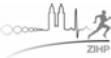




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Radio frequency electromagnetic fields: effects on brain physiology

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Questions

- Do radio frequency electromagnetic fields (RF EMF) have a biological effect?
- Thermal vs. non-thermal mechanism
- Long-term exposure to multiple sources of low intensity

Applied fields

- 'handset-like' GSM signal (CF=4.8)
- 'base-station-like' GSM signal (CF=1.2)
- continuous wave (cw) RF EMF (CF=1.0)
- sham (no field)

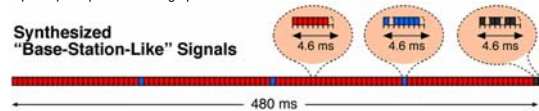
SAR = 1 W/kg (0.2 W/kg, 5 W/kg)

Applied signals

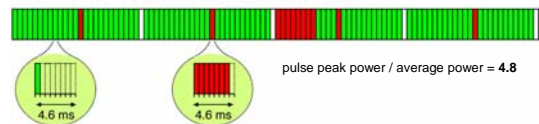
GSM 900 MHz

pulse peak power / average power = 1.2

Synthesized "Base-Station-Like" Signals

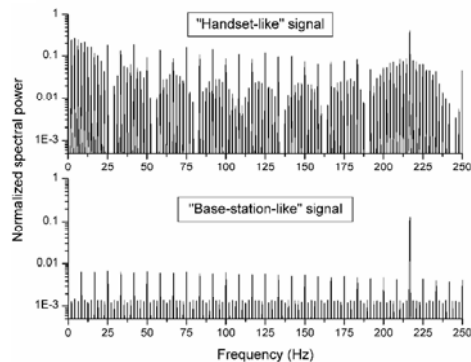


Synthesized "Handset-Like" Exposure Signals



pulse peak power / average power = 4.8

Power Spectrum

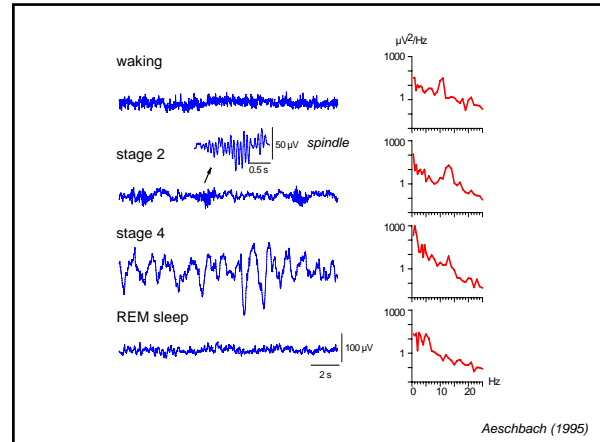


Effects of RF EMF on nonREM sleep EEG

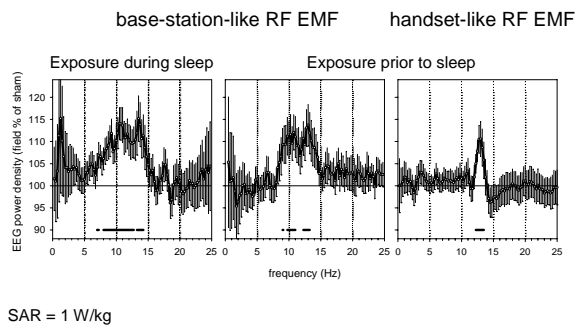


Sleep architecture

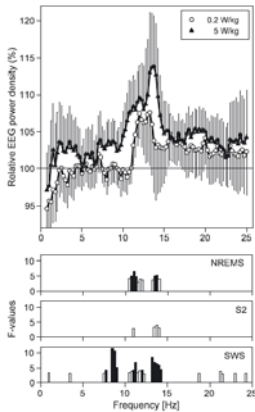
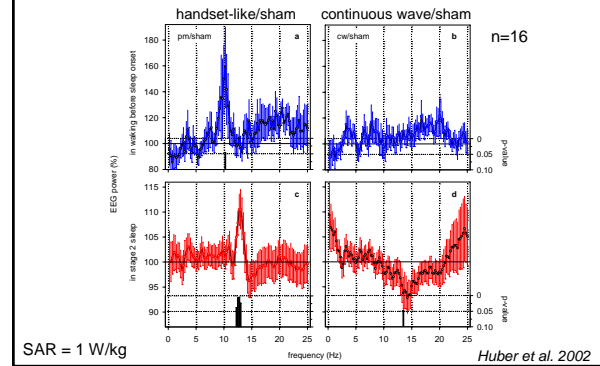
- Exposure during sleep (1 study): reduction of WASO
- Exposure prior to sleep (3 studies): sleep architecture not affected



Pulse-modulated RF EMF affect nonREM sleep EEG



'Handset-like' RF EMF affect waking and nonREM sleep EEG

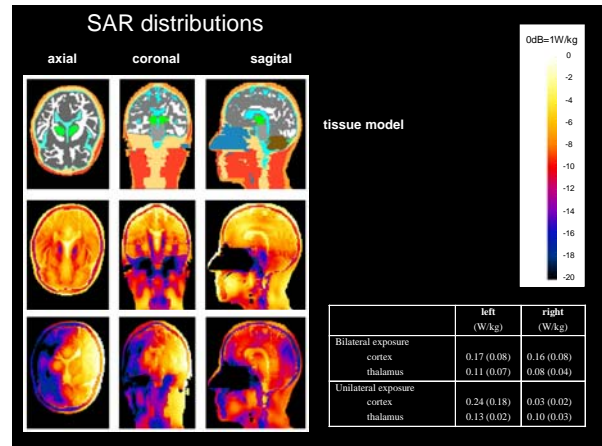
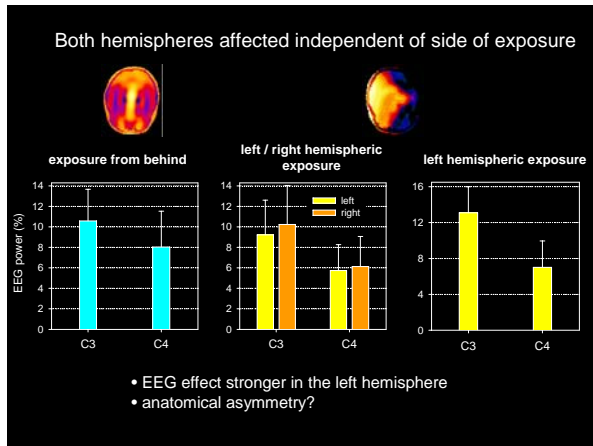


Power in spindle frequency range increased in dose dependent manner

Regel et al., 2007

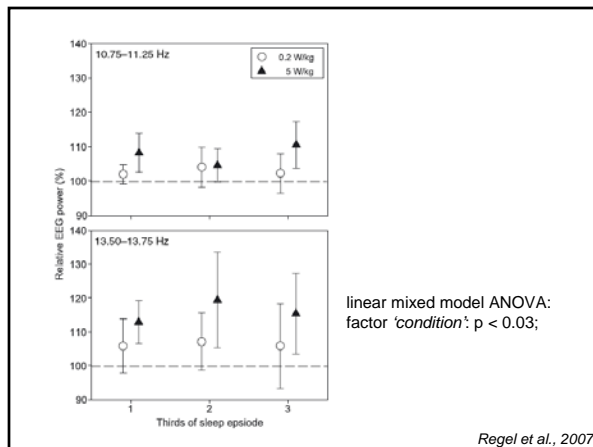
Summary & Conclusion (1)

- exposure to pulse-modulated RF EMF affects nonREM sleep EEG (4 studies) (in a dose-dependent manner)
- pulse modulation critical for RF EMF-induced EEG effect
- non-thermal effect



Summary & Conclusion (2)

- both hemispheres affected independent of side of exposure
- weak RF EMF ($\approx 1/10$) are capable of inducing observed EEG effects may be ruled out (dose-response study)
- subcortical brain regions (e.g. thalamus) may be responsible for the EEG effect



Summary & Conclusion (3)

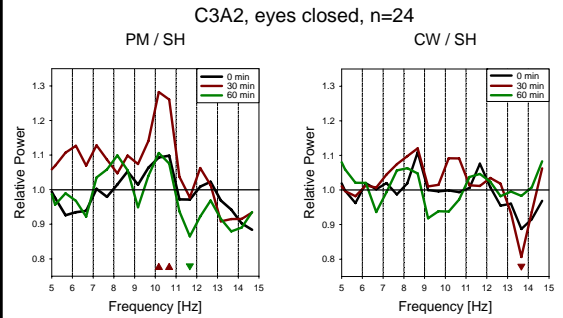
- Pulse modulation affects temporal evolution of effect of RF EMF exposure
- Effects outlast exposure up to hours
- Changes in cortical excitability after RF EMF exposure (Ferreri et al., 2006)

Effects of RF EMF on Waking EEG



Exposure

Increased alpha activity 30 min after exposure after pulse-modulated RF EMF exposure

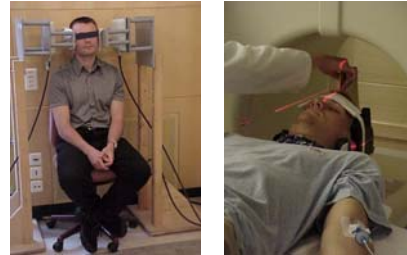


Regel et al., 2007

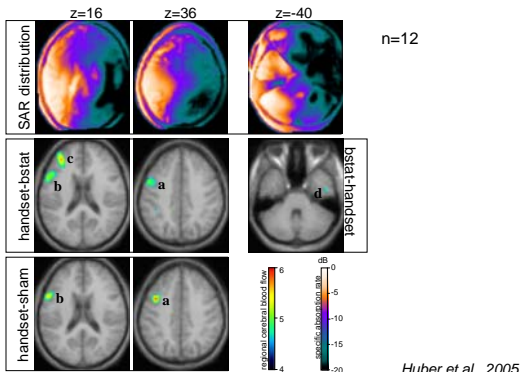
Summary & Conclusion (4)

- Effect appeared and disappeared within 60-min time window after exposure
- pulse modulation critical for RF EMF-induced EEG effect
- non-thermal effect

Effects of RF EMF on regional cerebral blood flow



'handset-like' RF EMF increased rCBF in dorsolateral prefrontal cortex of exposed hemisphere



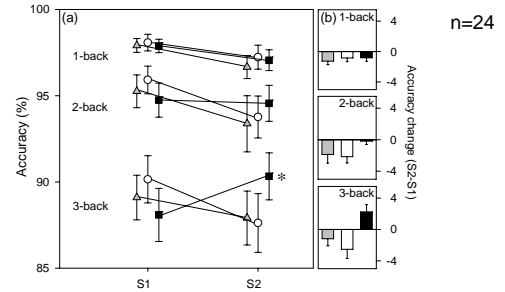
Summary & conclusion (5)

rCBF in waking

- affected by 'handset-like' RF EMF
- 'base-station-like' RF EMF similar to sham condition
- pulse-modulated RF EMF ('handset-like') affects rCBF in exposed hemisphere
- crucial role of *pulse modulation*
- evidence for *non-thermal* effect
SAR distribution \neq affected region
handset-like \neq base-station-like RF EMF

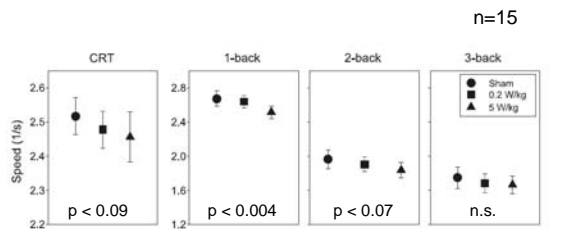
Effects of RF EMF on cognitive performance during exposure

Increased accuracy in 3-back task after pulse-modulated RF EMF exposure



Regel et al., 2007

Dose-dependent effect of RF EMF exposure on speed (1 / reaction time)



Regel et al., 2007

Summary & conclusion (6)

- 'handset-like' RF EMF affects accuracy in N-back task (load dependent)
- first indication of dose-response effect
- crucial role of *pulse modulation*
- effects on cognitive performance less consistent than EEG effects

Summary & Conclusion

- exposure to pulse-modulated RF EMF affects brain physiology (EEG, rCBF, cognitive performance)
- effects outlast exposure
- pulse modulation appears crucial for RF EMF-induced effects
non-thermal biological action
- underlying mechanisms unknown

Acknowledgments

R. Huber
S. Regel

IT'IS:

N. Kuster

A.A. Borbély

J. Schuderer

T. Graf

PET Center:

K. Cote
R. Dürr
B. Fuchs
E. Gallmann
J.M. Gottselig
K. Jütz
H.-P. Landolt
D. Matter
E. Werth
L. Wittmann

A. Buck

V. Treyer

- University of Zürich
- Swiss National Science Foundation
- Human Frontier Science Program
- Research Foundation 'Mobile Communication'
- Swiss Federal Office of Public Health
- SWISSCOM



Illustration: A. Locher