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Review

Spatial and temporal RF electromagnetic field exposure of children and adults in indoor micro environments in Belgium and Greece

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ABSTRACT

Personal radio frequency electromagnetic field (RF-EMF) exposure, or exposimetry, is gaining importance in the bioelectromagnetics community but only limited data on personal exposure is available in indoor areas, namely schools, crèches, homes, and offices. Most studies are focused on adult exposure, whereas indoor microenvironments, where children are exposed, are usually not considered. A method to assess spatial and temporal indoor exposure of children and adults is proposed without involving the subjects themselves. Moreover, maximal possible daily exposure is estimated by combining instantaneous spatial and temporal exposure. In Belgium and Greece, the exposure is measured at 153 positions spread over 55 indoor microenvironments with spectral equipment. In addition, personal exposimeters (measuring EMFs of people during their daily activities) captured the temporal exposure variations during several days up to one week at 98 positions. The data were analyzed using the robust regression on order statistics (ROS) method to account for data below the detection limit. All instantaneous and maximal exposures satisfied international exposure limits and were of the same order of magnitude in Greece and Belgium. Mobile telecommunications and radio broadcasting (FM) were most present. In Belgium, digital cordless phone (DECT) exposure was present for at least 75% in the indoor microenvironments except for schools. Temporal variations of the exposure were mainly due to variations of mobile telecommunication signals. The exposure was higher during daytime than at night due to the increased voice and data traffic on the networks. Total exposure varied the most in Belgian crèches (39.3%) and Greek homes (58.2%).

Contents

Abbreviations: DAB, digital audio broadcast; DECT, digital enhanced cordless telecommunication, cordless phone; DL, down link; FM, frequency modulation, FM radio; GSM, Global System for Mobile Communications; LOS, line of sight; MHz, megahertz; PMR, Personal mobile Radio; RF-EMF, radio frequency electromagnetic field; ROS, regression on order statistics; TV, television; UL, up link; UMTS, Universal Mobile Telecommunications System; TETRA, Terrestrial Trunked Radio; W-LAN, wireless local area network; WiFi, wireless fidelity.

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1. Introduction

Electromagnetic field exposure of the general public is nowadays assessed with narrowband equipment and personal exposure meters (exposimeters). Very little is known about radio frequency electromagnetic field (RF-EMF) exposure in everyday life in indoor environments such as schools, crèches, homes, and offices. In the last few years, research focus was on exposures in outdoor environments (urban and rural) such as public transportation, cars, and few about offices and homes (Frei et al., 2009; Joseph et al., 2008, 2010, 2012; Thuróczy et al., 2008; Viel et al., 2009). Röösli et al. (2010) and Mann (2010) discuss measurement protocols for exposimeters. Personal exposimeters are devices worn on the body. These register the electric fields in the presence of the subject that wears the device. Exposimeters are calibrated in free space and their accuracy strongly depends on the position on the body, given that multipath fading combined with shadowing by the human body result in large field variations for varying measurement positions (Thielens et al., 2013). Almost never child exposure is considered, moreover indoor data for schools, crèches, homes, and offices are mostly lacking. In Tomitsch et al. (2010) exposures in bedrooms of residences are investigated. Only in Juhász et al. (2011), personal exposure of employees of schools and crèches is considered. Moreover, temporal exposure variations are almost not considered in the literature. Only Joseph et al., 2009, Joseph and Verloock (2010), Mahfouz et al. (2011), and Manassas et al. (2012) contribute to temporal data but they are not based on personal exposimetry.

Juhász et al. (2011) reported that child exposures are comparable to the worktime exposure of adults. As stated in Juhász et al. (2011), difficulties arise when involving children in personal exposimetry such as the need for consent of parents, cooperation during longer periods, possible lack of self discipline to follow procedures, and increased risk on breaking equipment. Our paper builds on this idea that experiments with children are difficult, and assesses temporal and spatial child exposure without involving them.

In this paper, spatial and temporal RF exposure is assessed in Belgian and Greek schools, crèches, offices, and homes in different environments (rural, suburban, urban and urban dense). In Belgium and Greece, exposimeter and narrowband measurements with spectrum analyzers are performed at in total, 55 indoor location (schools, crèches, offices, and homes). At every indoor location, zones and rooms of maximal exposure were considered.

The objective of this paper is to present a method to assess spatial and temporal indoor exposure of children and adults without involving them. Moreover, extrapolation of spatial exposure to maximal daily exposure is performed by combining instantaneous spatial exposure and temporal exposure. In particular, three objectives are of interest, namely (i) to assess RF exposure in typical indoor microenvironments and also where children are often present, by performing spatial, instantaneous narrowband measurements with a spectrum analyzer, (ii) to characterize the evolution of RF signals during 24 h in different indoor microenvironments and in various environments, by assessing temporal variations with exposimeters, and (iii) to extrapolate the maximum field values using the instantaneous narrowband measurements and a scale factor calculated from the temporal measurements.

2. Materials and methods

2.1. Indoor microenvironments and environments

The investigated “indoor microenvironments” were homes, schools, crèches, and working offices. The considered “environments” were rural, suburban, urban and dense urban environments. In Belgium, measurements were performed at 29 indoor locations (10 schools, 11 crèches, 3 offices and 5 homes) and in Greece at 26 indoor locations (5 schools, 10 homes with babies and pre-school children, 5 offices and 6 homes). These indoor environments were located in four different environments (urban, urban dense, suburban, and rural) categorized based on population density and the expected amount and time of traffic (Joseph et al., 2009; Joseph and Verloock, 2010). Table 1 summarizes the number of measurement positions per microenvironment and per environment.

For the spatial measurements, a total number of 116 and 36 narrowband measurements were performed in Belgium and Greece, respectively. Per indoor microenvironment temporal exposimeter measurements were carried out in at least one room, by placing the device at a spot inside the room, instead of having it worn by an individual, avoiding, in this way, several problems related to the use of such equipment. In Belgium, also temporal exposimeter measurements occurred in a second room. For schools, a classroom for children between 6 and 12 years and a classroom for pre-school children (3–6 years) were considered. In Greece the selected classrooms were either for children from 6 to 12 years old or for junior highschool children (13–15 years). Furthermore, in Greece, measurements were performed in teachers’ room where indoor sources (such as DECT devices) are usually installed. For crèches, the bedroom of the baby’s and infants (below 3 years) and