Hermann Wygoda

Effects of GSM mobi on the Ce

Evaluation of nine EEG studies

The much-discussed alleged effects of electromagnetic fields caused by mobile phones operating via the actually applied GSM standard (Global Standard for Mobile Phones) on the Central Nervous System are analysed based upon a number of studies published in recent years

The studies mentioned above used the electroencephalogram (EEG) as a tool for measuring such interaction. During EEG measurements electrodes placed at the head skin transmit electric signals partially produced by processes occurring within the brain. As the active brain segments are located at different parts of the head, the signals are deducted by 21 different electrodes distributed in a given pattern. Since the low voltages recorded during EEG measurements are easily altered either by various technical influences or by the participant's behavior, these examinations require a particularly careful handling excluding all possible disturbances.

In the following, we will deal with nine studies on this topic published in recent years:

von Klitzing (1992)
CETECOM/von Klitzing (1994)
von Klitzing (1995)
Reiser et al. (1995)
Spittler et al. (1997)
Hietanen et al. (1997)
Röschke, Mann (1997)
Thuroczy et al. (1997)
Krafzyk et al. (1999)

In 1992, during experiments von Klitzing observed alterations in his test subjects occurring in the range of alpha waves. In 1995 he exposed 17 test subjects to an electromagnetic field for 3 x 15 min, each exposure being followed by a 15-min break. Field strengths were several points below the field strengths in other studies. Von Klitzing detected a decreased activity in the alpha wave range (8-12 Hz) and

bile phone
ntral Nervous System not proven

simultaneously, an increase of activity at lower frequencies (in the theta and gamma range) during exposure. However, there is no information available on the order of exposure and control intervals. As a statistical evaluation of results also is lacking, it is not possible to assess the significance of the study results.

Following the first study of von Klitzing from 1992, in 1994 an EEG measurement in three participants was carried out by CETECOM and von Klitzing. In two of three participants von Klitzing again detected EEG alterations possibly caused by electromagnetic fields. CETECOM as well evaluated the data comparing results with von Klitzing ultimately reaching the conclusion that von Klitzing's findings resulted from methodical or technical impairments. As only three participants were involved statistical evaluation is lacking. Interestingly, one of the participants allegedly fell asleep during measurements. As sleep as a rule causes EEG alterations, the obtained results are highly doubtful, regarding the issue at hand.

In 1995, Reiser and his co-workers too looked for effects of electromagnetic fields on the EEG. Their investigation was designed as a cross study during which each participant was examined various times and simultaneously served as a control. Besides, a double-blind set-up was selected, i.e. neither the scientist nor the paticipant knew when the exposure to an electromagnetic field began.

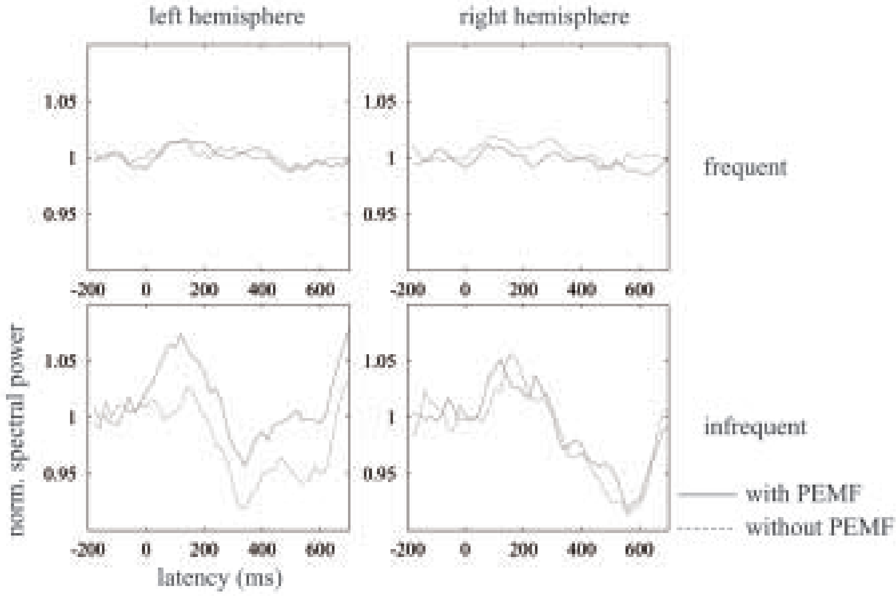
Evaluation of the 147-MHz field tests showed an increase of the alpha and beta activity at a measurement point at the back of the head when exposure and end phase are taken together. The measurement electrode was placed nearest to the field source. However, when the two measurement phases were evaluated separately the result could not be confirmed as significant. For the 900-MHz GSM field the result was a significant increase of the beta activity during the time period after the end of exposure. At other EEG measurement points no alterations of potentials could be detected. However, the effects can not be excluded by the statistical approach selected by the authors (sign-test for paired samples).

Hietanen et al. examined several mobile phones including GSM 900 and GSM 1800 devices looking at possible effects on the EEG. All devices operated at maximum transmission power exposing test participants for 20 min to the electromagnetic field. Sham exposures, too, were part of the study. Only at exposure to a mobile radio device alterations in the delta wave range were found; however, this effect can not be seen as significant. Measurements of delta waves prove especially critical, since there may occur strong disturbances caused by transpiration at measurement point areas. All other applied devices showed no impact on the participants' EEG. Consequently, the authors claim that mobile radio device emissions have no disadvantageous effects on the human brain.

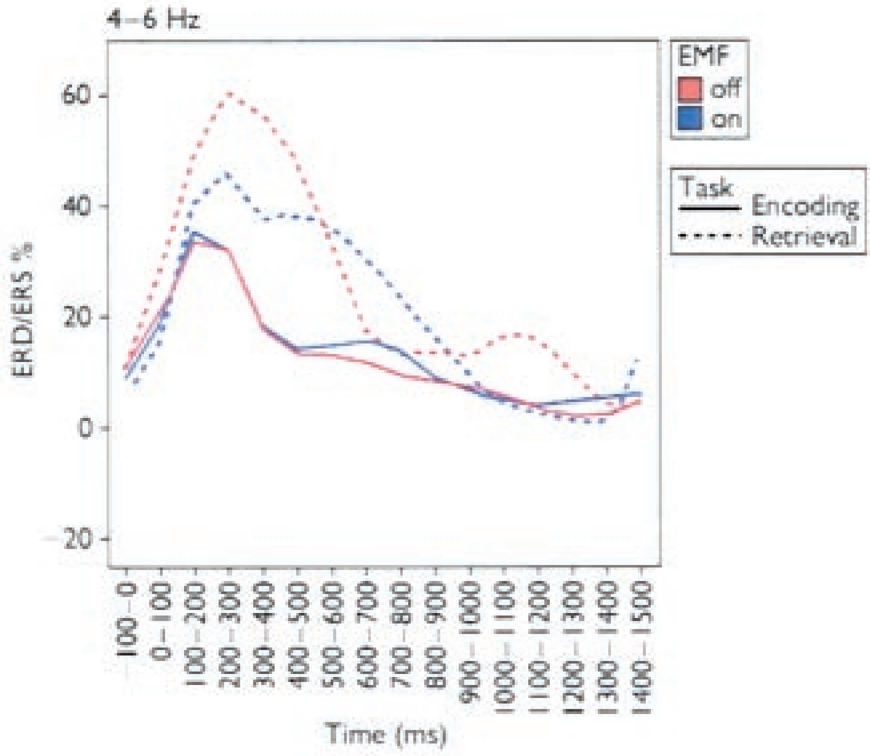
In 1997 Spittler et al. exposed 52 test subjects to the radiation of a GSM 900 mobile phone of a 217-Hz pulse frequency. The 52 subjects participating in this experiments were divided into two groups. While the members of one group were exposed for ten min to the electromagnetic field, the subjects of the other group were only sham exposed. Between exposure intervals there was a break of ten min during which the field was switched off. This experimental strategy offered the possibility to record individual alterations in single subjects as well as across all test subjects. Under the conditions of this experimental set-up no alterations of the EEG caused by the field of the GSM phone could be detected.

In the same year, however, Thuroczy et al. presented different findings. The scientists conducted two-channel EEG measurements in 76 persons seperately screening the side of the head exposed to the electromagnetic field and the side of the head without exposure. The experiment followed a firm pattern of exposures and sham exposures. By means of this experimental design alterations of the EEG's alpha waves could be proven. However, the authors did not compare all exposure and sham exposure intervals. Further – ss is seen in the figures – there were observed increases as well as decreases of the alpha activity, i.e. a uniform alteration of alpha waves is not recognisable. Therefore, an evaluation of results seems rather difficult, particularly as the exact conditions of controls were not available.

A similar EEG-based cross study was published in 1997 by Röschke and Mann. The EEGs of 34 participants again was recorded by means of two-channel technique. The study subjects were exposed and sham exposed to the electromagnetic field of a GSM 900 mobile phone in random sequence. Each interval had a duration of 10 min, each interval was followed by a break of 30 min. Ultimately, Röschke and Mann could not detect any alteration of the EEG caused by electromagnetic fields.



Taken from the study of Eulitz et al. (1998): Curve of the spectral short-term power at standard ('frequent') and aimed stimuli ('infrequent') in the frequency range of 19-31 Hz measured at two measurement points located symmetrically towards the head middle line ('left'/'right'). The radiation source was located to the left. As to the aimed stimuli (presentation at 0 ms) a difference is seen dependent of the exposure ('with PEMF'/ 'without PEMF') being significant from 260 ms onwards.



Taken from the study of Krause et al. (2000): Curve of the spectral short-term power in the frequency range of 4-6 Hz at encoding and retrieval of words during a memory experiment. Approximately from 300 ms onwards after word presentation (at 0 ms) the spectrum shows differences dependent of exposure ('EMF on'/'EMF off').

Krafzyk et al. conducted a sophisticated test series publishing their results in 1999. As a method, they selected a placebo-controlled cross study including a complex EEG measurement carried out over a time period of three and a half hours for each participant. Here, evoked potentials as well as MAEP (medium latency evoked potentials) were observed; further, the P-300 experiment was applied. During this experiment participants have to identify certain sounds out of a whole sound sequence. As an electromagnetic field source mobile phones of the GSM 900 and GSM 1800 standard were used. As the scientists claim in their evaluation, during the EEG participants showed no effects that could be explained by the irradiated electromagnetic fields.

Thus, it must be emphasized that none of the studies presented here gives evidence of interaction between GSM fields and comprehensive brain functions. This result is supported by the fact that the electromagnetic signals of a GSM mobile phone already are strongly dampened by head tissue. At a tissue depth of some cm the dampening of a GSM 900 field amounts to more than 90 per cent. As to a GSM 1800 field, the dampening effect is even stronger. Thus, theoretically only outer brain regions may be influenced by the electromagnetic field. Since the EEG during waking state is controlled by the thalamus being located deep inside the brain, an impact of GSM mobile phone electromagnetic fields on the EEG because of this natural position alone is very unlikely. Penetration depth of these fields is not sufficient to cause alterations.

Impact of electromagnetic fields caused by GSM mobile phones on sleep phases

Between 1996 and 1999 several studies were carried out aimed to decide wether electromagnetic fields of GSM mobile phones can have an impact on the human sleep. Apart from EEG measurements also the electrocardiogram (ECG), the electromyogram (EMG) and the electro-oculogram (EOG) provided additional physiologically relevant quantities being of importance for characterising sleep phases. The measurements were continuously recorded throughout the night.

In 1996 Mann and Röschke exposed test persons to a GSM field of an assessed power flux density of 0.05 mW/cm². This experiment was conducted as a double-blind study including sham exposures. To adapt to the unusual environment the participants had to spend the night before the measurements at the sleep laboratory. During statistical evaluation (ANOVA = standard analysis of variance) a shortened phase of sleep onset (reduced sleep onset latency) and a dimished percentage of REM-phase were registered when the electromagnetic field was switched on. The EEG of each participant was separately evaluated following the measurements of the different sleep phases. Apart from a significant increase of the EEG power during REM phase no effects were detected being possibly caused by the electromagnetic field.

The results of this study gave considerable cause for discussion. However, we must bear in mind that the observed effects may either be caused by the GSM carrier signal or by modulation frequency.

In 1998 a study of Hinrichs et al. showed that a GSM 1800 field has no effect at all on sleep relevant parameters. In a double-blind study participants were exposed to a GSM 1800 field with the mobile phone antenna being mounted in a distance of approximately 1.4 m to the head of the test subject. This set-up was meant to simulate conditions in the vicinity of a fully active base station. Exposures and sham exposures took place in four subsequent nights. Here too, participants spent the night prior to the experiment at the laboratory to adaptate to the new sleeping environment.

In 1998 Wagner et al. planned to repeat the results of the Mann study from the year 1996 in a study of their own. However, they reduced the power flux density of 0.5 mW/cm² to 0.02 mW/cm². They did not succeed in replicating the results of the Mann study, though at least a similar trend of parameters was recognisable.

These results led to the assumption that an effect of the GSM field might depend on its strength. To look into this assumption in 1999 Röschke conducted a third experiment with a comparable experimental set-up but a significantly increased power flux density of 0.2 mW/cm². Thus, his workgroup addressed the issue of the relation between results and the dose of the electromagnetic field. However, this test could neither detect any effect; even the trend of parameters determined by Wagner was not found during this third experiment.

In 1999 Borbély et al. exposed their participants during a placebo-controlled double-blind cross study to a 900-MHz GSM signal with different modulation frequencies. In this set-up, the frequency mixture of 2, 8, 217 and 1736 Hz was meant to simulate the simultaneous activity of a base station and a mobile phone. A three-dipole antenna was installed in the vicinity of the test person's head to simulate the near-field situation. The specific absorption rate (SAR) lay at approximately 1 W/kg. During one night the baseline of each participant was recorded by tests, in the following night measurements were made. Each participant had to absolve two of these sessions. Here too, exposure and sham exposure occurred in a random pattern.

Impact

The results showed an increased activity during the non-REM sleep phases in the alpha band (7-14 Hz). This trend was especially pronounced during the first non-REM sleep phase. Further, a shortened waking phase was observed. The authors report that in particular test persons who had been the first to be sham exposed more often woke during the first night. They explained this phenomenon rather by the fact that these participants spent adaptation night in a room other than the the test room; allegedly, the electromagnetic fields they were exposed to did not lead to this effect.

The contradictory results from the studies of Mann, Wagner and Röschke do not provide clear evidence of interaction between GSM fields and sleeping behavior, too, though the studies' experimental strategies are similar. A dose-dependent effect can only be assumed as long as there would be an extremely non-linear relation between dose and effect. Even at the highest power flux density (0.02 mW/cm²) no effects could be proven. This agrees with the results of Hinrichs et al. (1998) for the GSM 1800 field, though pulse frequency and field parameters (near-field/far-field) are different.

Only Paschke et al. (1996) and Reite et al. (1994) presented results from which an impact of electromagnetic fields on sleep can be derived. However, the applied field differs very much from the GSM field applied of the above mentioned studies, since the authors treated persons suffering from sleep disorders with a complex modulated high-frequency field of 27 MHz. Paschke and Reite report shortened sleep onset phases and an earlier beginning of deep sleep phases.

The results of Borbély et al. (1999), too, show an alleged impact of electromagnetic fields on sleeping behavior. However, the depicted effects only were significant because of the huge deviations between the first sham exposure and the following basic value and exposure measurements. Moreover, the erroneous results of this experiment could be the consequence of the fact that participants did not spend their adaptation night in the measurement room.

In his study, Borbély used highly complex pulse signals. Lyskov (1993) reported EEG alterations caused by a 45-Hz field. However, the field alone was not responsible for the alterations. Lyskov observed these EEG alterations only under conditions when the field repeatedly was switched on and off in a 1-second interval. Therefore, it can not be excluded that Borbély's results are caused by the complex signal structure. Thus, a replication of the Borbély study under standardised conditions seems reasonable and necessary.

Some uncertainty remains as long as the results of the Borbély study are not refuted by a replication study. Nevertheless, we may assume that there is no interaction between GSM fields and human sleeping behavior.

Impact of electromagnetic fields of GSM mobile phones on evoked potentials (EP)

In their 1998 study (see EEG) Krafczyk et al. conducted tests with evoked potentials. The participants were visually stimulated by a chess-board pattern changing eight times per second. At this fequency there was a distinctive EEG alteration. However, the evoked potential was not changed by the magnetic field. This result determined by means of the 'ANOVA method' was significant. Also the somewhat delayed evoked potentials (medium latency evoked potentials [MAEP]) were not influenced by the GSM field.

In 1998, Urban et al. examined 20 test persons in a cross study using Krafczyk's changing chess-board pattern to visually produce potentials. The frequency of the visual stimulus was 1.5 Hz, the simulation had a duration of five minutes. Sham exposures and exposures were performed; as a field source a GSM mobile phone was used. Information on frequency, field strength and SAR values is not available. All measurements were replicated after two weeks. Of particular notice is that the test persons were not 'blinded' and therefore knew when the field was activated. No significant effects were observed.

The studies until now performed could not confirm any effect of GSM fields on evoked potentials. Therefore, an impact of GSM fields on brain activity and functions so far seems to be unlikely. However, one must bear in mind that there are no results available on motor-sensorially evoked potentials. Existing studies should be revised considering this aspect, too.

Cognitive studies with event-related potentials (ERP) and event-related desynchronisations/synchronisations (ERD/ERS)

Another component of Krafczyk's 1998 study were tests of the so-called P-300 experiment. During this experiment participants have to identify certain sounds being part of a standard sound sequence. 300 milliseconds after the stimulus the EEG can register the corresponding response. Based upon the ANOVA evaluation, Krafczyk could not detect any EEG deviation caused by the GSM field neither in amplitude nor in time.

In a study from the year 1998, Freude et al. detected a possible impact of GSM fields on physiological processes. They examined the so-called readiness potential, for example occurring immediately prior to an involuntary movement. In a double-blind study test persons had to perform two tasks:

- mouse-click in self-selected time intervals (easy task) and
- observe a marker moving clockwise and stop it by mouse-click after three spins

precisely at the 12- o'-clock- position (complex task).

During experiment, a multi-channel EEG was recorded. The electromagnetic field was either switched on (three to five min) or off. During easy task performance the EEG showed no change caused by the GSM field. In contrast, the EEGs recorded during complex task performance showed a different result. A part of the measurement points showed a small, but still significant decrease of amplitudes was registered. Amazingly, this effect particularly occurred at head spots located opposite to the exposed area. The authors dealt with the question whether these effects were caused by alterations of the cortical stimilus susceptibility, as claimed by Adey in 1979. However, this assumption can not be verified since the relation between events at cellular level and the EEG at head surface so far is not known well enough.

In 1998, Eulitz et al. conducted a study of combined ERP and ERD/ERS tests. Here, participants too had to perform a hearing task being tied to a second task. At hearing a certain test sound in a sequence of 1000-Hz sounds (standard sounds), they had to push a button as fast as possible. The sounds they had to identify occurred in a random distribution. Event-related potentials from both tasks (sound identification; pushing button) as well as ERD/ERS spectra were separately evulated for each task. Response times and number of right and wrong responses were recorded, too. Two of the four total experiments took place at a GSM 900 field; each course had a duration of 15 minutes.

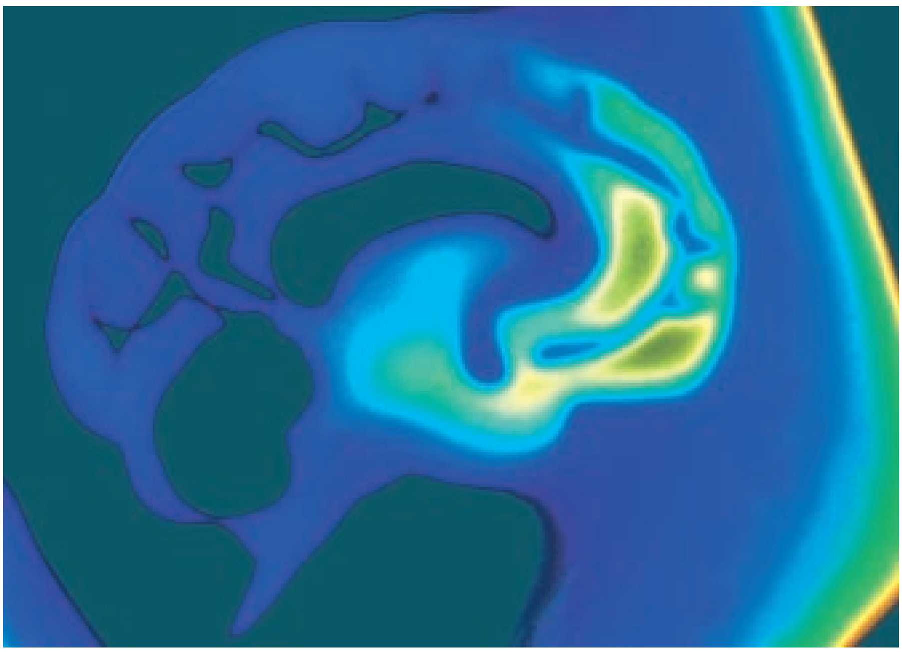
The evaluation of measurement results based upon the ANOVA method showed significant deviations for the ERD spectra under field exposure. Alterations were especially observed at the side of the head pointing to the field source in the range between 19 Hz and 31 Hz (beta band) and occurring with a delay of 260 to 380 milliseconds. Participants hearing the standard sounds showed no alterations. Response times as well showed no impact of the electromagnetic field. Eulitz' results demonstrate that the GSM field, though having an influence on the background EEG during task performance, does have no effect on event-related activities or behavior.

In a recent study from 2000, Krause et al. examined the impact of electromagnetic fields on memory. Test persons had to perform memory tasks when a GSM 900 mobile phone was switched on. During each experiment round in total 92 text passages each containing five verbs were read via headset to the test persons. The test persons had to decide whether the last word of a given passage also was part of the first four words of the previous passage. The decisions had to be communicated via a push-button. During the tests a multi-channel EEG was recorded. Evaluation showed alterations of the ERD/ERS in the lower frequency range of alpha waves (8-10 Hz). A differentiated analysis of the time interval in which the words were presented and of the phase of word identification showed that there are EMF-related ERD/ERS alterations. These alterations concern the tetha band (4-8 Hz) and the alpha band (8-12 Hz). Higher frequency bands were not examined. The quota of right answers under different test conditions was similar. Event-related potentials (ERP) showed no differences.

Krause et al. limited their tests to alterations within the lower bands of the EEG up to approximately 12 Hz. Eulitz et al. detected alterations within the beta band, i.e. in the range between 12.5 Hz and 30 Hz. Thus, the results of these studies can not be compared to each other.

In contrast to the Krause study, the effects detected by Eulitz et al. and Freude et al. mainly occurred in one brain hemisphere. Nevertheless, in a new study not yet published Krause et al. could confirm their earlier results.

Summarising the results of the different studies we must conclude that so far there is no proof of electromagnetic fields showing a systematical effect on the electric signals of the brain being caused by stimulus processing. Though ERD/ERS altera-



tions show that the specific cortical area may be influenced by electromagnetic fields during stimulus processing, there are neither correspondences in the frequency band nor concerning the relation between the exposed hemisphere and the hemisphere where effects occurred.

Random effects can only be definitely excluded by further studies. The observed effects did occur when the test persons had to perform complex tasks involving several brain regions - meaning that electromagnetic fields could either have an influence on communication between the involved brain regions or on intellectual capacity being challenged by the corresponding task.

Tasks of gradually increasing difficulty could contribute new insight concerning this issue. Also the fact that the applied electromagnetic fields because of tissue dampening only reach the top brain regions should be considered when defining tasks for new experiments particularly addressing these peripheral regions. Ultimately, all observed effects lie within a variation width also being expected from other potential altering influences. Here, we have to mention the use of drugs affecting the central nervous system as well as decreasing concentration levels or the circadiane rhythm. A health risk can not be derived from the effects detected until now.

Summary

Despite partially contradictory results not any of the presented studies did prove a dependence between EEG structure and exposure to electromagnetic fields. Therefore, the hypothesis that electromagnetic fields have no effect on the waking EEG seems to be highly probable.

In view of the sleeping EEG three out of five studies show no evidence of an impact of the GSM field on sleep. In spite of that we should not totally exclude the possibility that GSM fields have certain small effects on sleep.

Concerning the area of evoked potentials an interaction with GSM fields can be excluded. Insofar, all studies confirm the null hypothesis.

Only field effects on the ERD/ERS occuring during easy task performance could be established. However, one may speculate that pulsed high-frequency fields disturb intracortical communication transported by high-frequency brain currents or that they decrease intellectual capacity.

Hermann Wygoda, scientific journalist
(this article is a summary of a study presented by Prof. Dr. Hermann Hinrichs, University Magdeburg)