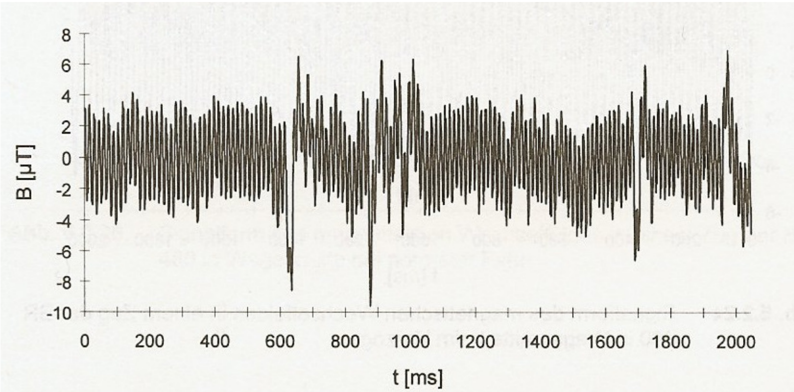
Verbund (Österreichische Elektrizitätswirtschafts-AG)

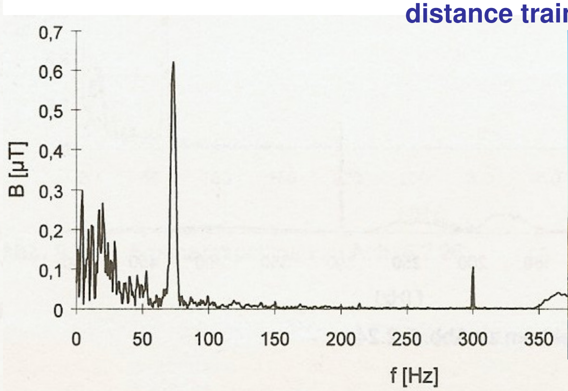
ELF sources
transport

Suburban train UK	up to 1 mT	floor level
100 Hz	16 – 64 µT	passenger
	16 – 48 µT	on platform
Mainline train	up to 15 mT	close to engine parts
	Up to 2,5 mT	equipment car
	< 50 µT	passenger coaches
Long distance train,	0.3 – 290 µT	passengers
Finland	10 – 6000 µT	Close to engine parts
underground	up to 20 µT	drivers cabin
Local city line	tens of µT	on platform



Magnetic field close to rails for a German long distance train.





INTERNATIONAL COMMISSION ON NON-IONIZING RADIATION PROTECTION ICNIRP

Bundesamt für Strahlenschutz

ELF sources
miscellaneous

Source	Magnetic flux density (µT)	Comment
Petrol engine devices	up to a few hundred	at operator’s position
Mobile phones	50	at 1 cm
Cars	0.02 – 4 13	different locations peak
Tires	500 2	close to the tire inside car
EAS inside gate	146	73 Hz; EM; 31.5 cm
	93	230 Hz; EM; 42 cm
Under floor heating	a few – a few hundred	depending on design
Induction hobs	a few	30 cm; up to 40 µT in 1 cm
		20-100 kHz

ELF sources
exposure

I general exposure result from use of electricity (50/60 Hz, etc.) but may contain harmonics, transients and other frequencies (occupational)

Average electric fields in homes:

		≈ 10 Vm^{-1}
Local peak		up to 1000 Vm^{-1}

Average magnetic fields in homes (geom. mean):

	Europe	0,025 – 0,07 µT
	USA	0,055 – 0,11 µT
local peak values		several hundred µT

Average magnetic fields at workplaces depend strongly on the occupation

	electricians	≈ 0,4 – 0,6 µT
	train drivers	≈ 3 µT
Local peak values		up to approx. 10 mT

Summary

- The dominant sources of exposure are man made.
- Static and ELF sources are associated with the generation, distribution and use of electricity.
- Since the use of electricity is an integral part of our modern lifestyle, power-frequency fields are ubiquitous in our environment.
- Special sources, in some workplaces and in medicine, use other frequencies
- Instantaneous magnetic-field values (close to sources) can be orders of magnitude higher than average values.
- Only few data exist on average residential exposure to electric fields.
- Average residential exposure to power-frequency magnetic fields does not vary dramatically across the world.
- The average exposure to magnetic fields in the workplace is job specific and has been found to be higher in “electrical” than in other occupations.

Many thanks for your attention !!!