

Exposure to Radio-Frequency Electromagnetic Fields emitted by a Mobile Phone in Three Exposure Conditions

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Summary

Mobile Phones emit radio-frequency (RF) electromagnetic fields (EMFs), which might be absorbed in the human body. It is suggested that this exposure to RF EMFs can be reduced by using a phone in speaker mode or by using a headset while calling. In order to investigate whether these non-technological measures of reducing exposure are valid, we studied the emitted RF power by a mobile phone as a proxy for the exposure. This emitted radio-frequency power was recorded for 53 subjects who carried out phone calls in three controlled exposure scenarios: calling with the phone at the ear, calling in speaker-mode, and calling with a headset. Phone calls were carried out using both WCDMA and GSM. The emitted power at the ear is higher than the emitted power in the other exposure conditions for both communication technologies.

Introduction

Wireless Communication between mobile phones is enabled by radio-frequency (RF) electromagnetic fields (EMFs) that are emitted by mobile devices on the one hand (uplink) and the wireless network infrastructure on the other hand (downlink). Humans are exposed to these RF-EMFs. These are partly absorbed in the human body. This absorption is quantified using the specific absorption rate (SAR), which is commonly averaged over a certain mass of volume [1]. The exposure to downlink RF-EMFs can be small compared to the potential RF-EMF exposure caused by uplink during a mobile phone call [2, 3].

Reduction of this exposure could occur in two ways: technological or non-technological. The latter referring to behavioral changes, which could reduce exposure. Often recommended behaviors are the use of a headset or speaker modus while calling [4], since this increases the distance between one's head and the emitting phone. Numerical simulations have already demonstrated that the SAR induced by uplink depends heavily on the location and output power of a mobile phone [4], but are unsuitable to detect a potential correlation between location and output power, which might occur due to protocols in the network. Our goal is to measure whether the usage of a headset or speaker-modus actually reduces one's exposure to mobile phone uplink.

In this study, we have measured the RF power emitted by a mobile phone during phone calls made by 53 subjects in a controlled environment in three exposure conditions: call next to the ear, call with headset (or earplugs), and a call using speaker-modus.

Materials and Methods

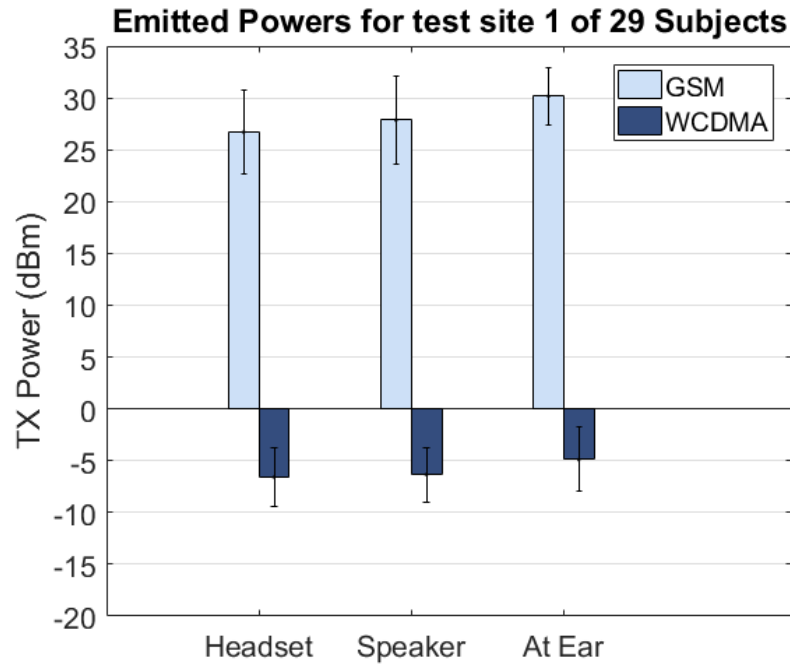
53 healthy subjects aged between 19 and 31 years, were divided into two test groups of 29 and 23 subjects, respectively. Each group was assigned a different measurement site. The subjects were first

asked to fill in a questionnaire (not discussed in this study) and then took place in a chair with the back of their heads against a headrest, which was adapted to their body height. The subjects were asked to keep their head in this pose during any call they make. Each subject was asked to make 18 phone calls with a duration of 5 minutes each. The subjects were asked to repeat the text they heard during each call. This ensured that data was transmitted from the user to the network. Six of the calls were made while holding the phone next to their preferred ear using their hand of preference. A headset consisting of two earplugs connected to the same phone was used during six more calls. The remaining six calls were made using speaker mode. The phone was always placed on a fixed position on the desk, 50 cm from the back of the chair the subject was sitting on, in front of the subject during the headset and speaker-mode calls. The order in which the calls took place was randomized and was communicated to the subject before each call.

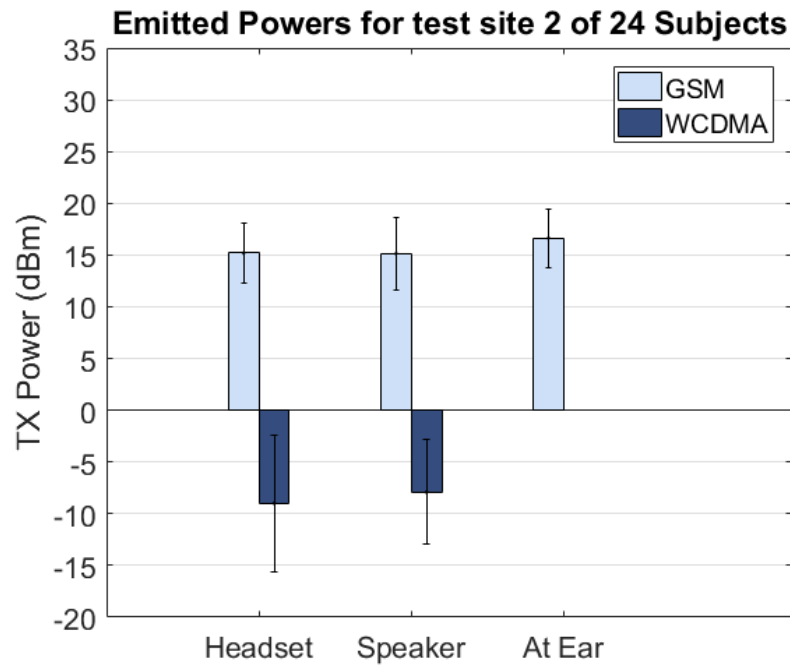
All calls were made using the same Nexus 5 (Google, San José, CA, USA), which is equipped with Azenqos Android (Freewill FX Company Limited, Bangkok, Thailand). This application ran a script in which it called the subject 18 times (randomized order of content, same content for each subject) with 45s intervals between each call. During these calls, the application registered the output power, which was provided to the phone's antenna in the 900 MHz (879-915 MHz), 1800 MHz (1710-1785 MHz), and 2100 MHz (1900-1980 MHz) uplink bands. During the calls, two technologies for mobile calls were used and registered by the application: Global System for Mobile communication (GSM) and Wideband Code Division Multiple Access (WCDMA). The network provider chose which technology was used.

The registered emitted powers were then pooled for all participants, calls and frequencies, but split for the three exposure conditions, the two locations, and the communication technology. We chose to split the data for the two locations, since the coverage and link with the network might have been different. We chose to split the data for the different telecommunication technologies since they have distinctly different ranges of operation in terms of emitted power.

Results and Discussion



(a)



(b)

Figure 1: Average emitted RF powers in three exposure conditions for (a) test site 1 and (b) test site 2. Whiskers indicate the standard deviations.

Figure 1 shows the geometric averaged emitted powers during the registered calls. On test site 1, 287 calls used WCDMA, while 235 used GSM. On site 2, the majority of the calls were executed using GSM, while only three calls used WCDMA. We have not processed the measurements of WCDMA on test site 2, due to this lack of samples. The emitted powers using GSM range from 16 dBm to 33 dBm on site 1 and from 11 dBm to 33 dBm on site 2. The emitted powers using WCDMA range from -13 dBm to 9 dBm on site 1.

The emitted powers using GSM in the 'At Ear' situation are significantly higher (determined using a two-sided Kolmogorov-Smirnov test and a Wilcoxon rank sum test, both at 5% significance level) than those in the other exposure conditions on both locations. We attribute this to the additional loss (in the head and hands) that occurs when the subjects hold the phone next to the ear. The same significant difference is found for WCDMA on test site 1. A significant difference in transmitted power levels is found between the two measurement sites for GSM in each exposure situation, which justifies the separation in two different pools of data. GSM is always found to be significantly higher than WCDMA.

Since the emitted powers are already significantly higher for the 'At Ear' exposure situation, we expect the peak SAR value in the head or the organ-specific SAR in brain or head regions [1] to be significantly higher as well. Since higher SAR values in the head are found for antennas near the ear in comparison to the other two exposure scenarios (more than a factor 10 higher [2, 3]). Whether the whole-body averaged SAR is higher, will depend heavily on the antenna in the mobile phone and its directivity towards the body in all exposure situations. Given these results, we do expect a reduction in SAR in the head when speaker-mode or a headset is used, in comparison to calling next to the ear.

In [6] median WCDMA output powers during voice calls of -17 to -14 dBm are reported for a Swedish network. Their data set was obtained over a very large set of subjects, with unregistered exposure conditions (modus of operating the phone), and on different locations in Sweden for more than 100k hours of call time. The interquartile range on the emitted powers during voice calls in [6] is more than 30 dB, while the full range of measured powers is more than 55 dB. Our measured WCDMA data, for variable subjects, two fixed locations, and three exposure conditions, fall in the highest quartile of their measured data and have a full range of 22 dB. This suggests that the location of a subject within the network is responsible for most of the variation seen in [6]. We also observe higher differences in average emitted powers for fixed exposure conditions and variable test sites, than between different exposure conditions on fixed test sites. In [7], mean and median values of 5 dBm and -11.5 dBm, respectively, were reported for WCDMA voice calls in India. Our measurement data lies in the three upper quartiles of the distribution for voice calls presented in [7]. The authors of [5] do not report absolute values for GSM and WCDMA calls in Switzerland, but find similar differences between GSM and WCDMA. In [8], the same application was used to record the emitted powers during GSM voice calls for a single subject in a moving train to the fixed network outside the train. A median emitted power of 18-21 dBm was reported for GSM on the train. The median values measured in this study range from 23 to 32 dBm on site 1 and from 13 – 17 dBm on site 2, depending on the subject and exposure situation.

Conclusions

In this study, the emitted radio-frequency power was recorded for 53 subjects who carried out phone calls in three controlled exposure scenarios: calling with the phone at the ear, calling in speaker-mode, and calling with a headset. Phone calls were carried out using both WCDMA and GSM. The emitted power at the ear is found to be higher than the emitted power in the other exposure conditions for both

communication technologies. From our results and SAR data reported in literature, we do expect a reduction in SAR in the head when speaker-mode or a headset is used, in comparison to calling next to the ear.

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