Impact of own mobile phone in stand-by mode on personal radiofrequency electromagnetic field exposure

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ABSTRACT

When moving around, mobile phones in stand-by mode send periodically data about its position. The aim of this paper is to evaluate how personal radiofrequency electromagnetic field (RF-EMF) measurements are affected by such location updates. Exposure from mobile phone handset (uplink) was measured during commuting using a randomized cross-over study with three different scenarios: disabled mobile phone (reference), an activated dual-band and a quad-band phone.

In the reference scenario, uplink exposure was highest during train rides (1.19 mW/m^2) and lowest during car rides in rural areas (0.001 mW/m^2). In public transports, the impact of the own mobile phone on personal RF-EMF measurements was not observable due to high background uplink radiation from other people's mobile phone. In a car, uplink exposure with an activated phone was orders of magnitude higher compared to the reference scenario.

This study demonstrates that personal RF-EMF exposure is affected by the own mobile phone in stand-by mode due to its regular location update. Further dosimetric studies should quantify the contribution of location updates to the total RF-EMF exposure in order to clarify whether duration of mobile phone use, the most common exposure surrogate in epidemiological RF-EMF research, is actually an adequate exposure proxy.

Keywords:

Radiofrequency electromagnetic fields (RF-EMF)

Personal exposure meters (PEM)

Location update

Mobile phone

Stand-by

INTRODUCTION

The applicability of personal exposure meters (PEM) has successfully been demonstrated in several epidemiological studies to characterize personal exposure to environmental radiofrequency electromagnetic fields (RF-EMF) such as mobile phone base stations or broadcast transmitters.[1-6] It is acknowledged, however, that personal measurements are affected by the own mobile phone use (uplink emissions), which is a severe limitation for the interpretation if one is interested to differentiate between exposure from own and other people's mobile phone. Such a differentiation is important since exposure of the body depends heavily on the distance to the source which is different for the own mobile phone compared to other people's mobile phone.

Mobile phones are not only emitting RF-EMF when being used for calls and texting, but also in stand-by mode due to location updates; i.e. changing from one cluster of base stations to the next.[7] Since a network is divided into cells (location areas), covered by a group of base stations, a mobile phone informs the cellular network about changes of their location area, based on different location area codes. Such location updates are necessary to maintain constant connectivity with the network. In particular, when moving in a car or train, a mobile device sends periodically information about its position while changing location. However, little is known so far on the extent of such location updates in real life situations.

Most personal exposure assessment studies have focussed on environmental EMF and thus exposure from the own mobile phone (uplink) is not of interest and different strategies have been used to deal with that problem[8]: 1) noting wireless calls in a diary and excluding the corresponding PEM measurements from the data analysis[9], or 2) hiring people for taking measurements and force them to shut down their own mobile phone[8]. The latter approach is the best solution from a scientific point of view but is unlikely to be acceptable for volunteers of a population survey.[1]

With the diary approach,[9] higher mean mobile phone uplink exposure levels for study participants owning a mobile phone compared to participants not owning a mobile phone (0.0417 mW/m^2 vs. 0.0189 mW/m^2, respectively) had been observed.[9] This difference may be explained by forgotten or imprecise diary entries, by different behaviour between the two groups in terms of spending time close to other mobile phone users or due to location update procedures of the own mobile phone in stand-by mode.

In order to systematically evaluate the impact of the own mobile phone in stand-by mode on PEM measurements, two measurement studies were conducted: a public transport and a car study. Since we hypothesized that the impact of an own mobile phone is increasing with increasing movement velocity, we included measurements from different types of settings: in trains, buses and cars while moving and staying at train and bus stations. We also considered the frequency bands Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS) separately as well as the distance between the mobile phone and the PEM.

METHODS

Study design

We used a three-way randomized cross-over study design with three scenarios: i) a disabled mobile phone (reference); ii) a dual-band mobile phone (Nokia 2600) working on two frequency ranges: GSM 900 (880-915 MHz) and GSM 1800 (1710-1785 MHz) and a quad-band smart phone (Blackberry bold 8800 and an iPhone 4) capable to transmit and receive on four frequency ranges: GSM900, GSM1800, CDMA (Code Division Multiple Access, 850-1910 MHz) and UMTS (1920-1980 MHz).

An overview of the study design is shown in Figure 1. During the non-reference scenarios, the mobile phones were in stand-by-mode without own use. Measurements were taken close to the mobile phone (proximal), with a distance of approximately 10 to 15 cm between PEM and mobile phone (for both studies), and distal from the source (exact location see Figure 2), with a distance of about 50 cm for the public transport study and around 70 to 80 cm for the car study. During data collection in the framework of the public transport study, the device distant to the source was carried in a bag at the back of the body (confer figure 2) in order to maintain a distance of about 50 cm to the emitting device.

The public transport study was carried out in four different settings: bus stop, train station, bus ride and train ride. Data collection took place during three weeks (from 25th January 2010 to 23rd March 2010) in the morning and in the evening during regular commuting hours, always at the same times of the day on the same travel routes. The scenarios were rotated each day to obtain for each scenario one morning and one evening measurement for each workday. The scenarios were rotated each day to obtain for each scenario one measurement for each workday. During the measurements, a pre-specified activity diary was filled in to unequivocally attribute each measurement to the correct setting or area.

The car study consisted of five car rides which were conducted at five different days between 13th November 2010 and 4th January 2011 on the same routes. In each ride a distance of about 280 kilometres had been covered. Rural, urban and highway areas were defined when leaving or entering the city or a highway respectively by passing the road sign. Using GPS recordings, measurements of each ride were classified as rural, urban or highway measurements.

All measurements of both studies had been collected by the same trained collaborator.

Personal measurements

We used two PEMs of the type EME Spy 120 (SATIMO, Courtaboeuf, France, http://www.satimo.fr/), which were placed proximal and distal to the mobile phone. This portable device is capable to measure 12 different frequency bands of RF-EMF, ranging from 88 MHz (frequency modulation), to 2500 MHz (W-LAN). Up- and downlink mobile phone bands are measured separately. The measured frequency ranges for the uplink bands are 880-915 MHz (GSM 900), 1710-1785 MHz (GSM 1800) and 1920-1980 MHz (UMTS) which fits to the emission spectrum of the used mobile phones. Note that CDMA is not in use in the study country.

The measurement interval was set to four seconds in order to collect a large amount of data points.

Statistical analysis

In order to take into account measurements below the detection limit, arithmetic mean values, standard deviation and other summary statistic measures were calculated using the robust regression on order statistics (ROS) method[10] for each setting at each day separately. If less than three measurements were above the detection limit for a given setting and frequency band, the arithmetic mean value was set to 0.000265 mW/m².

RESULTS

A total of 109,668 measurements had been collected (64,551 measurements from the public transport study and 45,117 from the car study). The power flux density of total uplink measurements of the three uplink bands combined (GSM 900, GSM 1800 and UMTS) was highly variable. For the reference scenario, highest uplink values were found during train rides (1.19 mW/m^2), whereas lowest values occurred during car rides in rural areas (0.0012 mW/m^2) (Figure 3a). Uplink levels during the reference scenario (mobile phone turned off) were higher in the public transport study than in the car study and total uplink exposure mainly originates from GSM 900 and GSM 1800 frequency bands, while contribution of UMTS is negligible (<0.001 mW/m^2, except for train rides: 0.0013 mW/m^2) (Figure 3a and 3b). Even during the quad-band scenario the GSM bands were higher than the UMTS band in all settings.

Public transport study

Total power flux density of all measured frequency bands (88-2500 MHz) for all settings combined for the PEM placed proximal to the mobile phone was 0.65 mW/m^2 in the reference, 0.43 mW/m^2 in the dual-band and 0.73 mW/m^2 in the quad-band scenario. The average proportions of uplink measurements in all four transportation modes combined were 81.6% (reference), 72.6% (dual-band) and 55.3% (quad-band), respectively.

For all settings and scenarios combined the percentage of nondetects for the device in vicinity to the source was 60.8% (67.7% for the distant device) for GSM 900 and GSM 1800 combined and 98.2% (98.6%) for UMTS.

During the scenarios with activated phones, GSM uplink (sum of GSM900 and GSM1800) measurements in public transports were not consistently higher compared to the reference scenario (Figure 3a and 3c), as would have been expected based on our hypothesis. During train rides, where most of the location updates are expected to occur, measurement levels were actually lower with the activated phones. In contrast, UMTS uplink levels were always higher in the scenario with an activated quad-band phone compared to the two other scenarios without own UMTS emissions (Figure 3b). Except during train rides, this difference was smaller for the distal measurement device (Figure 3d). The data distribution for each scenario and frequency band is presented as supplementary material (Figure 4a-d).

Car study

Total power flux density of all measured frequency bands in all areas for the PEM placed proximal to the mobile phone was 0.12 mW/m^2 in the reference, 0.35 mW/m^2 in the dual-band and 1.62 mW/m^2 in the quad-band scenario. The proportions of uplink bands were 4.9%, 62% and 81.9%, respectively. For all settings and scenarios combined the percentage of nondetects for the device in vicinity to the source was 88.4% (93.4% for the distant device) for GSM 900 and GSM 1800 combined and 99.2% (99.7%) for UMTS.

During the scenarios with activated phones GSM uplink measurements were considerably higher compared to the reference scenario (Figure 3a-3d). For instance, in rural areas GSM uplink of the proximal device was 0.0014 mW/m² for the reference scenario, 0.395 mW/m² for the dual-band scenario and 2.923 mW/m² for the quad-band scenario (Figure 3a). The Proximal and distal devices showed similar values for GSM frequency bands. Regarding UMTS uplink, levels were increased for the quad-band scenario compared to the two other scenarios (Figure 3b). This increase was more pronounced for the proximal device than for the distal device. For the distal device, it was even negligible for the urban area (Figure 3d). The data distribution for each scenario and frequency band is presented as supplementary material (Figure 4a-d).

DISCUSSION

Our study demonstrates that PEM measurements are affected by the own mobile phone in stand-by mode. The effect was more pronounced in the car study than in the public transport study. This pattern is not surprising because measurements in the own car are hardly affected by other people's mobile phone. During commuting in public transports, however, other people's mobile phone are influencing the uplink measurements considerably. Thus, GSM levels in the reference scenario during bus and train rides were about 100 times higher than during car rides. As a consequence of this high background exposure in trains, due to the use of other people's mobile phone in a closed area intensified by the Faraday cage effect, the relative contribution of the location update from the own mobile phone is small and the contribution of the own mobile phone is masked in our measurements.

This measurement study provided additional insights. First, UMTS uplink exposure is considerably lower than GSM uplink exposure. For UMTS, the impact of the own quad-band mobile phone (smart phones) was observable in almost all scenarios. However, the absolute contribution of UMTS signals to total uplink exposure (GSM900, GSM1800 and UMTS signals combined) was very small (0.2 % for the public transport study and 5.4% for the car study). Second, for location updates quad-band phones seem to use both, the GSM and the UMTS frequency bands. We measured higher GSM than UMTS levels and found even indication that GSM location update of quad-band phones is more pronounced than GSM location update of dual-band phones. This suggests that quad-band phones execute more location updates than dual-band phones. Possibly, quad-band mobile phones need more frequent location updates due to new applications (apps) including push-notifications. Push-notifications, which require W-LAN or cellular connection, are a way for applications (newspaper, e-mail, messages, etc.) to provide alerts and information. Third, even for the distal PEM of the car study we found considerable impact from the own mobile phone. This implies that the own mobile phone in a car is a relevant exposure source to the passenger(s) even if not carrying the phone on the body.

Our study implies that PEM uplink measurements are affected by the own mobile phone in stand-by mode. This was best visible in the car study, where measurements were barely affected by other people’s mobile phone. In public transports or when being stationary (bus stop and train station), the relative impact of the own phone was small compared to the other sources and thus less clearly visible. Nevertheless, an impact on the measurement has to be expected, in particular when moving. We found also some indications that RF-EMF contributions in stand-by mode will become more relevant in the future because of the increasing use of smart phones that need regular location updates. To the best of our knowledge, no study has yet investigated exposure from location updates in real life situations.

The study offers amendatory information about exposure provoked by other people. In this context, we observed higher RF-EMF exposure in settings where a lot of people are present as especially was perceived in public transports, particularly in trains, and in urban environments augmenting exposure levels. This was clearly showed by higher exposure levels for the reference scenario where only background exposure levels were quantified.

Our results reflect a snap-shot in time based on one type of for each scenario and two mobile phone operators. Thus, it cannot be generalized to other countries or to the future, since extent of location update is determined by various factors such as the type of phone and the implemented technology of the mobile phone network operators.[11] Thus, there is an urgent need to evaluate more thoroughly how personal RF-EMF exposure is affected by the own phone in stand-by mode. A better knowledge of the relevance of this exposure source in comparison to RF-EMF exposure when talking on a phone helps to clarify whether duration of mobile phone use, the most common exposure surrogate in epidemiological RF-EMF research, is actually an adequate exposure proxy. In particular, when interested in whole body exposure, new exposure assessment approaches have to be considered by taking into account the emission behaviour of mobile phones in stand-by mode. Whole body exposure is of interest for instances in studies on leukaemia[12] or on foetus during pregnancy.[13-14]

Our measurement study has some relevance for people who want to minimize their personal exposure. The study indicates that own uplink exposure during car driving can be considerably reduced (about a factor of 100) when turning off the own mobile phone in order to prevent it from location updates. Recently, use of UMTS phones has been recommended as a precautionary measure because UMTS calls are carried out with lower amount of radiation emissions.[15] Before this precautionary measure can be firmly given to the public, it has to be ensured that lower exposure during calls is not compensated with higher emissions in stand-by mode.

In summary, this study demonstrates the complexity of the RF-EMF emission pattern of mobile phones in stand-by mode. So far, this exposure source has been neglected in the RF-EMF research. More thorough studies are needed to quantify this contribution to the total personal exposure. Such knowledge is needed for the interpretation of previous RF-EMF research and for the design of future high quality epidemiological research.

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FIGURES

Figure 1. Overview of the study design consisting of the two sub-studies public transport study (a) and the car study (b).

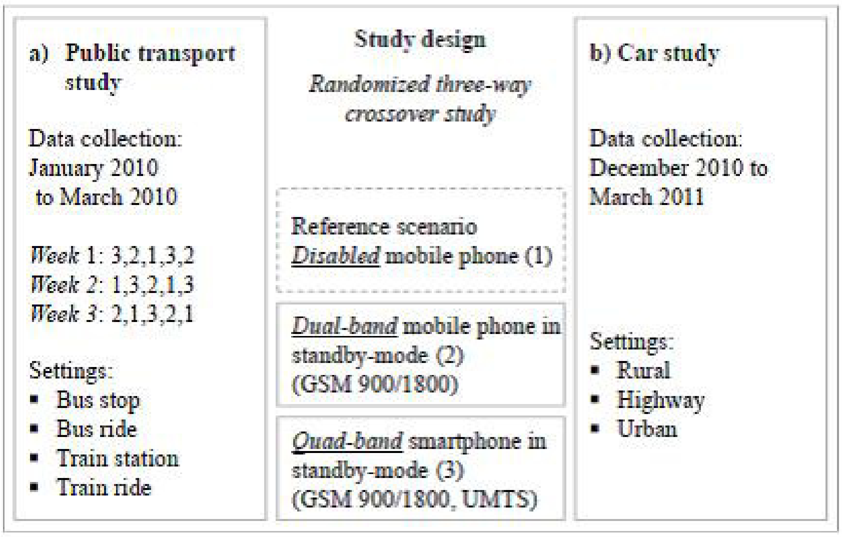


Figure 2. Overview of the placement of the mobile phone and the measurement devices in the public transport (a) and the car study (b).

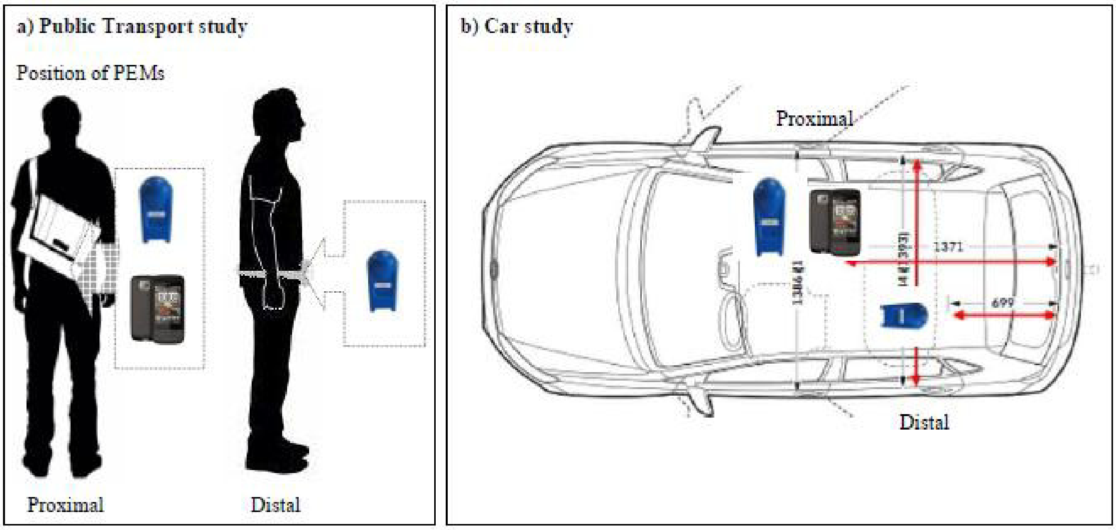
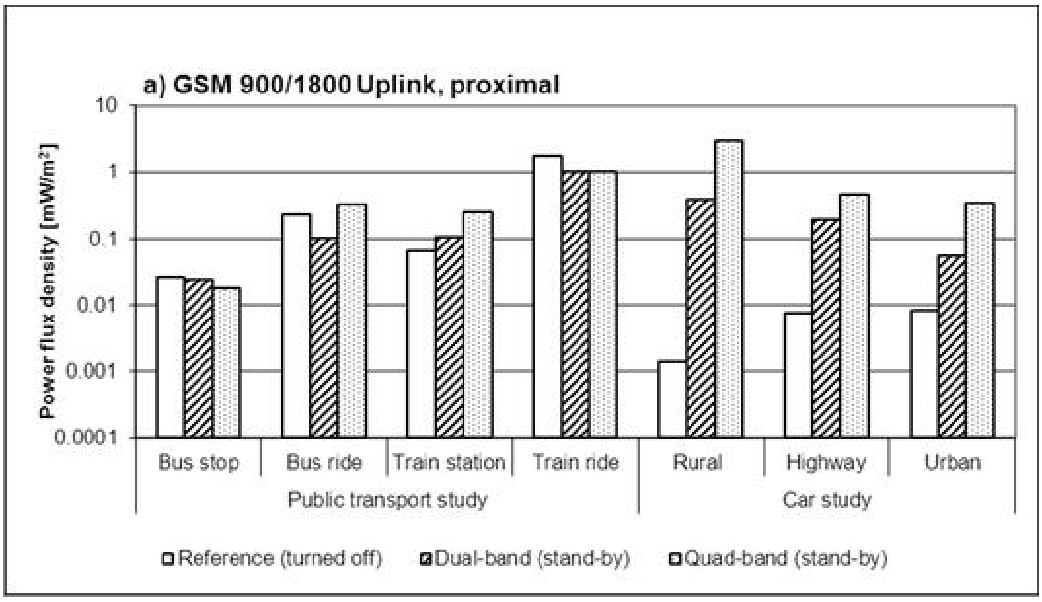
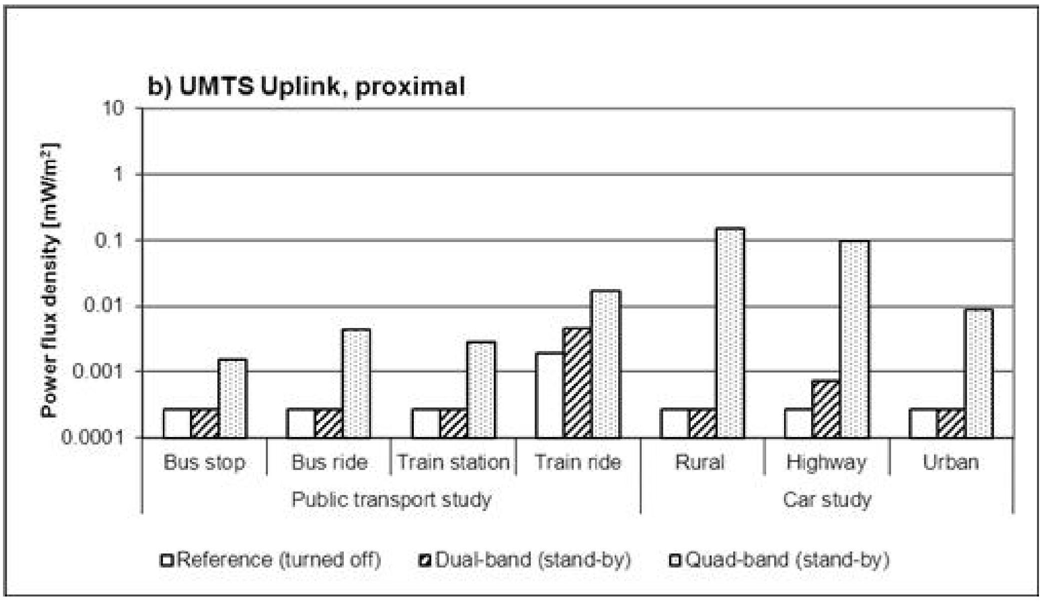
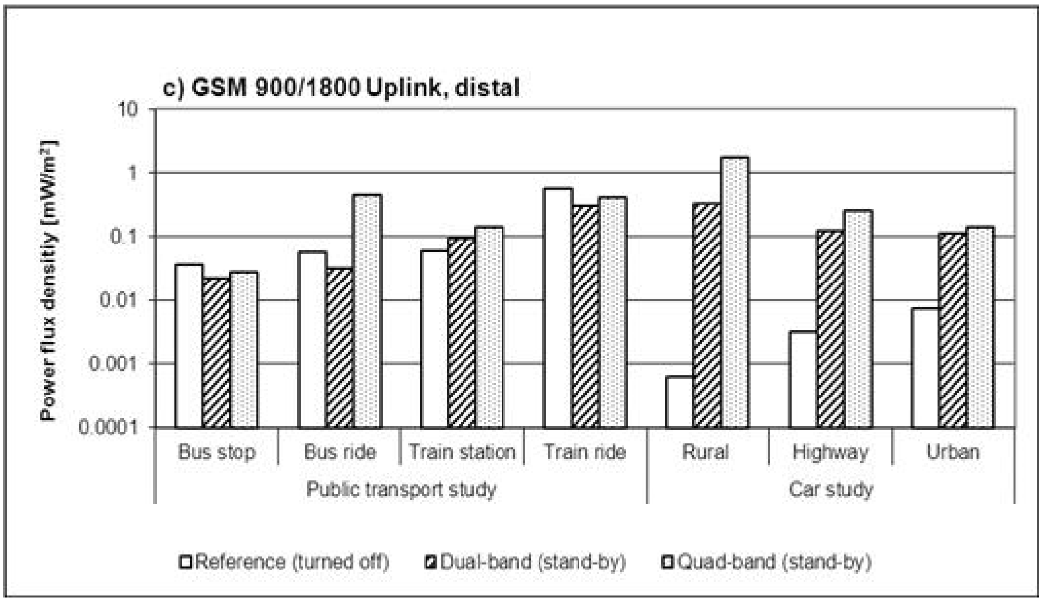
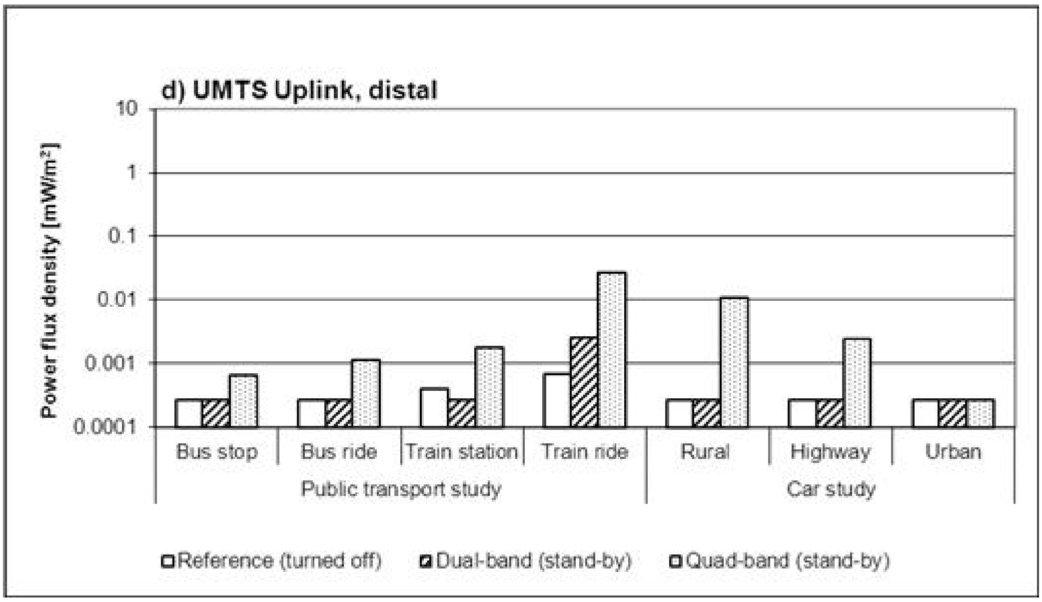


Figure 3: Arithmetic mean uplink power flux density levels (mW/m^2) and standard deviation in the public transport study and the car study subdivided in the GSM 900/1800 and UMTS frequency bands for the devices proximal (figures a and b) and distal (figures c and d) to the source (mobile phone).



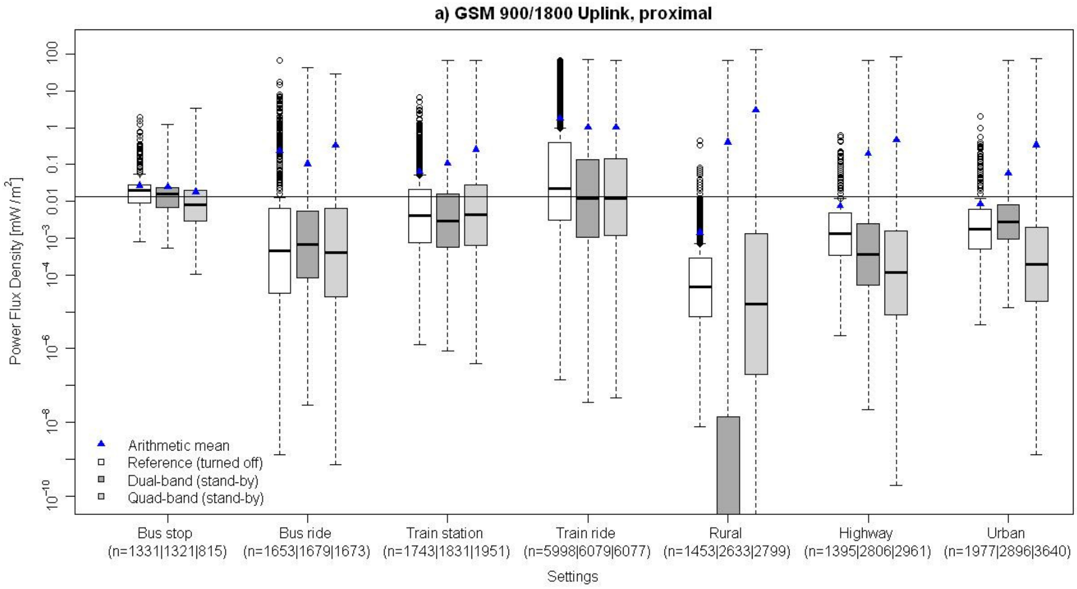


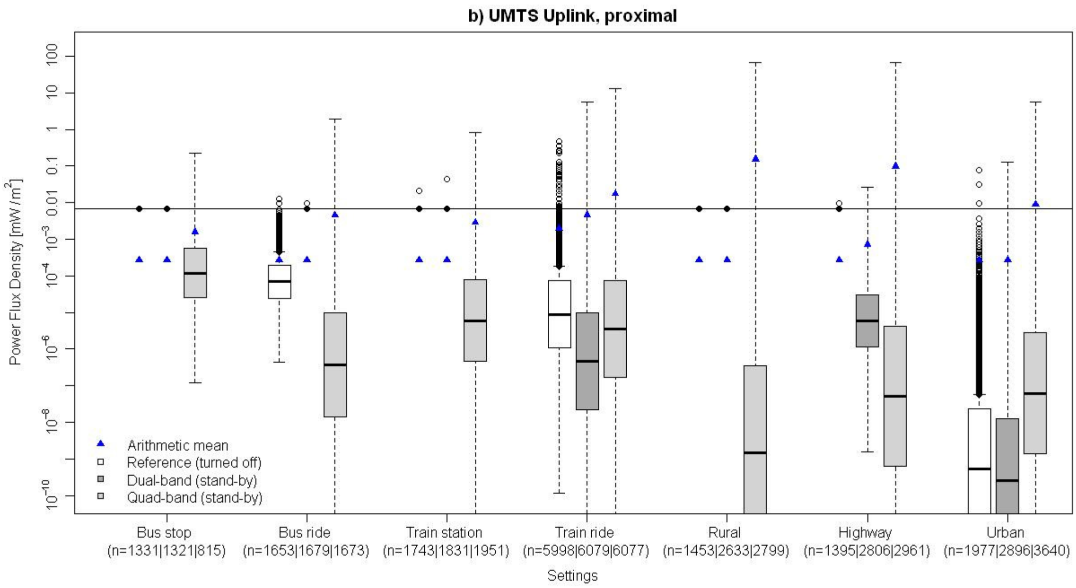

c) GSM 900/1800 Uplink, distal
Power flux density [mW/m²]
10
1
0.1
0.01
0.001
0.0001
Bus stop
Bus ride
Train station
Train ride
Rural
Highway
Urban
Public transport study
Car study
Reference (turned off)
Dual-band (stand-by)
Quad-band (stand-by)

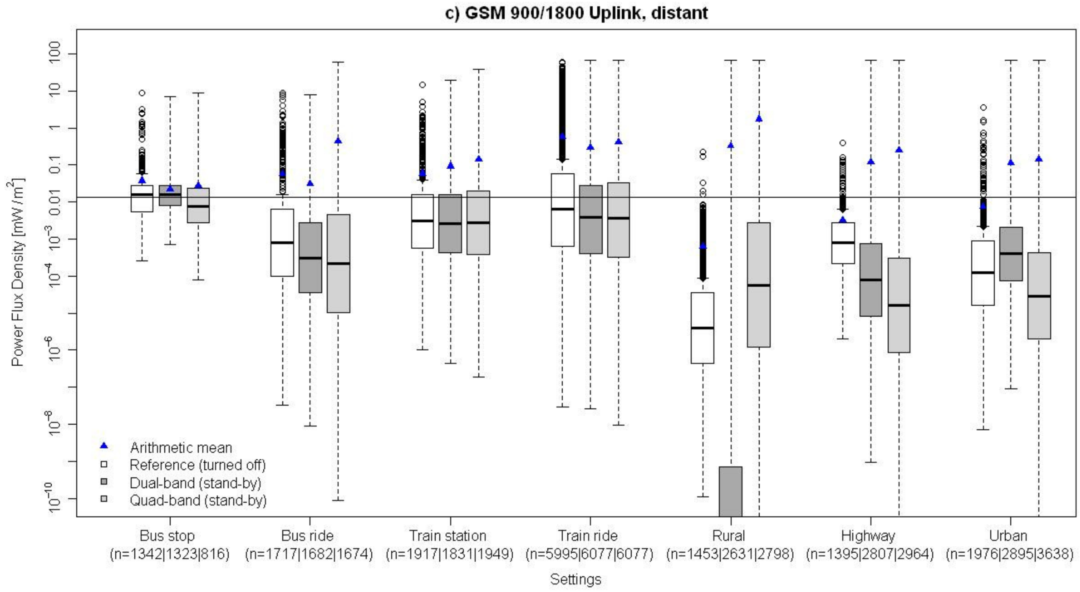

d) UMTS Uplink, distal
Power flux density [mW/m²]
10
1
0.1
0.01
0.001
0.0001
Bus stop
Bus ride
Train station
Train ride
Rural
Highway
Urban
Public transport study
Car study
Reference (turned off)
Dual-band (stand-by)
Quad-band (stand-by)

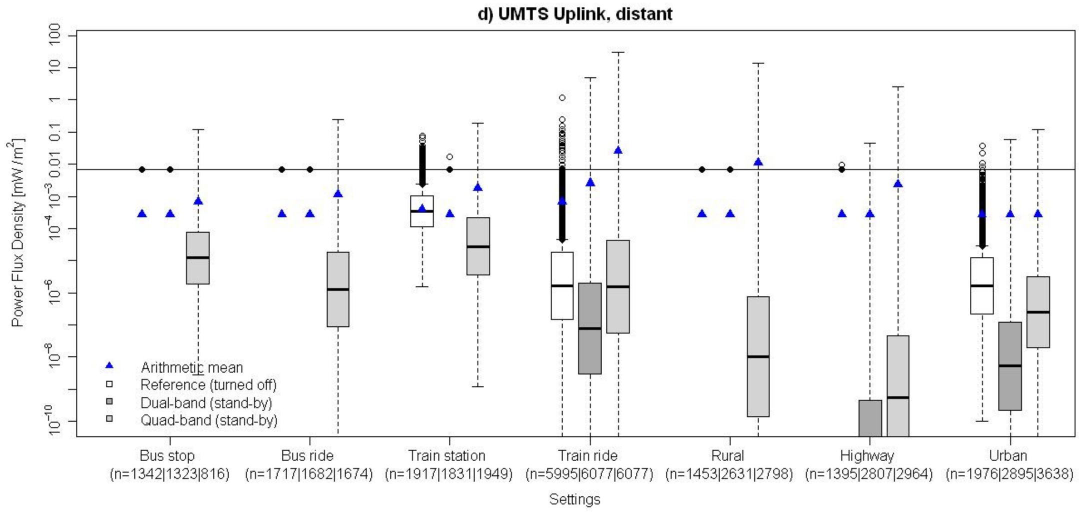
SUPPLEMENTARY MATERIAL

Figure 4: Boxplots and arithmetic means (triangle) of uplink power flux density levels (mW/m^2) in the public transport study and the car study subdivided in the GSM 900/1800 and UMTS frequency bands for the devices proximal (figures a and b) and distal (figures c and d) to the source (mobile phone). Data distribution below the detection limit (horizontal) line was estimated using robust order on regression statistics.






c) GSM 900/1800 Uplink, distant
Power Flux Density [mW/m2]
Arithmetic mean
Reference (turned off)
Dual-band (stand-by)
Quad-band (stand-by)
Bus stop (n=1342|1323|816)
Bus ride (n=1717|1682|1674)
Train station (n=1917|1831|1949)
Train ride (n=5995|6077|6077)
Rural (n=1453|2631|2798)
Highway (n=1395|2807|2964)
Urban (n=1976|2895|3638)
Settings


d) UMTS Uplink, distant
Power Flux Density [mW/m2]
Arithmetic mean
Reference (turned off)
Dual-band (stand-by)
Quad-band (stand-by)
Bus stop (n=1342|1323|816)
Bus ride (n=1717|1682|1674)
Train station (n=1917|1831|1949)
Train ride (n=5995|6077|6077)
Rural (n=1453|2631|2798)
Highway (n=1395|2807|2964)
Urban (n=1976|2895|3638)
Settings