



## Effects of Pulse-Modulated RF-EMF on the Human Brain: Critical Field Parameters and Site of Interaction


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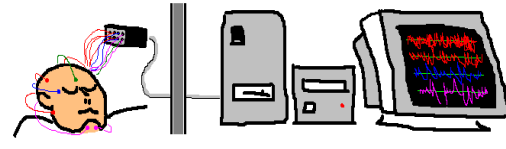




## Overview

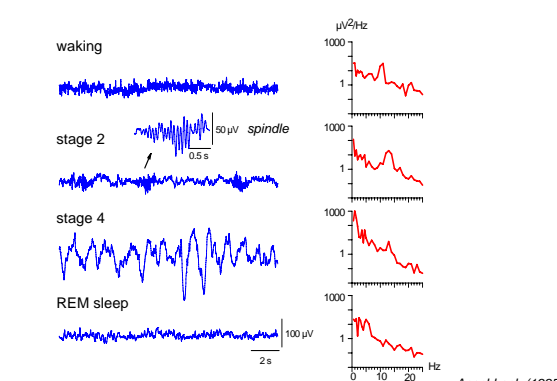
- Introduction
  - Sleep and the EEG
  - Sleep EEG "fingerprints"
- Effects of RF EMF on the human brain
  - Effects of RF EMF on nonREM sleep and waking EEG
  - Effects of RF EMF on regional cerebral blood flow
  - Effects of RF EMF on cognitive performance during exposure
- Summary and Conclusions
- Outlook



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## Analysis of the sleep EEG

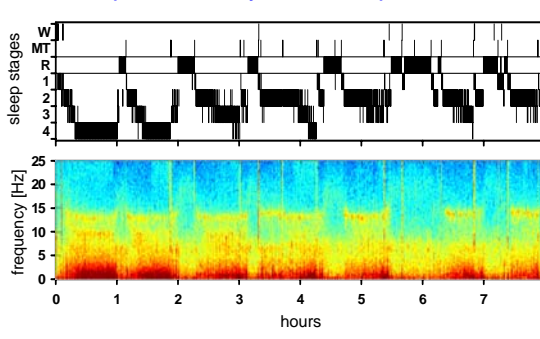




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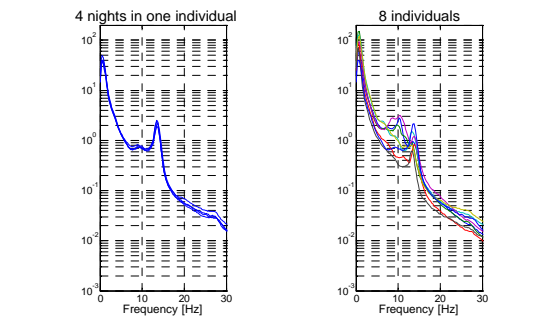

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## Spectral analysis of sleep EEG

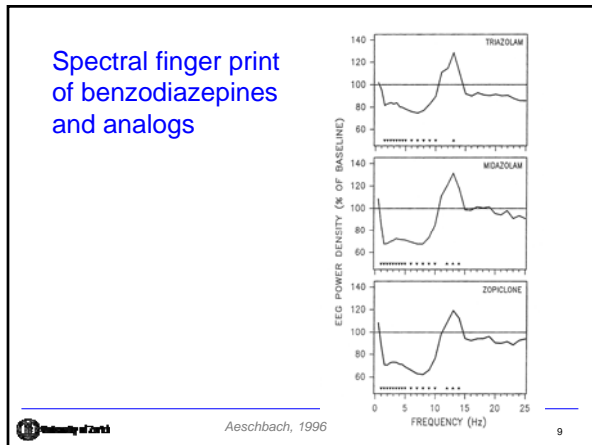
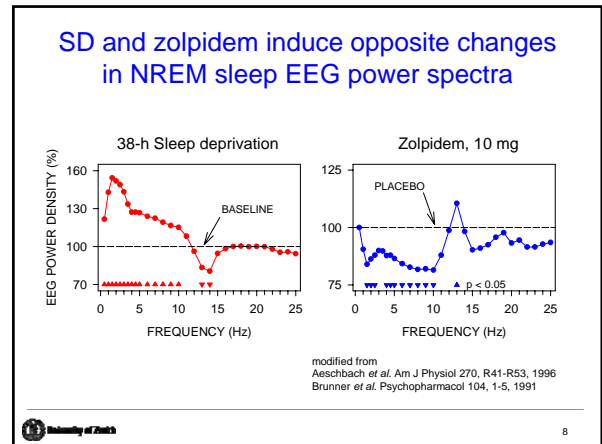
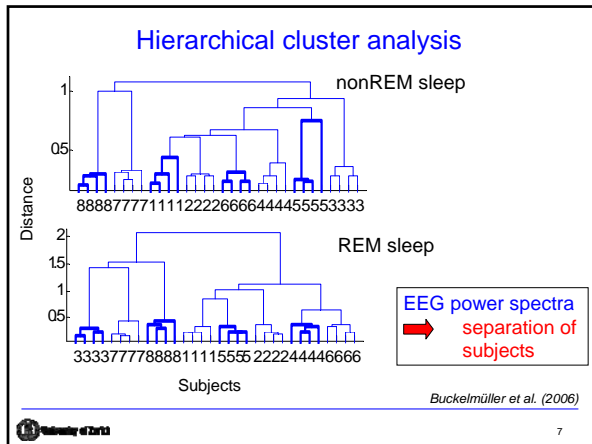



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## nonREM sleep power spectra: variability within and between individuals




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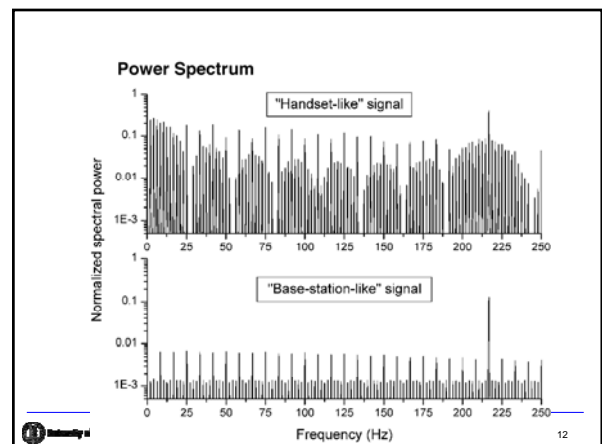
### The press and our findings

Neue alarmierende Studien


Handy am Ohr wirkt so stark wie ein **Psycho-Medikament**

Samstag, 13. Oktober 2007 | 17

- ### Applied fields
- 'handset-like' GSM signal
  - 'base-station-like' GSM signal
  - pulsed signals (14 Hz, 217 Hz)
  - continuous wave (cw) RF EMF
  - sham (no field)
- SAR = 1 W/kg, 2 W/kg, 0.2 W/kg vs. 5 W/kg



## Effects of RF EMF on nonREM sleep and waking EEG



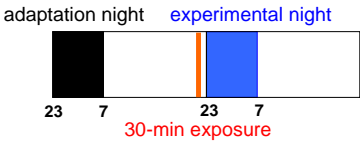
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## Well controlled sleep studies (1)

- Inclusion/ exclusion criteria
  - No sleep disturbances (screening night)
  - Habitual bedtimes approx. 23.00 to 07.00 h
  - Non-smoker
  - Low/ medium consumption of caffeinated beverages and alcohol
  - < 1 h (2 h) use of mobile phone per week
  - Young male subjects; right handed
- Conditions prior to experiment
  - 3 day prior to experimental block
    - Regular bedtimes (controlled with sleep logs and actigraphy)
    - No consumption of caffeinated beverages and alcohol (controlled in lab)
    - No medications
  - On day of experiment
    - No sport
    - No phone calls

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## Well controlled sleep studies (2): Experimental design

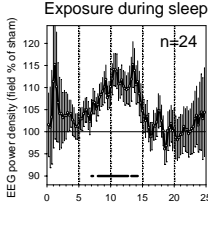


- within subject design
- double-blind, crossover, randomized
- weakly intervals (same week days)

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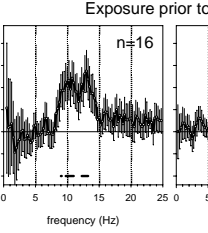
## Pulse-modulated RF EMF affects nonREM sleep EEG

base-station-like RF EMF



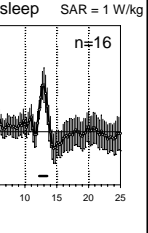
*Borbély et al. 1999*

handset-like RF EMF



*Huber et al. 2000*

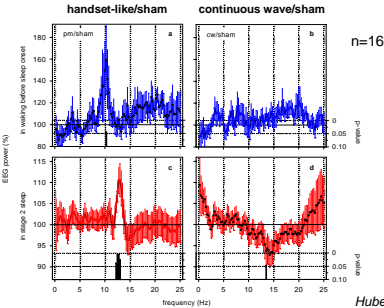
handset-like RF EMF



*Huber et al. 2002*

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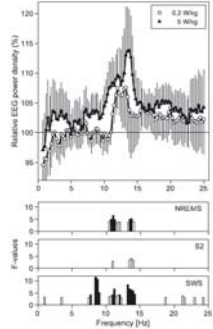
## 'Handset-like' RF EMF affects waking and nonREM sleep EEG



Huber et al. 2002

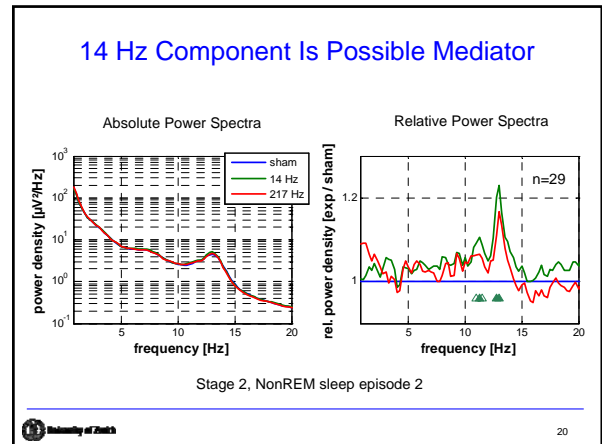
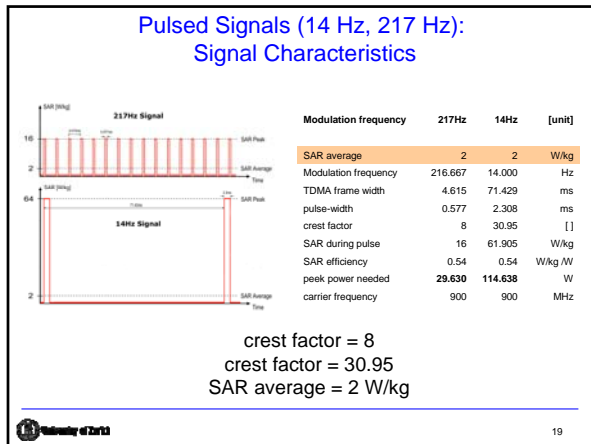
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## Effect is dose-dependent

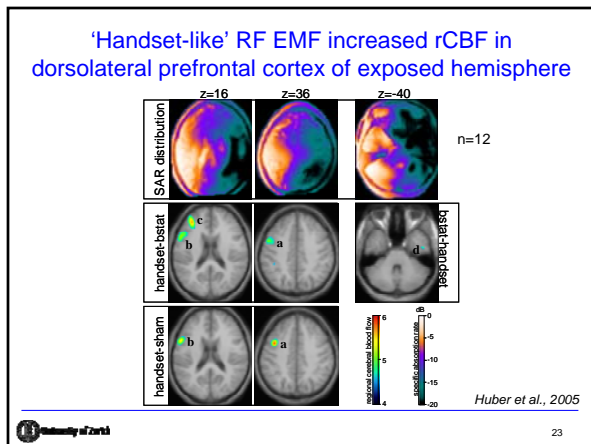
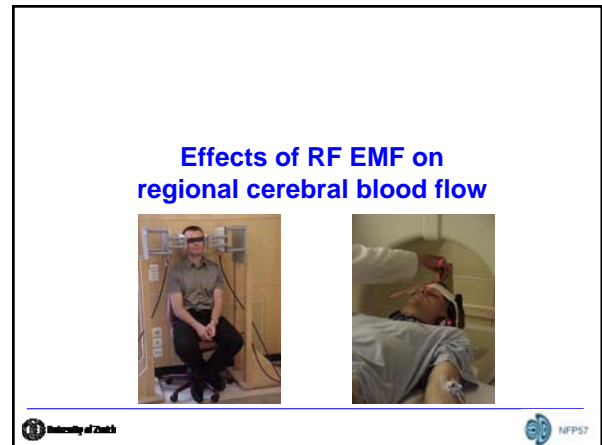


Regel et al., 2007

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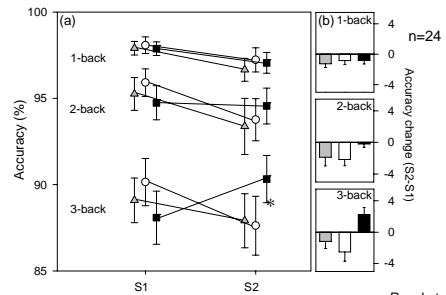
- ### Summary & Conclusion (1)
- Exposure to pulse-modulated RF EMF affects:
    - NonREM sleep EEG (5 studies) in a dose-dependent manner
    - Waking EEG
  - Pulse modulation critical for RF EMF-induced EEG effect
  - RF EMF effects:
    - Outlast exposure
    - Non-thermal
    - Independent of exposure side
  - Subcortical brain regions (e.g. thalamus) may be responsible for the EEG effect
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- ### Summary & Conclusion (2)
- 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
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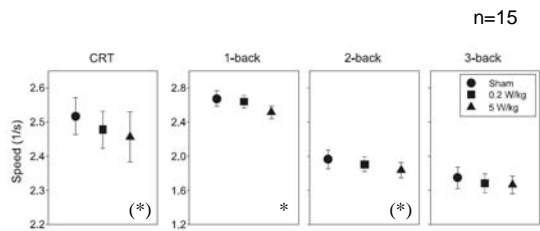
## Effects of RF EMF on cognitive performance during exposure

## Increased accuracy in 3-back task after handset-like 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 (3)

- 'Handset-like' RF EMF affects accuracy in the 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

## Outlook

## NRP 57 Projects

### 1) Critical field parameters:

Which low frequency modulation components are causing the observed changes in brain activity?

### 2) Site of interaction:

Is the thalamus, a subcortical structure, involved in mediating observed effects?

### 3) Sensitivity in early adolescence:

Are adolescents particularly sensitive to RF EMF exposure?



## Acknowledgments

### University of Zurich

M. Maire  
T. Rusterholz  
A. Bersagliere  
H.-P. Landolt  
R. Dürr  
B. Fuchs  
E. Gallmann  
J.M. Gottselig  
E. Werth  
M. Neubauer

A.A. Borbély  
R. Huber  
T. Graf  
K. Cote  
K. Jütz  
D. Matter  
G. Tinguely  
L. Whittmann  
S. Münt  
A. Bratic Grunauer

### ITIS Foundation

S. Kühn  
M. Christopoulou  
J. Schuderer

### PET Center

A. Buck  
V. Treyer