

Developing and Implementing Protective Measures for ELF EMF - Sources and exposures-

**Rüdiger Matthes
Federal Office for Radiation Protection
Germany**

Non-ionising Radiation

Ionising Radiation

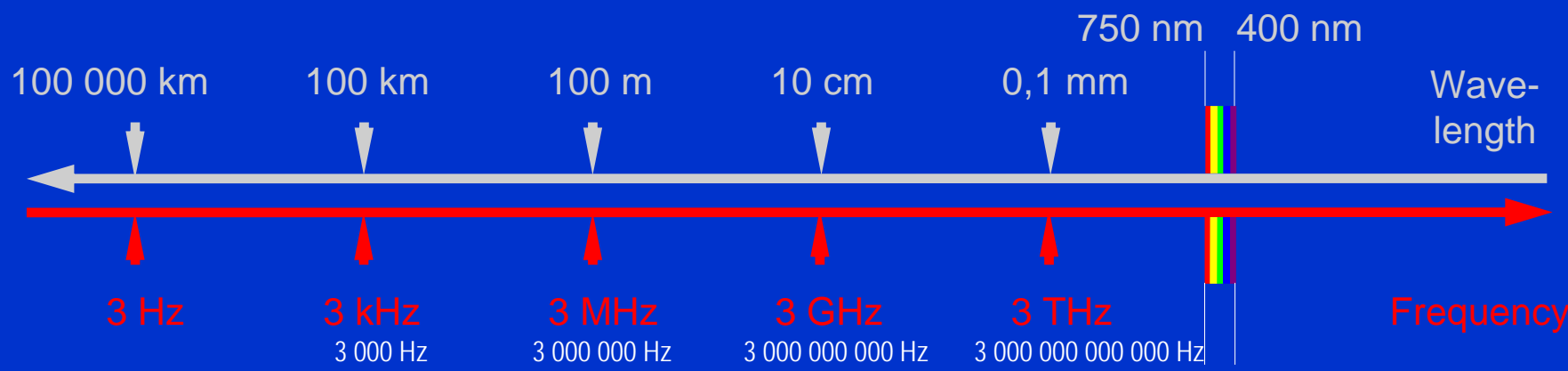


Slowly varying Fields
ELF VF VLF LF

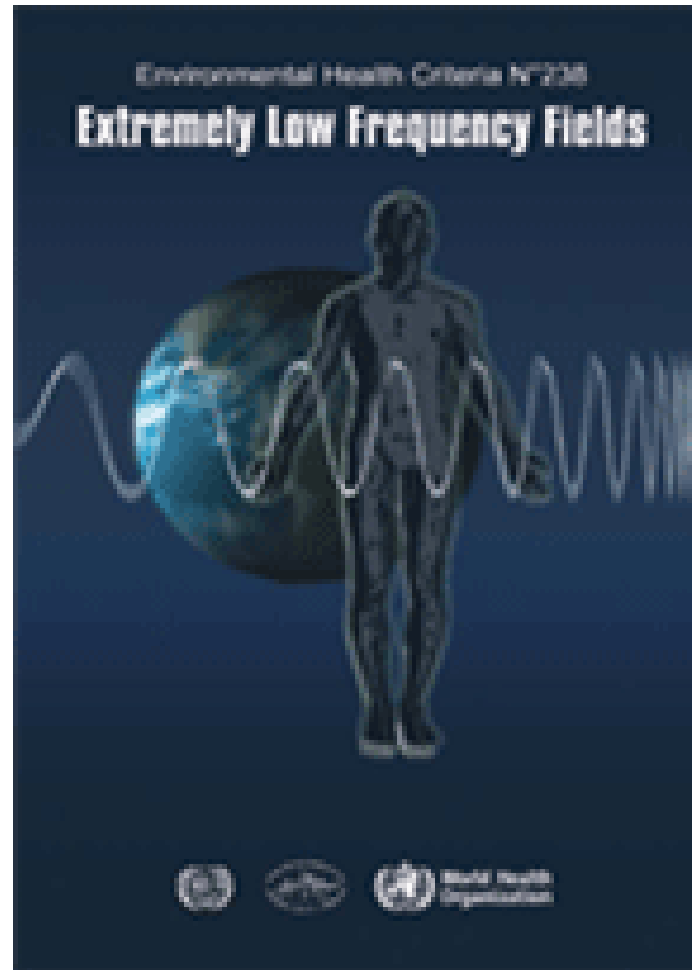
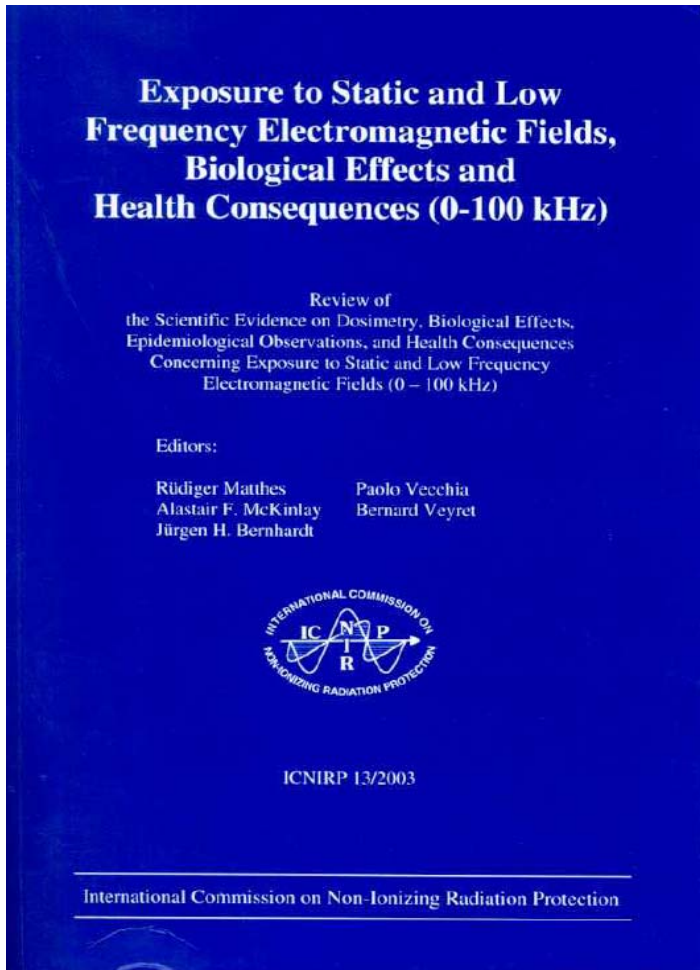
RF Fields
Radiowaves Microwaves

Optical Radiation
IR Light UV

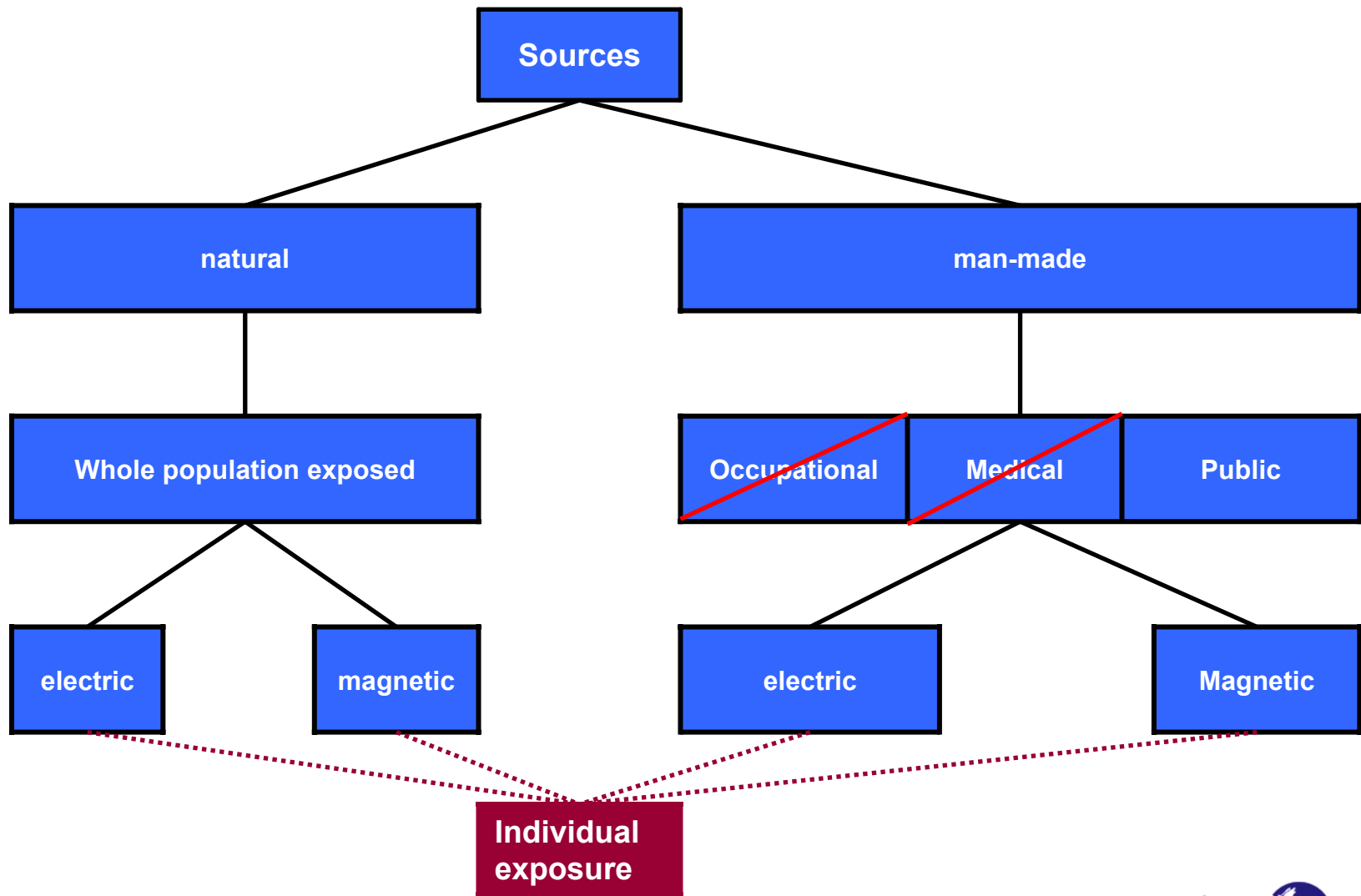
X-Ray →
Gamma →



International Reviews



Sources and exposure in the ELF range



Electric and magnetic fields in the environment

- Fields are vector quantities (polarisation)
- Fields are often not single frequency (harmonics)
- Fields may have complex time course (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 (e.g. power lines)
- Fields can be disturbed by the environment (especially E-fields)

Characteristics of the earth's electric field in the ELF range

Frequency range (Hz)	Electric field strength (Vm ⁻¹)	Comment
0.001 – 5	0.2 - 10 ³	Short duration pulses of magneto hydrodynamic origin
7.5-8.4 and 26-27	(0.15-0.6) · 10 ⁻⁶	Quasi-sinusoidal pulses of undetermined origin
2-1000	10 ⁻⁴ - 0.5	Related to atmospheric changes

Characteristics of the earth's magnetic field

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

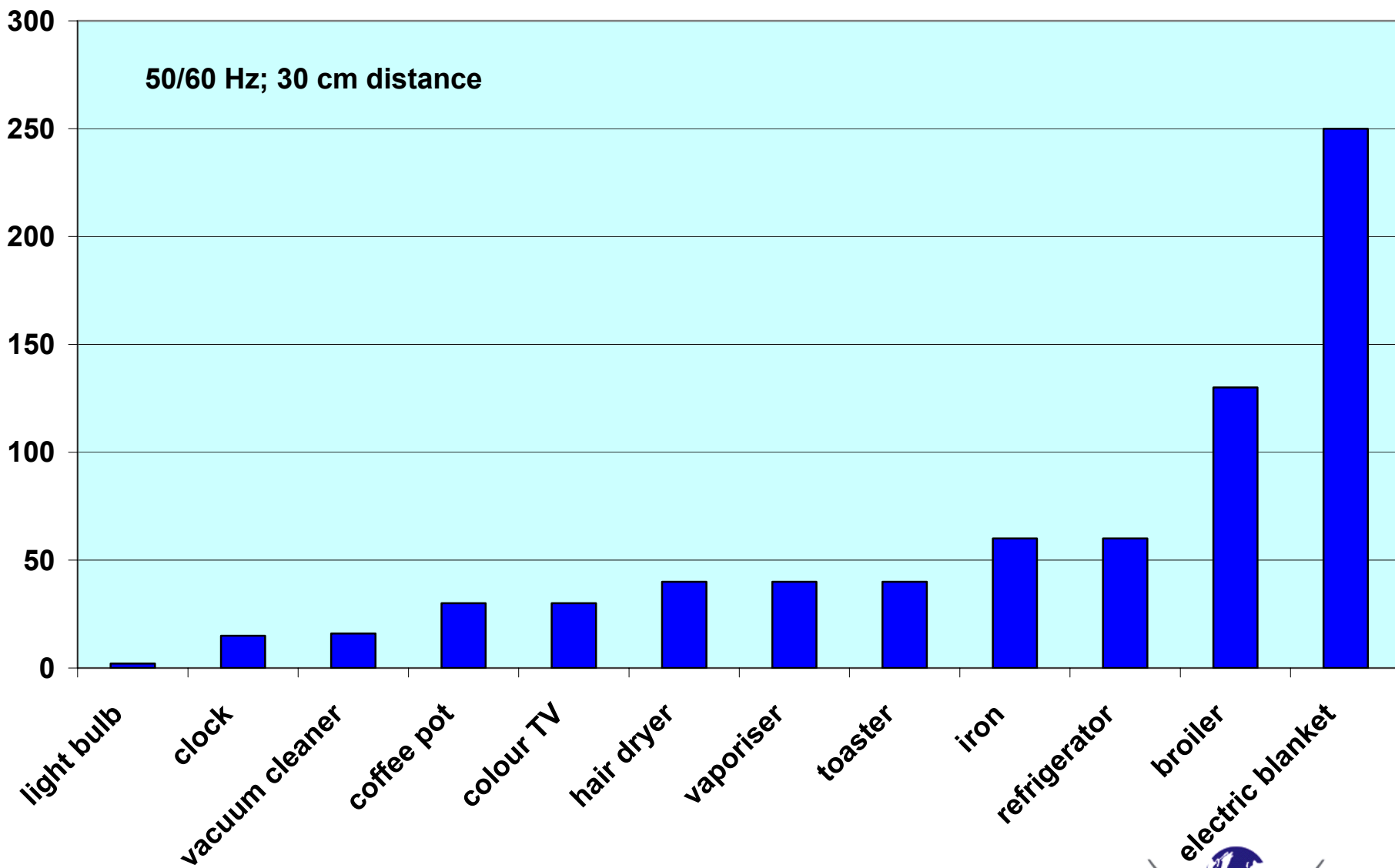
Man-made sources of electric fields

Source	Typical electric field strength (Vm^{-1})	Comment
Overhead power lines	1 000 – 10 000	High exposure only outdoors below the line
Underground cables	0	Usually screened
Substations	~ 0	Usually housed or fenced
House wiring	< 100	On average; very inhomogeneous, everybody exposed
Outlet	700	On surface, 60V/m in 10 cm
Electro cable (2wire)	40	On surface of isolation
Electric trains	< 10	Inside train

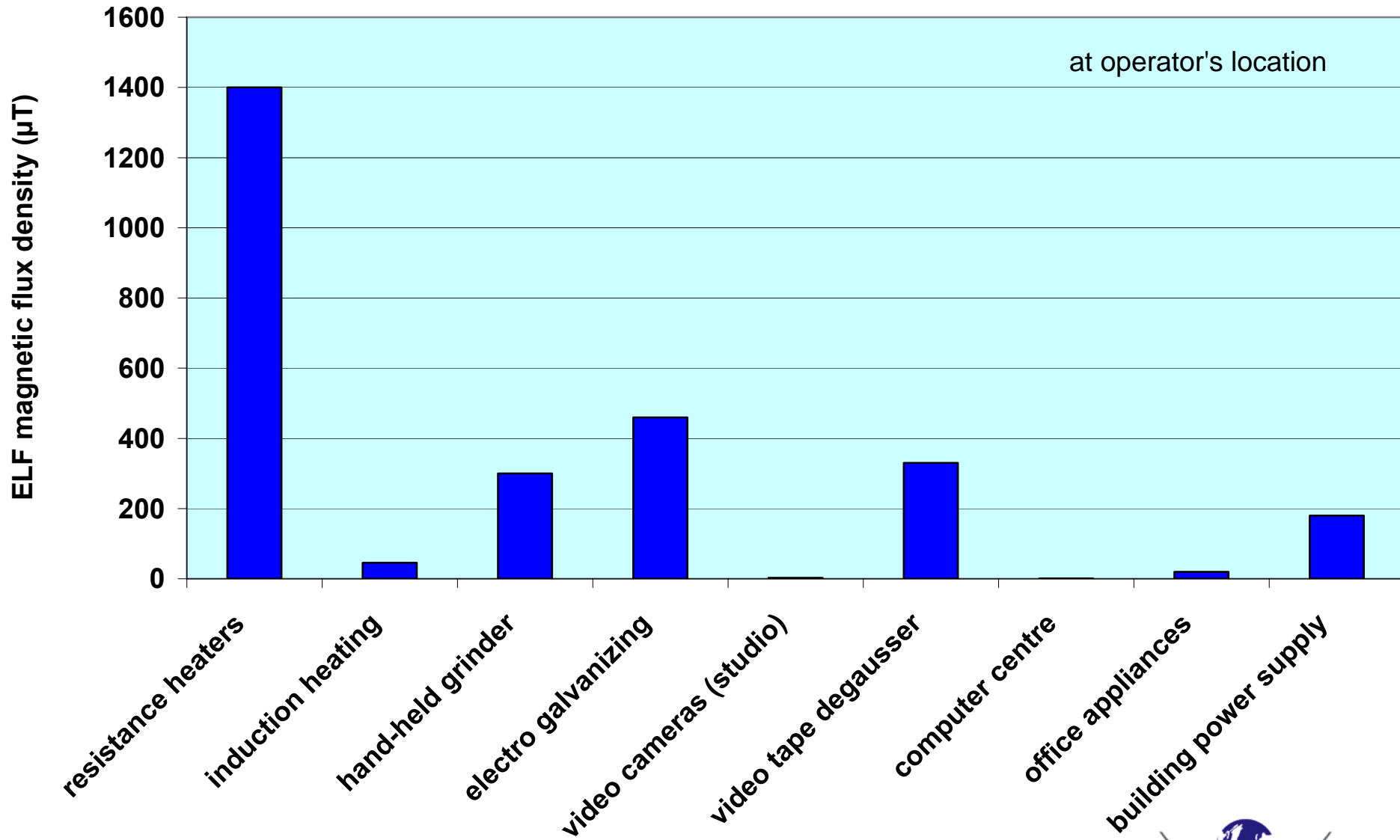
Domestic sources of electric fields

50/60 Hz; 30 cm distance

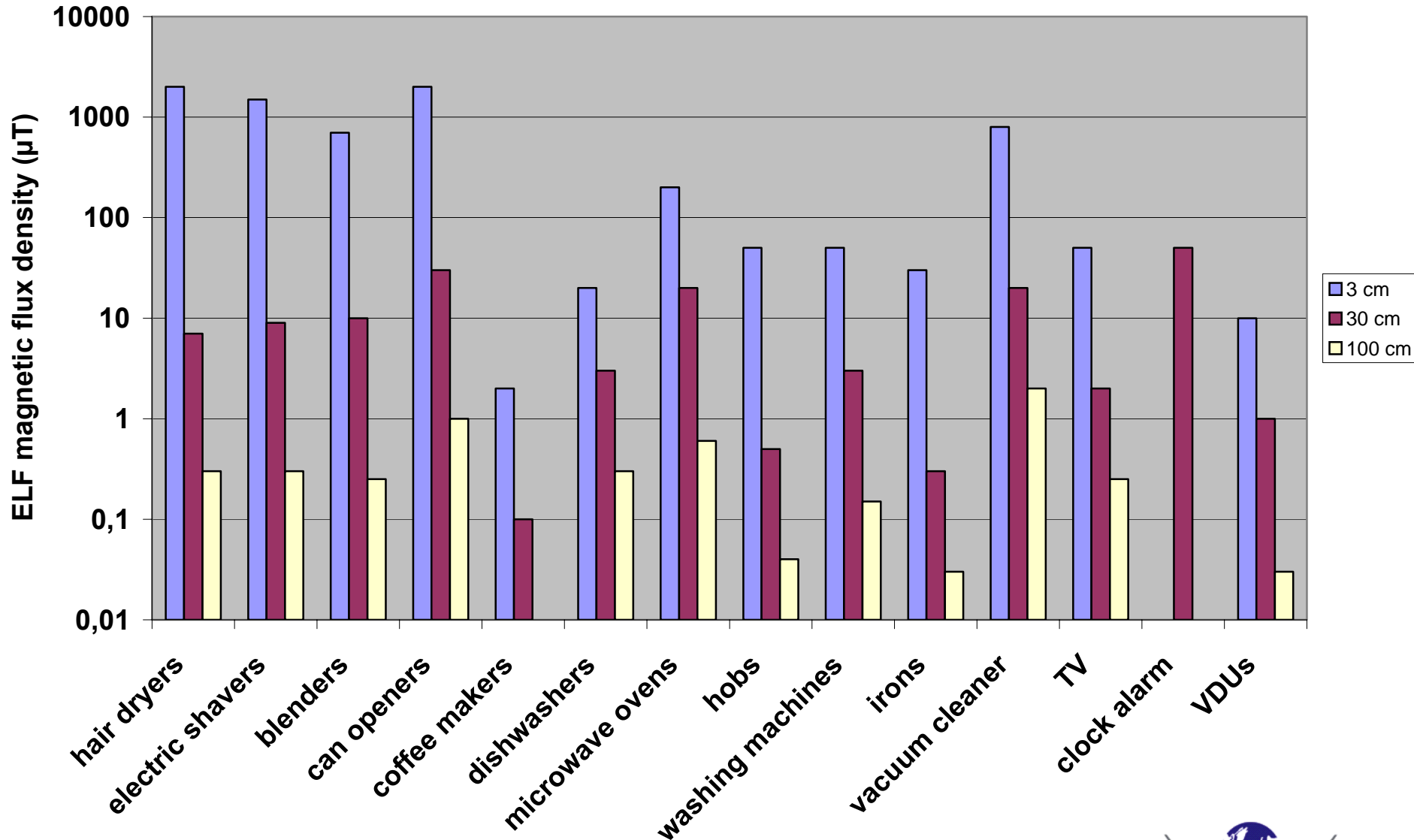
Typical electric field strength (V/m)



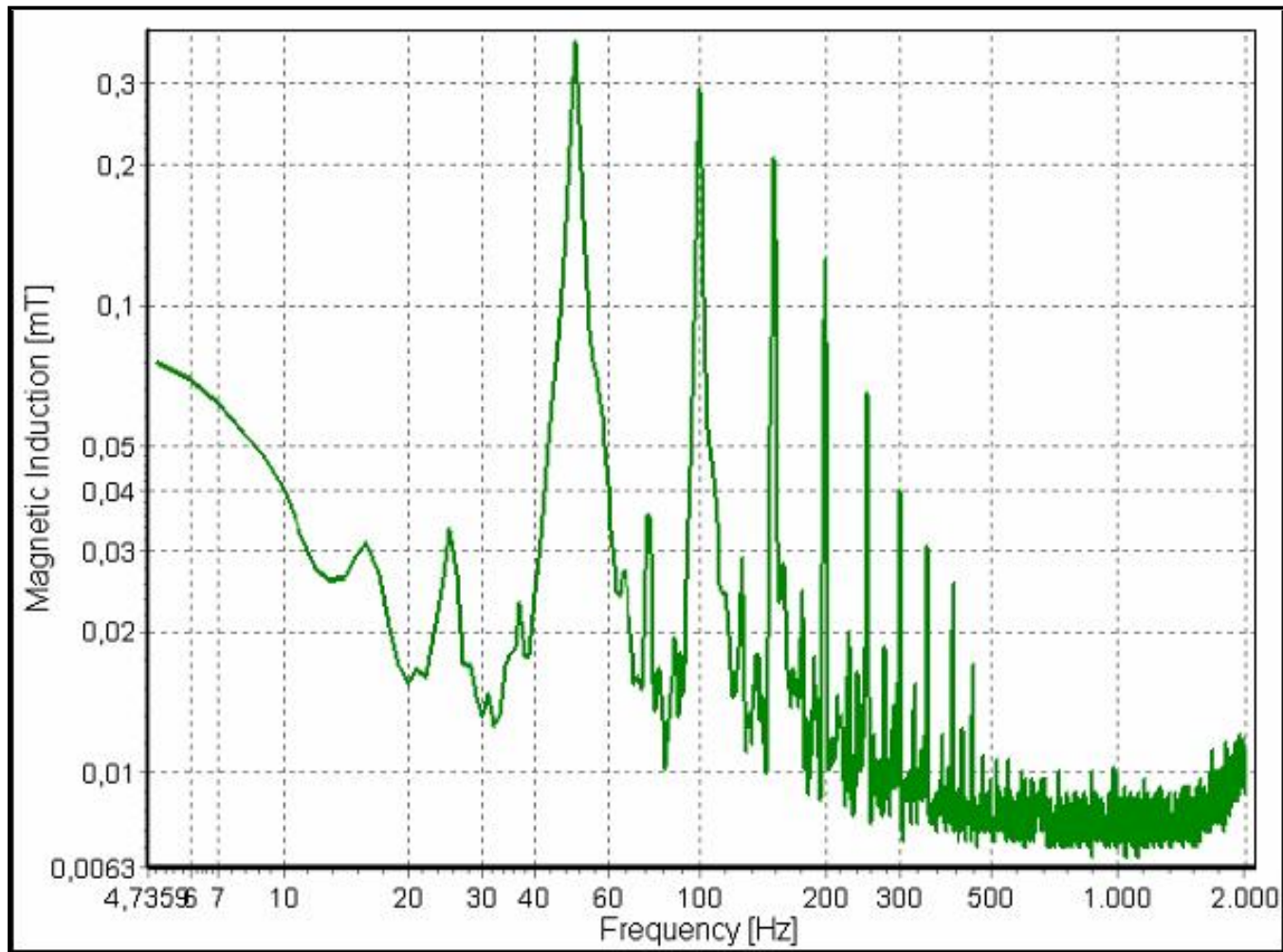
Occupational sources of magnetic fields



Domestic sources of magnetic fields



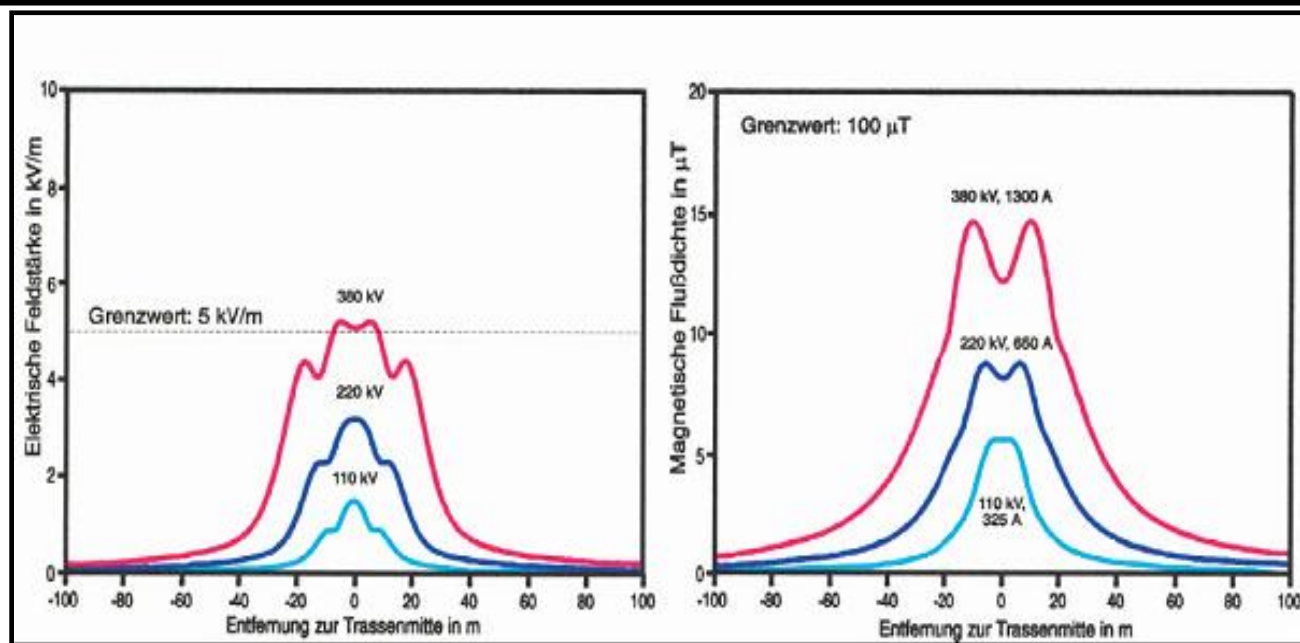
Electric engine



Magnetic fields from power transmission lines

Overhead

Voltage	Maximum on right-of-way	Average magnetic flux densities (μT)			
		at 15 m	at 30 m	at 60 m	at 90 m
115 kV	3	0.7	0.2	0.04	0.02
230 kV	5.8	2	0.7	0.18	0.08
500 kV	8.7	2.9	1.3	0.32	0.14



| Verantwortung für Mensch und Umwelt | ■ ■ ■ ■ ■ ■ ■

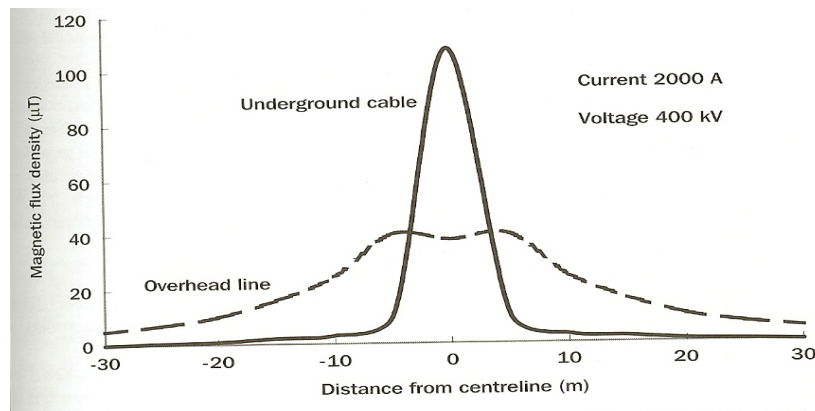


Bundesamt für Strahlenschutz

Magnetic fields from power transmission lines

Underground

Voltage	Geometry	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



Magnetic fields from miscellaneous sources

Various frequencies

Source	Magnetic flux density (μT)	Comment
Petrol engine devices	up to a few hundred	at operator's position
Mobile phones	50 μT	at 1 cm
Cars	0.02 – 4 13	different locations peak
Tires	500 2	close to the tire inside car
EAS inside gate	146 93	73 Hz; EM; 31.5 cm 230 Hz; EM; 42 cm
Suburban train UK	16 - 64	100 Hz in passenger car
Long distance train, Finland	0.3 - 290	passengers
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

Summary on man-made fields

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

Average electric fields in homes: **several tens of Vm^{-1}**
Local peak **up to 1000Vm^{-1}**

Average magnetic fields in homes (geom. mean):

	Europe	0,025-0,07 μT
	USA	0,055-0,11 μT
local peak values		several hundreds of μT

Average magnetic fields at workplaces depend strongly on the occupation

Local peak values **up to approx. 10mT**

Exposure of people

Relevant exposure metric still uncertain.

Average over time generally used to describe exposure.

Guidelines limit instantaneous local field level.

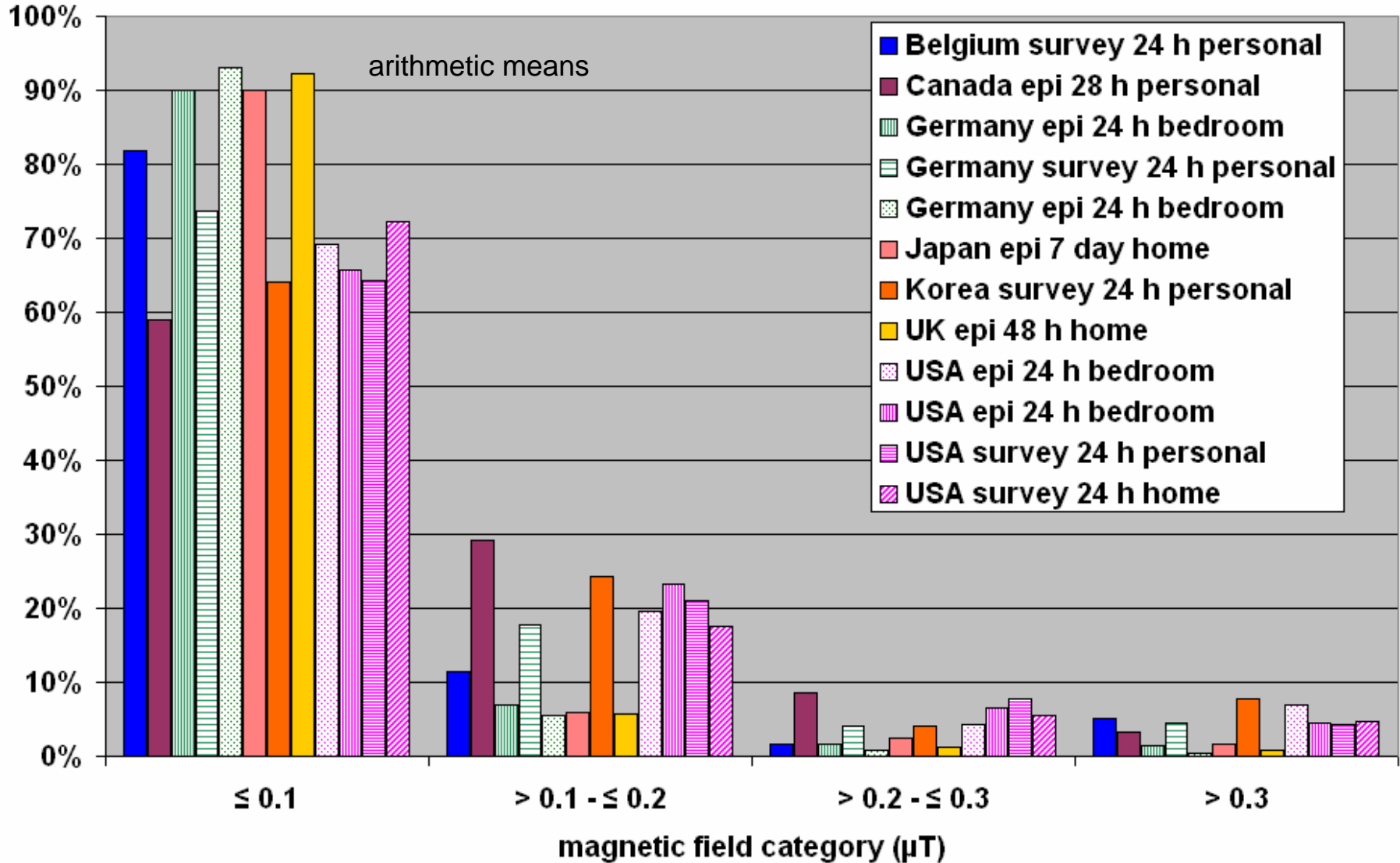
Localised field levels (appliances) contribute only a fraction to average exposure.

- Exposure depends largely on individual situation and behaviour
- Low general exposure from natural fields and man-made background

Factors that increase average exposure

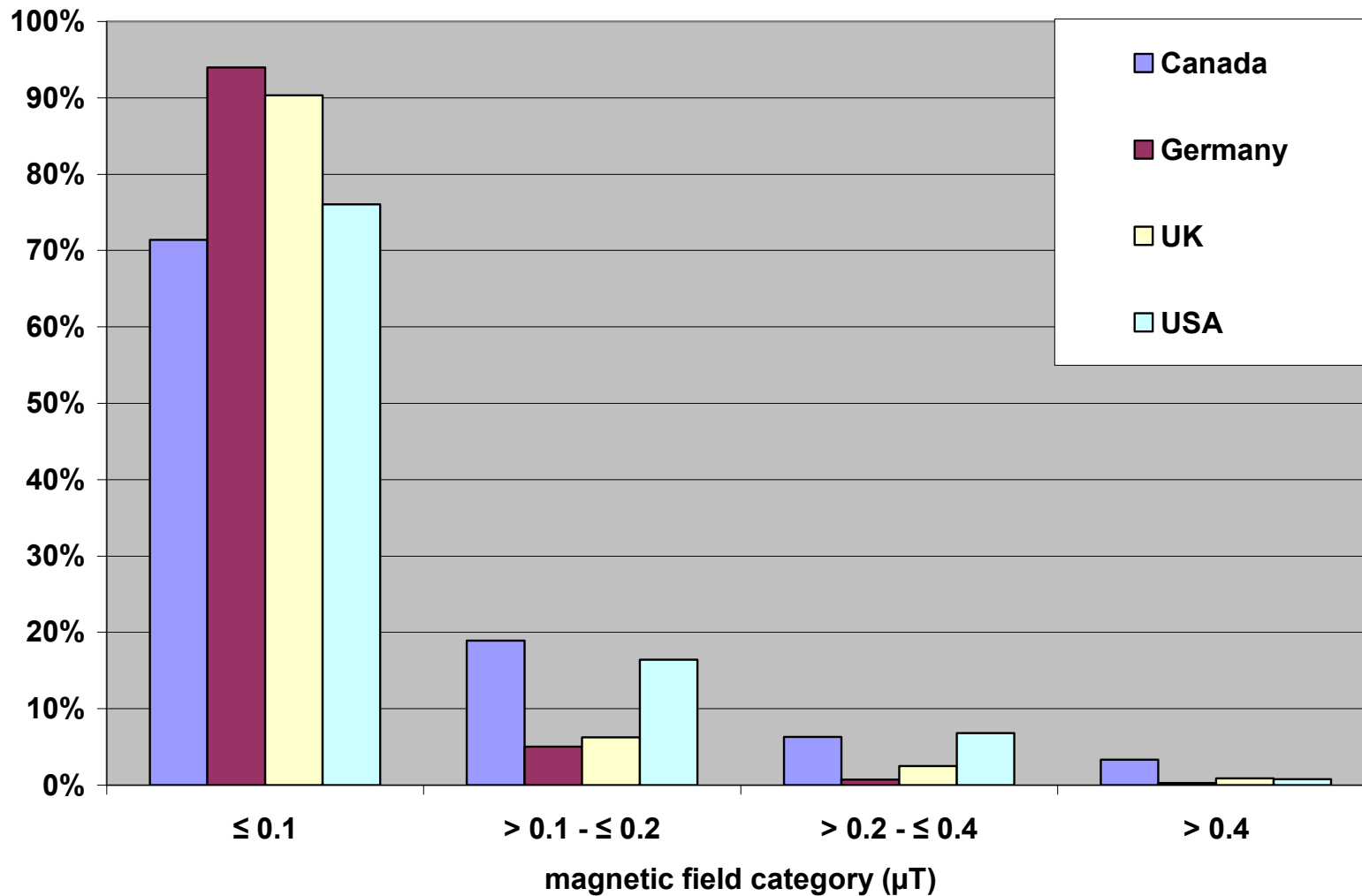
- Long stay close to installations that operate at high currents
- Using electric machines or appliances regularly for a long time (parts of the body)
- Using electric powered transportation systems for longer distances
- Certain occupations

Results from exposure assessments



Results from exposure assessments

Night time



Personal exposure vs. background fields

Country	Subjects	Sample	Personal exposure (nT)	Background field (nT)	Ratio
USA	Adults at home	15	134	58	2.3
	Adults at home, not in bed	396	111	74	1.5
	Children residential	29	96	99	1.0
	Children	31	96	67	1.4
Canada	Children at home	31	117	107	1.1
	Adults at home	31	133	107	1.2
UK	Adults at home	204	54	37	1.5
	Adults	44	42	29	1.5

geometric mean

Conclusions

- **ELF fields from natural sources are generally low**
- **ELF fields from use of electricity ubiquitous**
- **Electric fields easily screened (or disturbed). High field strengths in everyday life rare**
- **Magnetic fields close to some appliances high (temporal, local)**
- **Exposure metric unknown (average over time used)**
- **Contribution of different sources to total exposure complex**
- **Residential exposure does not vary much across the world**
- **High exposure category rare**