

Brain activity is influenced by RF EMF: The role of pulse- modulation parameters

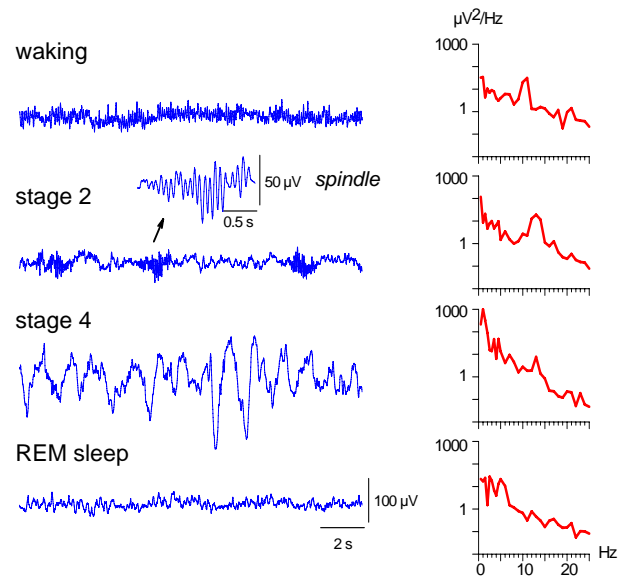
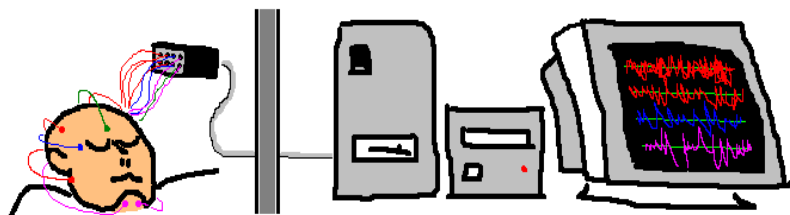
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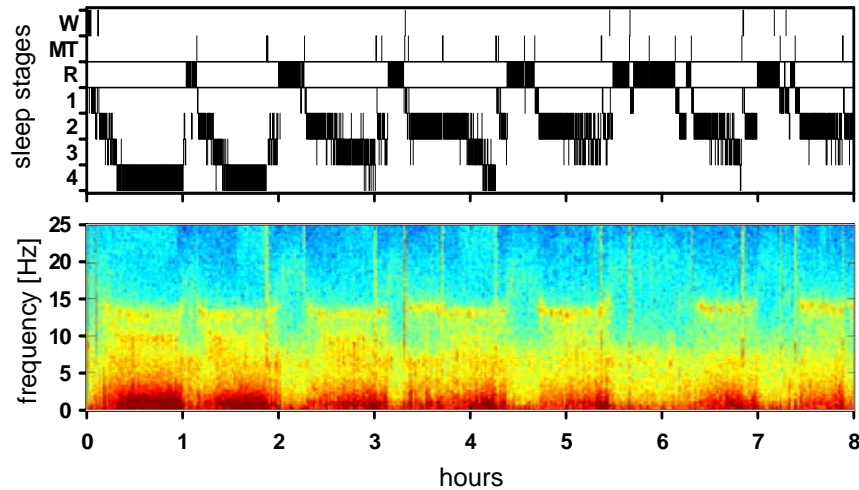
Questions

- 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

Analysis of the sleep EEG



Spectral analysis of sleep EEG



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)

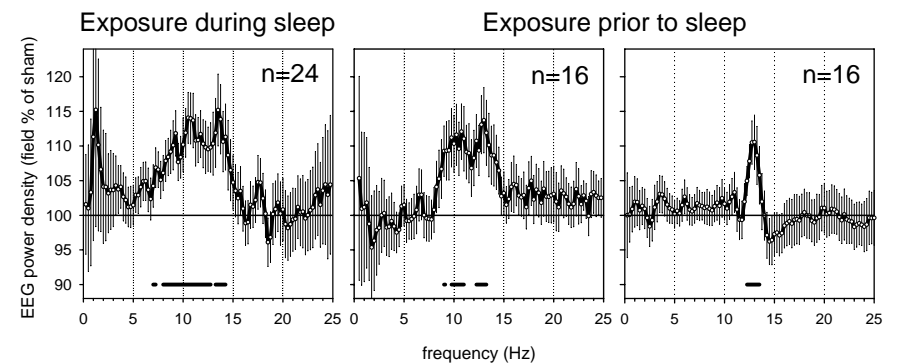
Effects of RF EMF on nonREM sleep EEG

Pulse-modulated RF EMF affect nonREM sleep EEG

SAR = 1 W/kg

base-station-like RF EMF

handset-like RF EMF

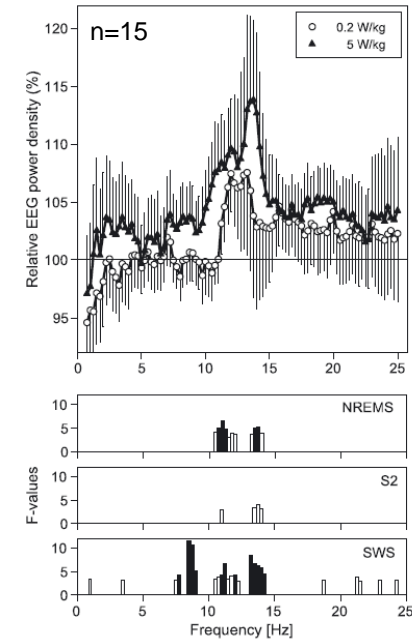
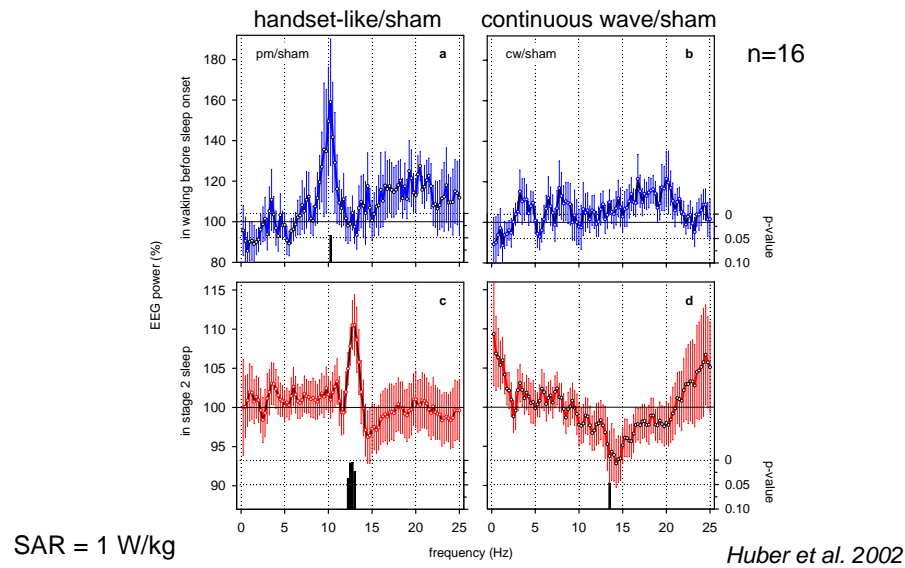


Borbély et al. 1999

Huber et al. 2000

Huber et al. 2002

'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)

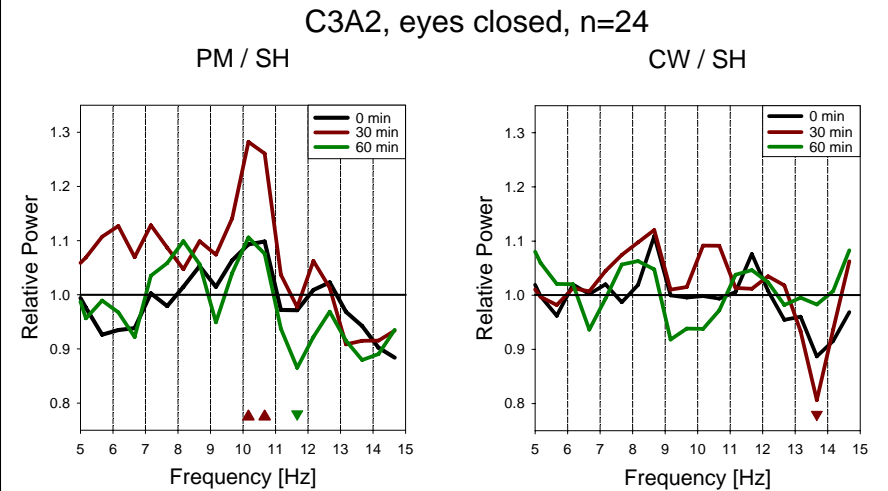
- exposure to pulse-modulated RF EMF affects nonREM sleep EEG (4 studies) (in a dose-dependent manner)
- pulse modulation critical for RF EMF-induced EEG effect
- effects outlast exposure
- non-thermal effect

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

Effects of RF EMF on Waking EEG

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

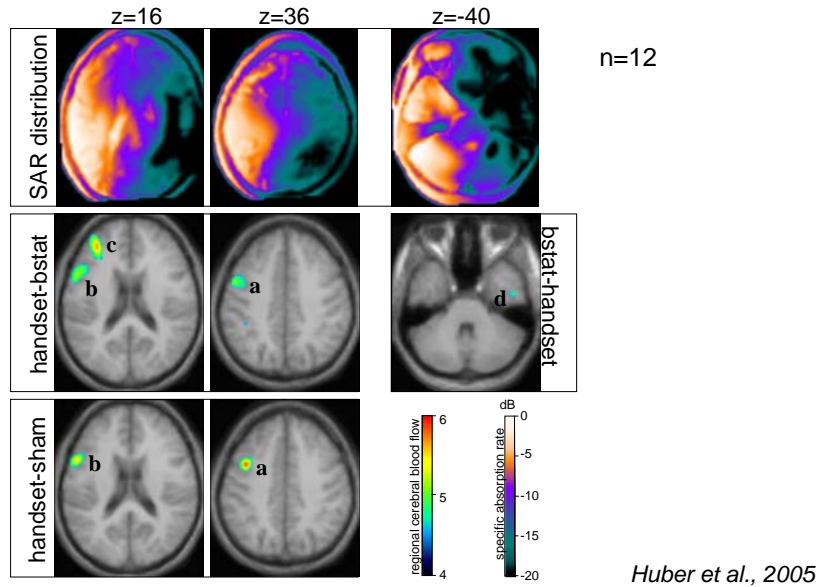


Summary & Conclusion (3)

- 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



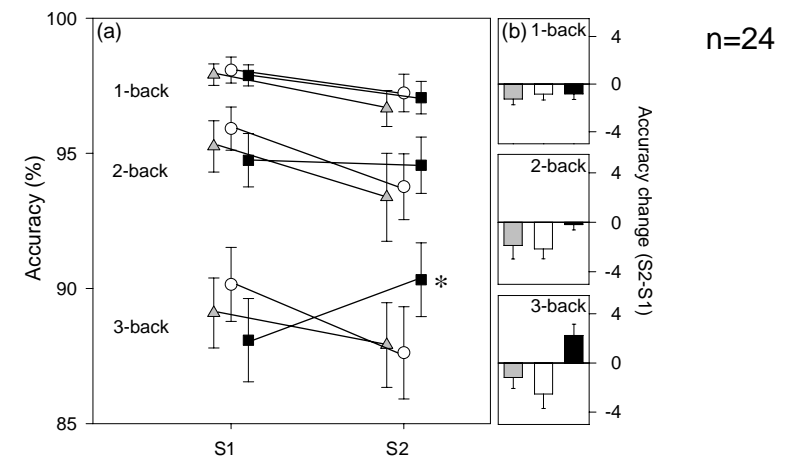
Summary & conclusion (4)

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



Summary & conclusion (5)

- '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

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?

Critical field parameters



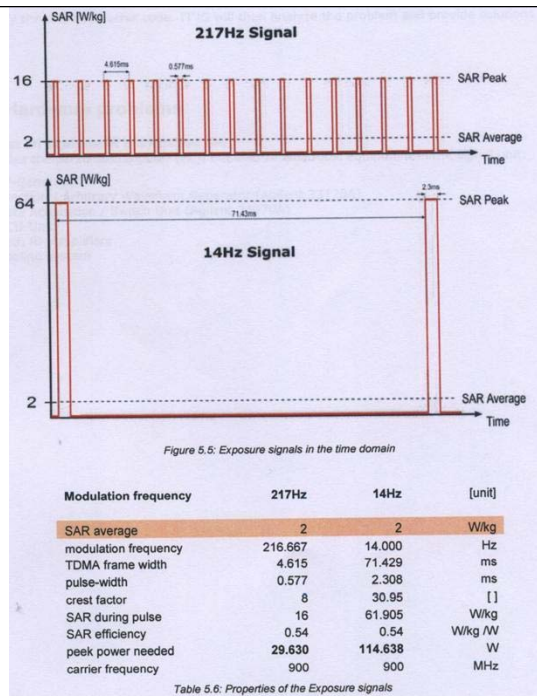
Exposure conditions:

- 14 Hz pulse-modulation
- 217 Hz pulse-modulation
- Sham

crest factor = 8

crest factor = 32

SAR average = 2 W/kg



Study design

- 30 subjects (male, right-handed, 20-26 years old, non-smokers)
- 2 nights per week for 3 weeks
- 3 exposure conditions (one per week; 30 min prior to sleep) in a double-blinded crossover design
- cognitive tasks during exposure (SRT, CRT, N-back)
- Polysomnographic recordings (EEG, EOG, EMG, ECG) during 8 h of post-exposure sleep

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