In-situ RF Exposure in Schools, Houses, and Public Places

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INTRODUCTION

Nowadays, smartphones and tablets are used for educational purposes and for daily use by children in schools, at home, and at public places. Also wireless local area (WLAN) networks using WiFi technology are introduced in schools and are being used at home. This rapid expansion of networks and wireless devices in schools and homes causes a growing concern for parents and school boards regarding the adverse health effects due to radio-frequency (RF) electromagnetic fields (EMF).

In this study, RF–EMFs are assessed experimentally in various “sensitive” microenvironments such as schools, homes, and public places, where children are present. We distinguish between external and internal sources. Moreover, we compare indoor and outdoor exposures in the various microenvironments. The contributions of external and internal sources are determined and compliance of the fields of these emerging technologies with the ICNIRP guidelines for general public exposure is evaluated [1].

MATERIALS AND METHODS

The considered microenvironments were schools, homes, and public places. In these environments children and youth are often present. All microenvironments were located in urban environments. Five schools, homes and public places were considered. The schools were selected based on the presence of internal RF sources and the use of laptops, tablets, and smart boards. Also five homes where children reside and where WiFi was present were investigated. Additionally, measurements in two offices were performed. Broadband and narrowband measurements were executed at in total 713 and 119 positions, respectively. The majority of the measurements were performed indoor (535 broadband measurements and 90 narrowband measurements, in class rooms, rooms in homes, etc.), while 178 broadband and 29 narrowband measurement positions were outdoor (school gate, playing grounds).

A broadband probe of type Narda NBM-550 (measurement equipment) equipped with EF0391 and EF0691 (measurement probe; frequency range of 100 kHz to 3 GHz and 6 GHz, respectively) was used to measure the total electric-field value. For the narrowband measurements, the setup consisted of tri-axial Rhode and Schwarz R&S TS-EMF isotropic antennas (dynamic range of 1 mV/m – 100 V/m for the frequency range of 80 MHz – 3 GHz, and 2.5 mV/m – 200 V/m for a frequency range of 2 GHz – 6 GHz) in combination with a spectrum analyzer (SA) of type R&S FSL6 (frequency range of 9 kHz – 6 GHz).

Firstly, broadband measurements were performed at each site to determine positions of maximal exposure. These positions were identified through sweeping the area with the broadband probe at a height of 1.5 m above floor level. Secondly, at a position of maximal exposure, the frequency spectrum was measured from 80 MHz to 6 GHz to determine the significantly present signals. Only the downlink signals (i.e., signals originating from base stations) were considered in this study. Finally, the significant signals were then measured spread across the measurement site.

RESULTS AND DISCUSSION

Figure 1 shows a histogram of the total electric-field values measured with the broadband probe (cumulative fields) for all field data From the 713 measurements, 39% (277) of the values were below the sensitivity of the broadband probe, indicated in dark blue in Fig. 1. 94% of the values were below 1 V/m. The highest value was measured in offices and was 3.5 V/m. Lowest fields were measured in homes and the highest percentage of measurements in homes, namely 67%, had values below 0.20 V/m (sensitivity of probe). For the schools, 92% of the measurements were below 1 V/m and 56% were lower than the sensitivity level of the broadband probe (0.2 V/m, Fig. 1). The broadband measurements give a good view on the levels of cumulative exposure in the environments. Good agreement is obtained with the cumulative value determined from the narrowband measurements (see further e.g., maximum of 3.5 V/m in offices for broadband vs. 3.3 V/m for narrowband measurements).

We distinguish external signals (broadcast and telecommunication signals) and internal signals (WiFi and DECT). Table 1 summarizes the narrowband measurements: the maximum (E_{max}), average (E_{avg}), standard deviation σ of the measured RMS electric-field values and the average (AC) contributions are listed.

All measured electric-field values of Table 1 satisfy the ICNIRP guidelines for general public (ICNIRP, 1998). The maximum cumulative field value determined with the accurate narrowband setup was 3.3 V/m in offices due to *external* sources, namely, telecommunication signals. The highest cumulative field value for *internal* sources was 3.2 V/m, in schools and originating from WiFi.

In schools, the highest maximal and average field values were thus mainly due to internal signals (WiFi, E_{max} = 3.2 V/m, E_{avg} = 0.2 V/m). In homes, public places, and offices the highest maximal and average field values originated from telecommunication signals (1.1 V/m (E_{max}) and 0.1 V/m (E_{avg}) in homes, 2.4 V/m (E_{max}) and 0.6 V/m (E_{avg}) at public places, and 3.3 V/m (E_{max}) and 0.9 V/m (E_{avg}) in offices, Table 1). Lowest exposure values were obtained in homes (average of 0.2 V/m). The reason for this is that in the selected homes less internal sources such as WiFi and DECT are present than in schools and in offices and less people are using wireless applications, resulting in lower WiFi duty cycles and lower exposure values [2, 3]. Homes also mostly have less higher floors that can be in line-of-sight (LOS) with base station antennas, delivering lower exposure due to external sources than in multi-floor offices where the highest exposure was obtained LOS conditions. The homes in this study were single or two-story houses and no apartments in multi-storey blocks were considered here.

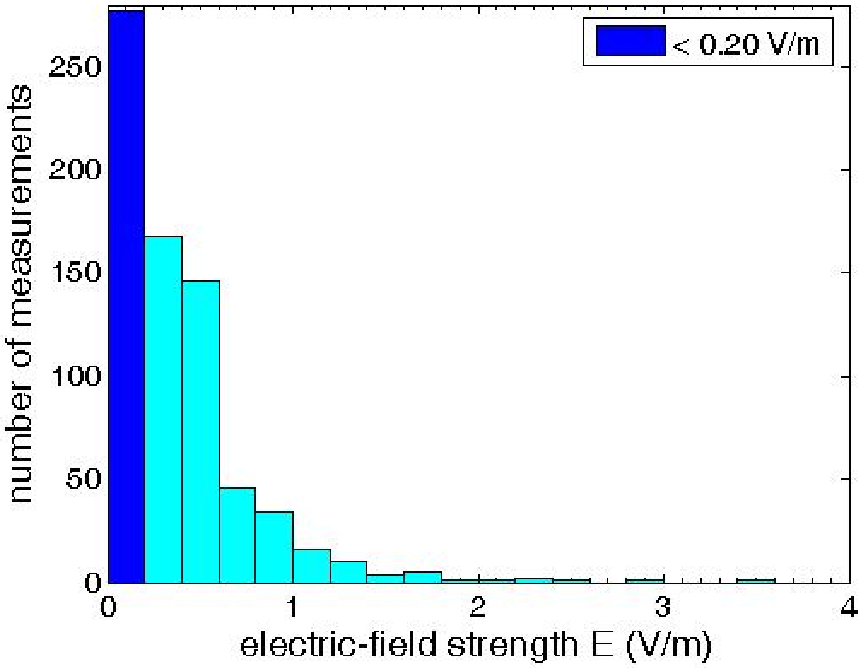

Figure 1: Histogram of broadband measurements performed in all microenvironments, dark blue represents data below the sensitivity of the broadband probe.

TABLE 1: Summary of the electric-field values of the narrowband measurements in the different microenvironments for internal and external sources (maximum, average, standard deviation), and the average (AC) contribution per RF signal.

microenvironment	signal type	source type	E_{max} (V/m)	E_{avg} (V/m)	σ (dB)	AC (%)
schools	External	Broadcasting	0.42	0.12	7	41
		Telecommunication	0.59	0.11	10	17
		Other external signals	0.14	0.05	18	5
	Internal	DECT	0.73	0.01	13	4
		WiFi	3.21	0.24	15	33
	Total	Cumulative all sources	3.27	0.35	8	100
		Cumulative external sources	0.63	0.18	7	63
		Cumulative internal sources	3.21	0.28	15	37
homes	External	Broadcasting	0.37	0.10	6	36
		Telecommunication	1.07	0.15	10	37
		Other external signals	-	-	-	-
	Internal	DECT	0.47	0.06	6	5
		WiFi	0.29	0.06	8	22
	Total	Cumulative all sources	1.08	0.23	7	100
		Cumulative external sources	1.07	0.20	8	73
		Cumulative internal sources	0.47	0.08	7	27
public places	External	Broadcasting	0.50	0.14	7	21
		Telecommunication	2.40	0.58	12	70
		Other external signals	-	-	-	-
	Internal	DECT	0.04	0.03	3	2
		WiFi	0.14	0.05	7	7
	Total	Cumulative all sources	2.40	0.62	10	100
		Cumulative external sources	2.40	0.61	10	91
		Cumulative internal sources	0.14	0.05	6	9
offices	External	Broadcasting	1.14	0.33	7	16
		Telecommunication	3.25	0.89	8	77
		Other external signals	-	-	-	-

	Internal	DECT	0.03	0.03	2	0
		WiFi	0.29	0.08	9	7
	Total	Cumulative all sources	3.29	0.10	7	100
		Cumulative external sources	3.29	0.97	8	93
		Cumulative internal sources	0.24	0.08	9	7
all microenvironments	External	Broadcasting	1.14	0.15	7	32
		Telecommunication	3.25	0.32	13	42
		Other external signals	0.14	0.05	18	2
	Internal	DECT	0.73	0.06	9	3
		WiFi	3.21	0.12	11	21
	Total	Cumulative all sources	3.29	0.45	9	100
		Cumulative external sources	3.29	0.38	10	76
		Cumulative internal sources	3.21	0.13	10	24

Cumulative all sources= total exposure of all measured RF signals, cumulative external sources = total exposure of all external signals (FM, PMR, T-DAB, TETRA, DVB-T, GSM900, GSM1800, LTE and UMTS-HSPA), cumulative internal sources = total exposure of all internal signals (DECT, WiFi at 2.4 GHz and WiFi at 5 GHz).

CONCLUSIONS

In this study, exposure to radio-frequency (RF) electromagnetic fields (EMF) was assessed in four environments, namely schools, homes, public places, and offices in suburban and urban environments (Flanders, Belgium). In-situ assessment was conducted by performing spatial broadband and accurate narrowband measurements. A distinction between internal and external sources was made.

All measured field levels satisfied the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP). From the 713 broadband measurements, 39% were below the sensitivity of the broadband probe and 94% were below 1 V/m. For the external sources, the highest cumulative field value was 3.3 V/m and 1 V/m on average, measured in offices and originated from telecommunication signals. The highest cumulative field value for internal sources was 3.2 V/m and 0.3 V/m on average, measured in schools and originating from WiFi. FM, GSM, and UMTS dominate the total downlink outdoor exposure.

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