Electromagnetic fields and childhood cancer

Prof. Dr. Martin Röösli
# The electromagnetic spectrum

<table>
<thead>
<tr>
<th>Force</th>
<th>cell and nerve stimulation</th>
<th>heating</th>
<th>photo-chemistry</th>
<th>Ionisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>static</td>
<td>extremely low frequency</td>
<td>radio frequency / microwave</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Wave length</th>
<th>3000km</th>
<th>30km</th>
<th>300m</th>
<th>3m</th>
<th>3cm</th>
<th>0.3mm</th>
<th>3µm</th>
<th>30nm</th>
<th>0.3nm</th>
<th>3pm</th>
<th>30fm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency in Hertz (Hz)</td>
<td>10^2</td>
<td>10^4</td>
<td>10^6</td>
<td>10^8</td>
<td>10^10</td>
<td>10^12</td>
<td>10^14</td>
<td>10^16</td>
<td>10^18</td>
<td>10^20</td>
<td>10^22</td>
</tr>
</tbody>
</table>

- Non-ionizing radiation
  - extremely low frequency
  - radio frequency / microwave

- Ionizing radiation
  - infrared
  - ultraviolet
  - X-ray/radioactive
  - visible light
RF EMF exposure change over time

Mobile phone subscribers per 100 inhabitants

(ITU, 2015)
Content

- RF-EMF exposure in the general environment
- Brain tumours and mobile phone use
- Childhood cancer and exposure from transmitter
- Childhood leukaemia and ELF-MF (power lines, etc)
RF-EMF: Two types of exposure

- close to body (near field)
  - mobile phone (uplink)
  - cordless phone

- environmental (far field)
  - W-LAN
  - broadcast transmitter
  - mobile phone base station (downlink)
  - Other people’s mobile and cordless phones (uplink)
Radiofrequency exposure measure

- **Far-field exposure**
  Electric field (E) in V/m
  (sometimes called incident field)
  ICNIRP regulatory limits for mobile phone radiation: <61 V/m

- **Near-field exposure**
  SAR in W/kg: Specific absorption rate.
  Regulatory limits for mobile phones: 2 W/kg
Heat effect of mobile phone use

- Exposure condition: GSM900, SAR=0.8 W/kg for 30 minutes:
  - ~1.5 °C due to insulation, ~0.7 °C due to electrical power dissipation (battery), no additional RF heating.
- Other studies reported 0.1-0.2 °C from RF heating

Sträume et al., BioEM, 2005
### SAR-value

<table>
<thead>
<tr>
<th>Vorkommen</th>
<th>Grössenordnung</th>
<th>Temperaturanstieg (nach 30 min.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sport, Spitzenwert</td>
<td>20 W/kg</td>
<td>&gt;1°C</td>
</tr>
<tr>
<td>Grundumsatz</td>
<td>1 W/kg</td>
<td>nein</td>
</tr>
<tr>
<td>starkes Ganzkörper Hochfrequenzfeld</td>
<td>4 W/kg</td>
<td>1°C</td>
</tr>
<tr>
<td>Grenzwert Handy (lokales Maximum)</td>
<td>2 W/kg</td>
<td>0.15°C</td>
</tr>
<tr>
<td>Grenzwert* berufliche Exposition</td>
<td>0.4 W/kg</td>
<td>0.1 °C</td>
</tr>
<tr>
<td>Grenzwert* Bevölkerung</td>
<td>0.08 W/kg</td>
<td>&lt;0.1 °C</td>
</tr>
</tbody>
</table>
ZüMe: Population based personal radiofrequency electromagnetic field exposure measurements in Zurich

- Random population sample from 12 communities from canton of Zürich (Switzerland) with various degrees of urbicity
- 42 pairs of one parent and adolescent (12-15 years) and 30 young adults (18-30 years)
- Measurement device ExpoM-RF: 14 frequency bands between 88 MHz – 2690 MHz
- Electronic diary app, GPS recorded by Expom-RF
Average source contributions (mean=0.18 V/m)

Röösli et al, 2016
RF-EMF per activity

- **At home**: 0.11 V/m (5039 h, n = 115)
- **School**: 0.15 V/m (465 h, n = 49)
- **Work place**: 0.22 V/m (541 h, n = 46)
- **Outdoor**: 0.30 V/m (387 h, n = 109)
- **Train**: 0.55 V/m (75 h, n = 44)
- **Tram**: 0.33 V/m (28 h, n = 30)
- **Bus**: 0.39 V/m (43 h, n = 34)
- **Car**: 0.29 V/m (190 h, n = 69)
- **Others**: 0.32 V/m (409 h, n = 91)

**Power flux density [µW/m²]**

- **Uplink**
- **Downlink**
- **Broadcast**
- **DECT**
- **WLAN**

**Electric field [V/m]**

- **0 to 0.6 V/m**

**SCCR symposium Bern, 08-09 Sept. 2016**

Martin Röösli
RF-EMF dose calculation

Near-field

Far-field

\[ \sum \text{dose} = \text{output power} \times \text{SAR} \times \text{use duration} \]

\[ \text{dose} = \text{incident field} \times \text{SAR} \times \text{exposure duration} \]

SAR = normalized Specific Absorption Rate

RF-EMF = radiofrequency electromagnetic fields

Roser et al., IJERPH, 2015

brain

whole body
Average wireless device use in Züme

- Calls with mobile phones: 5.2 Min/day (8% with headset/speaker)
- Calls with cordless phones: 4.8 Min/day
- Mobile data traffic on mobile phone: 19.0 Min/day
- WLAN data traffic on mobile phone: 33.3 Min/day
- Mobile phone transmission on the body in stand-by mode: 1.2 Min/day
- WLAN Use on computer: 9.8 Min/day; with Laptop: 50.2 Min/day; with Tablet: 15.6 Min/day; game console: 2.4 Min/day.
- Mean measured far field exposure as presented before
Average cumulative dose

**Brain**

- Mobile phone calls: 600 mJ/kg/day
- Cordless phone calls: 200 mJ/kg/day
- Mobile data traffic: 96.2%
- Mobile phone stand-by data traffic: 3.8%

**Whole body**

- Broadcasting: 200 mJ/kg/day
- Mobile phone base stations: 89.8%
- WLAN access points: 10.2%
- DECT cordless phone base stations: 500 mJ/kg/day
- Mobile phones: 450 mJ/kg/day

Legend:
- Blue: Mobile phone calls
- Turquoise: Cordless phone calls
- Green: Mobile data traffic
- Pink: Mobile phone stand-by data traffic
- Red: Broadcasting
- Black: WLAN Computer, laptops, tablets

**Close to body**

- Mobile phone calls: 600 mJ/kg/day
- Cordless phone calls: 200 mJ/kg/day
- Mobile data traffic: 96.2%
- Mobile phone stand-by data traffic: 3.8%

**Far field**

- Broadcasting: 200 mJ/kg/day
- Mobile phone base stations: 89.8%
- WLAN access points: 10.2%
- DECT cordless phone base stations: 500 mJ/kg/day
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Legend:
- Blue: Mobile phone calls
- Turquoise: Cordless phone calls
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- Pink: Mobile phone stand-by data traffic
- Red: Broadcasting
- Black: WLAN Computer, laptops, tablets
**Mobile Phone Use and Brain Tumors in Children and Adolescents: A Multicenter Case-Control Study**

Denis Aydin, Maria Faychting, Joachim Schüz, Tore Tynes, Tina Veje Andersen, Lisbeth Samsø Schmidt, Aslak Harbo Poulsen, Christoffer Johansen, Michaela Prochazka, Birgitta Lannering, Lars Klæboe, Tone Eggen, Daniela Jenni, Michael Grotzer, Nicolas Von der Weid, Claudia E. Kuehni, Martin Röösli

Manuscript received February 9, 2011; revised May 27, 2011; accepted June 7, 2011.

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CEFALO: study methods

- Multinational case-control study
- Brain tumor patients 2004–2008
- Age 7–19 years
- 352 case patients, 646 controls (gender, age, geographical region)
- Participation: 71% controls, 83% cases
- Face-to-face interviews with children and parents
Main results CEFALO

- Regular use
  - Odds ratio: 1.36
  - Time since first subscript: $P_{\text{trend}} = 0.001$

- Never regular user
  - Odds ratio: 2.15
Brain tumour incidence in Swedish children

Aydin et al, JNCI, 2011
New study from Australia on adult brain tumours

- 19,858 male and 14,222 females diagnosed with brain cancer between 1982 and 2012 from national cancer registry; mobile phone usage data from 1987 to 2012.

Proportion of mobile phone subscribers:

Observed vs. predicted for 10 years lag time:

Chapman et al, 2016
Dose Züme: assuming max. downlink (0.51 V/m)

Brain

- Mobile phone calls: 69.9%
- Cordless phone calls: 30.1%

Whole body

- Mobile phone calls: 52.3%
- Cordless phone calls: 47.7%

Dose [mJ/kg/day]

- Mobile phone calls
- Cordless phone calls
- Mobile data traffic
- Mobile phone stand-by data traffic
- WLAN Computer, laptops, tablets
- Broadcasting
- Mobile phone base stations
- WLAN access points
- DECT cordless phone base stations
- Mobile phones

SCCR symposium Bern, 08-09 Sept. 2016

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Transmitters and childhood leukemia: research in 2003

<table>
<thead>
<tr>
<th>Studie</th>
<th>Exposition</th>
<th>Intensität [V/m]</th>
<th>Studiengruppen</th>
<th>Anz. Fälle</th>
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<tbody>
<tr>
<td>Sevin et al. 1992</td>
<td>TV/Radiosender</td>
<td>&lt;3,5 km</td>
<td>Cluster</td>
<td>98</td>
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<tr>
<td></td>
<td></td>
<td>1,22</td>
<td>Lymphome Leukämie</td>
<td>0,9 (n.s.)(1,09-1,40)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Leukämien</td>
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</tr>
<tr>
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<td>1,72</td>
<td>akute lymphatische Leukämie</td>
<td>1,32 (n.s.)(1,09-1,59)</td>
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<td>chronische lymphatische Leukämie</td>
<td>1,55 (n.s.)(1,06-2,41)</td>
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<td></td>
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<td>Hodgkin-Lymphom</td>
<td>1,00</td>
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<td></td>
<td></td>
<td>Non-Hodgkin-Lymphom</td>
<td>1,03 (n.s.)</td>
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<tr>
<td>Maskarinec et al. 1994</td>
<td>Radiosender</td>
<td>&lt;4,2 km</td>
<td>Cluster</td>
<td>12</td>
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<td>1,42</td>
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<td>1,0 (n.s.)(1,07-2,34)</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Leukämien</td>
<td></td>
</tr>
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<td>Hoching et al. 1996</td>
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<td>&lt;0,9–5,5 V/m</td>
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<td>Non-Hodgkin-Lymphom</td>
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<td>Dolk et al. 1997b</td>
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<td>&lt;5 V/m</td>
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<td>Non-Hodgkin-Lymphom</td>
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<td>Dolk et al. 1997a</td>
<td>TV/Radiosender</td>
<td>&lt;5 V/m</td>
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<td>Cooper et al. 2001</td>
<td>TV/Radiosender</td>
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<td>Lymphome Leukämie</td>
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<td>Michelozzi et al. 2002</td>
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<td>Lymphome Leukämie</td>
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<td>1,02 (0,95–1,09)</td>
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<td>1,06 (0,85–1,15)</td>
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<td></td>
<td>Non-Hodgkin-Lymphom</td>
<td>1,02 (0,95–1,09)</td>
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</tbody>
</table>

OR=1.55 (1.00-2.41)  
OR=1.32 (1.08-1.62)  
OR=1.58 (1.07-2.33)  
OR=2.09 (1.08-3.65)  
OR=1.23 (1.11-1.36)  
OR=1.03 (n.s.)

- Real risk increase?  
- Publication bias?  
- Surveillance bias?  
- Texas sharpshooter fallacy?

All but one risk estimates >1!

Röösli et al, 2003
Original Contribution

Exposure to Radio-Frequency Electromagnetic Fields From Broadcast Transmitters and Risk of Childhood Cancer: A Census-based Cohort Study

Dimitri D. Hauri, Ben Spycher, Anke Huss, Frank Zimmermann, Michael Grotzer, Nicolas von der Weid, Adrian Spoerri, Claudia E. Kuehni, and Martin Röösli* for the Swiss National Cohort and the Swiss Paediatric Oncology Group
Swiss study on RF-EMF exposure from broadcast transmitters

- Census based cohort study based on data from the Swiss Childhood Cancer Registry (SCCR) and the Swiss National Cohort (SNC).

- All children aged between 0 and 15 years and living in Switzerland on 5 December 2000 (cohort analysis) or any time between 1985-2008 (incident density analysis)

Exposure modelling of 28 major short-wave, medium-wave, very high frequency (VHF) and ultra high frequency (UHF) radio and TV transmitters in Switzerland.

Hauri, AJE, 2014
Modelled exposure to broadcast transmitter

Hauri, AJE, 2014
Cohort analyses (n=997 from 2000-2008): All type of transmitters

Hauri, AJE, 2014
Incident density analysis (n=4,246 cases 1985-2008)

Table 2. Incidence Rate Ratio for Cancer Among Children Under Age 16 Years in Incidence Density Cohort Analysis, by Exposure Category and Time Period, Switzerland, 1985–2008

<table>
<thead>
<tr>
<th>Cancer Type and Exposure Category</th>
<th>1985–2008</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No. of Cases</td>
</tr>
<tr>
<td>All cancers, V/m</td>
<td></td>
</tr>
<tr>
<td>&lt;0.05</td>
<td>3,591</td>
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<tr>
<td>0.05–0.2</td>
<td>511</td>
</tr>
<tr>
<td>&gt;0.2</td>
<td>144</td>
</tr>
<tr>
<td>All types of leukemia, V/m</td>
<td></td>
</tr>
<tr>
<td>&lt;0.05</td>
<td>1,149</td>
</tr>
<tr>
<td>0.05–0.2</td>
<td>138</td>
</tr>
<tr>
<td>&gt;0.2</td>
<td>39</td>
</tr>
<tr>
<td>Acute lymphoblastic leukemia, V/m</td>
<td></td>
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<tr>
<td>&lt;0.05</td>
<td>917</td>
</tr>
<tr>
<td>0.05–0.2</td>
<td>112</td>
</tr>
<tr>
<td>&gt;0.2</td>
<td>33</td>
</tr>
<tr>
<td>CNS tumors, V/m</td>
<td></td>
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<tr>
<td>&lt;0.05</td>
<td>718</td>
</tr>
<tr>
<td>0.05–0.2</td>
<td>108</td>
</tr>
<tr>
<td>&gt;0.2</td>
<td>33</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; CNS, central nervous system; IRR, incidence rate ratio.

<sup>a</sup> Adjusted for age, calendar year, and sex.

Hauri, AJE, 2014
Conclusions: transmitters and childhood leukaemia

- 2003: (Small) ecological studies on childhood leukaemia
  - most ecologic studies found increased risk
    (eg. Dolk et al., 1997, Hocking et al., 1996, Michelozzi et al., 2002)

- 2016: Four (large) case-control studies:
  - no association between RF-EMF exposure and leukaemias other childhood tumours (Merzenich et al., 2008, Ha et al., 2007, Elliott et al, 2010, Hauri et al, 2014)
Childhood leukaemia: ELF-MF $\geq 0.3$ µT vs $<0.1$ µT vs.

- 2 studies without exposed controls and 2 studies without exposed cases not shown.
- Test of heterogeneity: $I^2=0.0\%$, $p=0.86$
Arimmora risk evaluation: childhood leukaemia and ELF-MF

If causal, 1 excess case per year in Switzerland
Cancer registries are important for public health

- Complete registry information allows monitoring for new emerging exposure (mobile phone)
- Information of place of residence is needed for environmental exposures
- Large sample size are needed for small risks
- SCCR contributed significantly to EMF research evidence
- IARC: ELF-MF and RF-EMF «Possibly Carcinogenic to Humans (Group 2B)»:
  - Limited evidence of carcinogenicity in humans and less than sufficient evidence of carcinogenicity in experimental animals
- No link between EMF and childhood cancer established
Uncertainty over time
Many thanks!

- All my colleagues
- Swiss National Cohort Study Group
- Swiss Paediatric Oncology Group
UMTS phones emit **100-500 times less** than GSM phones!

### GSM:

<table>
<thead>
<tr>
<th>Study centre</th>
<th>900 MHz</th>
<th>1800 MHz</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Output power per call (mW)</td>
<td>Output power per call (mW)</td>
</tr>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Median</td>
</tr>
<tr>
<td>Sweden</td>
<td>118.2 (95.2)</td>
<td>101.6</td>
</tr>
<tr>
<td>Total</td>
<td>133.3 (91.7)</td>
<td>127.2</td>
</tr>
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### UMTS:

<table>
<thead>
<tr>
<th>Location</th>
<th>Median</th>
<th>Mean</th>
<th>90th percentile</th>
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<tbody>
<tr>
<td>Rural</td>
<td>0.04</td>
<td>0.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Suburban</td>
<td>0.02</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Urban</td>
<td>0.02</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Dense urban</td>
<td>0.008</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Indoor net</td>
<td>&lt;0.008</td>
<td>0.2</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Adapted from Vreiheid, OEM, 2009

Persson et al., BioEM, 2012
Dose Züme: assuming UMTS call only

### Brain
- **83.4%**: Mobile phone calls
- **16.6%**: Cordless phone calls

### Whole body
- **84.8%**: Broadcasting
- **15.2%**: Mobile phone base stations

<table>
<thead>
<tr>
<th>Dose [mJ/kg/day]</th>
<th>Mobile phone calls</th>
<th>Cordless phone calls</th>
<th>Mobile data traffic</th>
<th>Mobile phone stand-by data traffic</th>
<th>WLAN Computer, laptops, tablets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Whole body</td>
<td></td>
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</tr>
</tbody>
</table>

Legend:
- Mobile phone calls
- Cordless phone calls
- Mobile data traffic
- Mobile phone stand-by data traffic
- WLAN Computer, laptops, tablets
- Broadcasting
- Mobile phone base stations
- WLAN access points
- DECT cordless phone base stations
- Mobile phones
Predictions for brain tumours for the US

Potential Yearly Cellphone-Induced Brain Tumors
Assuming a 30-Year Latency Time and 10% of Users\(^1\)
Diagnosed with a Brain Tumor

Source USA Cellphone Subscribers: CTIA
Source brain tumor diagnosed in 2004: CBTRUS

\(^1\) Based on 10% of long-term smokers are diagnosed with lung cancer

New Dx \(\sim 380,000\)

\(\sim 50,000\) Dx
\(\sim 1,900\) from cellphone use

Fig. 1. Long-delay followed by sudden onset of brain tumor epidemic.

Morgan, Pathophys, 2009