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REGULAR PAPER

Assessment of personal radio frequency electromagnetic field exposure in specific indoor workplaces and possible worst-case scenarios

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ABSTRACT

The aim of this study is to examine the electromagnetic field (ranging from 80 MHz to 6 GHz) exposure level at different locations over time in Prishtina, Kosovo, and develop possible worst-case exposure scenarios. We performed personal exposure measurement for persons working in the offices of some companies which are characterized by extensive use of wireless technologies. The measurements were recorded during working hours, after working hours and during the weekends. The results showed that the total mean power density value of the working day was 0.524 mW/m^2. During the weekend, for the same exposure hours as working day, the mean power density value was 0.828 mW/m^2. The total mean power density value has been just 0.676 mW/m^2. Due to the usage of the DECT system, the total mean power density value of the work day was approximately 37% less when compared to the weekend. Based on the results obtained from our measurement campaign, we may conclude that the mean values of the power density for office environments in Kosovo are comparable with those of several European countries.

1. Introduction

The massive shift towards the use of wireless and internet technologies and specifically the massive increase of wireless connectivity in household and office devices has raised huge concerns about possible health effects of personal exposure to radio frequency electromagnetic fields (RF-EMFs) [1].

Exposure levels have been reported differently, with a large portion of reported measurements being far below safety standards given by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [2], sometimes even falling below the detection limits of the measurement equipment used. Since safety standards aim to protect health of the public in areas where members of the public spend significant time, personal exposure levels to RF-EMFs should be monitored and balanced with the health, safety and other security issues. Most personal exposures from the signals of radio and television broadcast towers were observed to be weak, while the contribution made to RF exposure from wireless telecommunications technology is continuously increasing and its contribution was above 60% of the total exposure [3]. In light of this, lowering the output powers of base station antennas could be necessary to maintain personal exposure levels far below safety standards. The results of the power density (mW/m^2) exposure level measurements obtained via various methodologies for different countries are published in [4–12]. Most of these studies are focused on the base-station exposure levels.

Since exposure depends on individual habits and time spent in a specific environment, the use of Personal Exposure Meters (PEMs) is considered to be an established method to derive reliable personal exposure levels necessary for epidemiological studies on possible health effects [13].

Even though few studies using PEMs are published [14–18], very limited data is available on personal RF-EMF exposure levels in everyday life and especially for indoor workplaces, such are offices where people spend a considerable amount of time. The recent study of temporal RF-EMF exposure trends in outdoor environments completed for a few countries shows a significant increase of exposure within one year [19] suggesting to extend the study to workplaces and homes where people spend most of their time.

The observed differences in exposure levels may not reflect the true differences in exposure and may be partially or fully caused

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by methodological differences. Researchers have thus developed a study protocol for future studies that will address personal exposure to RF-EMFs [20].

In study [21], the mean power density exposure levels for different countries for specific microenvironments are presented, such as: home, office, outdoor and transport. The commonly used protocol serves as a way to calculate the mean exposure levels in accordance to specific measurement protocol but not to identify the worst-case exposure scenarios based on real-life exposure. Resultes presented in [22] confirm the spatial and temporal variability of RF-EMFs exposure during daily life activities.

In this study we present results of the first large scale measurement campaign in Kosovo, focusing in specific indoor workplaces. The assessment of exposure is carried out collecting measurements with novel dosimeter EME Spy 140 (Satimo, Cortaboeuf, France, http://www.satimo.fr) resulting in a large data pool of exposure levels enabling derivation of reliable average exposure values and possible worst-case exposure scenarios. The study proprietary protocol instructed participants to engage in routine activities without limiting them on usage of specific wireless personal devices, such as mobile phone. One of the advantages of the study is the presentation of measurements in two more frequency bands of wireless technologies: WiMAX and Wi-Fi 5G, since most of the previous published studies were conducted with EME SPY 120 exposimeter (Satimo, Cortaboeuf, France, http://www.satimo.fr), measuring on 12 frequency bands. The results presented in this study can be used for many purposes, e.g., maintenance of the safety guidelines, reduction of exposure while keeping the communication quality, and for the prediction of RF-EMF distribution at different workplaces.

2. Materials and methods

The measurement protocol in the present study is based on the potential worst-case scenario of personal exposure to RF-EMFs in Kosovo. Participants are chosen for measurements mainly based on their occupation and anticipated behaviors in their use of wireless communications technologies. Of particular interest are the data measured in the workplaces due to the specific services offered by their companies in the context of the use of wireless technologies. In this case, their personal exposure to RF-EMFs in the frequency range of 80 MHz – 6 GHz has been measured during their daily activities in different microenvironments.

2.1. Measurement instruments and statistical analysis

The study with regard to personal exposure to RF-EMFs was performed with the use of the **EME Spy 140** exposimeter. This exposimeter measures 14 frequency bands (88 – 5850 MHz) used for wireless communications. Measured frequency bands of the EME Spy 140 are summarized in Table 1.

Table 1
Measured frequency bands and characteristics of the EME SPY 140 exposimeter.

BAND	Frequency (MHz)
FM	88 – 108
TV3	174 – 223
TETRA	380 – 390
TV4&5	470 – 830
GSM Tx (GSM + UMTS 900(UL))	880 – 915
GSM Rx (GSM + UMTS 900(DL))	925 – 960
DCS Tx (GSM 1800(UL))	1710 – 1785
DCS Rx (GSM 1800(DL))	1805 – 1880
DECT	1880 – 1900
UMTS Tx (UMTS 2100(UL))	1920 – 1980
UMTS Rx (UMTS 2100(DL))	2110 – 2170
Wi-Fi 2G	2400 – 2500
WiMAX	3400 – 3800
Wi-Fi 5G	5150 – 5850

This device also measures the total level of exposure. The configuration of the EME Spy is performed via its software, **EME Spy Analysis V3**. Data stored in the memory of the exposimeter **EME Spy 140** were transferred in text/Excel file format to a computer and were analyzed using EME Spy Analysis V3. The variability at the level of exposure to the RF-EMF was analyzed by calculating statistical parameters of registered profiles: maximum and median values and the total level of exposure. Processing the measurement results linked us to the problem of the non-detected values. All of the values below the lower limit have automatically been set as the lowest possible detection value. The lower detection limit of the **EME Spy 140** differs from band to band (6.631 μW/m^2 for FM, 0.265 μW/m^2 for TETRA and TV4 and 5, 1.061 μW/m^2 for TV3, WiMAX and Wi-Fi 5G and 66.312 nW/m^2 for the rest), while the upper limit is 95.49 mW/m^2 across all bands. The 'half of the limit' detection method [23] was used for the statistical analysis of the obtained results in the present study. All measured values below the detection limit were replaced by half of the limit values before analysis. This method is often used in the context of environmental epidemiology, and the results seem plausible because all values have to be between zero and the limit of determination. Each of measurement samples was screened for possible technical errors and suspicious samples were removed. It is found that measurement accuracy depends on the carrier and also on the number of occupied time slots for Time division Multiple Access services. The simplicity of the measurement setup and the uncomplicated measurement protocol increase the possibility of fast validation and a higher accuracy in the characterization and testing of PEMs [24]. There is a proposal underway for a new compact personal dosimeter, composed by multiple RF sensor modules minimizing uncertainties caused by the human body, the specific antenna used and the exact position of the PEM [25]. It should be noted that PEM used in this study have valid calibration certificate.

2.2. Measurement procedure

Fifteen persons from the age of 22 – 26 participated voluntarily in the study. In each company, three people were selected to use the device during a week, according to defined protocol. Invited persons attended the measurements campaign successfully and were correct in all rules of the measurement protocol. They were surrounded by several smart phones, Wi-Fi routers, DECT (somewhere) and other wireless technologies, depending on the workplace. Participants were previously trained in using portable EME Spy device and signed an informed consent form. The same measurements were repeated for 6 months, and the results obtained have been similar. The second measurement of participants that took part in the study twice were only used for evaluation of repeatability of exposure assessment.

To obtain the measurements, we carried out the study in two different types of microenvironments: the office and home/outdoor urban areas. The offices included the Swiss Embassy, KEK (Kosovo Energy Corporation), PTK (Post and Telecommunications of Kosovo), IPKO (Private Telecommunication Company) and KOSTT (Transmission, System and Market Operator). The home/outdoor urban areas microenvironment was on an individual basis because these places represented the free-time activities of each person. Fig. 1 shows the locations of the microenvironments used for measurements on a map along with their GPS Coordinates. All microenvironments are close to the center of Prishtina.