View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Ghent University Academic Bibliography

Exposure to electric and magnetic fields at intermediate frequencies of household appliances

Sam Aerts*, Carolina Calderon†, Blaž Valič‡, Matthias Van den Bossche*, Leen Verloock*, Myron Maslanyj†, Darren Addison†, Peter Gajšek‡, Luc Martens*, Martin Röösli§, Elisabeth Cardis¶, and Wout Joseph*
*Ghent University / iMinds, Ghent, Belgium
Email: sam.aerts@intec.ugent.be
†Public Health England, Chilton, Didcot, Oxon OX11 0RQ, United Kingdom
‡Institute of Non-Ionizing Radiation (INIS), Ljubljana, Slovenia
§Swiss Tropical and Public Health Institute (Swiss TPH) and University of Basel, Basel, Switzerland
¶Barcelona Institute for Global Health (ISGlobal), Barcelona, Spain

***Abstract*—Human exposure to electric and magnetic fields has been amply investigated in the extremely-low frequency (ELF) and radiofrequency (RF) ranges. However, research on typical emissions in the intermediate-frequency (IF) range remains limited. In this study, an extensive measurement survey was performed on the levels of electric and magnetic fields at intermediate frequencies typically emitted by a wide range of household appliances. The emissions contained either harmonic signals, with fundamental frequencies between 6 kHz and 100 kHz, or much more capricious spectra, dominated by 50 Hz harmonics emanating far in the IF domain. Use at close distance (20 cm) of certain appliances may result in a relatively high exposure, but no appliance's IF emissions exceeded the ICNIRP exposure summation rule (maximum electric- and magnetic-field exposure quotients were respectively 1.00, for a compact fluorescent lamp, and 0.13, for an induction cooker).**

I. Introduction

In the last decades, electric appliances have become indispensable in our households. Historically, the assessment of human exposure to electric and magnetic fields emitted by household appliances has focused on the extremely-low-frequency (ELF) [1] and radiofrequency (RF) ranges. However, the range of household appliances with electrical components working in the intermediate-frequency (IF) range (300 Hz to 1 MHz) has grown significantly in recent years (e.g., induction cookers and compact fluorescent lighting) and there is still only limited information available on either the typical strength of the IF fields emitted by household appliances [3]. In this study, the IF emissions in everyday circumstances were measured of 281 household appliances in residences across three European countries (Belgium, Slovenia, and the United Kingdom).

II. Materials & Methods

In each residence, a standardised measurement protocol was followed.

Identification of IF-emitting household appliances was done by measuring the electric- or magnetic-field strength around the operational appliance in the 2 kHz to 1 MHz band with a compact handheld NFA-1000 meter (Gigahertz Solutions, Langenzenn, Germany).

Then, the appliance's electric- and magnetic-field emissions in the 1 kHz to 100 kHz range were accurately characterized with a computer-operated narrowband EHP-50 probe (Narda Safety Test Solutions, Milan, Italy) at a measuring distance of 20 cm. During this measurement, the appliance was operated at settings typical for the residents and the probe was positioned in front of the face of the appliance closest to the user.

Finally, to assess the total electric- (E) or magnetic-field (H) exposure of an IF-emitting household appliance, the Exposure Quotient (EQ_F, with $F = E$ or H) was calculated following the summation rule of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [4]:

$$EQ_F = \sqrt{\sum_{i=1}^{N} \left(\frac{F_{peak,i}}{F_{R,i}} \right)^2}, \qquad (1)$$

where only the peak field strengths $F_{peak,i}$ higher than 5% of the corresponding reference level $F_{R,i}$ at frequency i were considered in the EQ calculation (for i between 3 kHz and 150 kHz, $E_{R,i} = 83$ V/m and $H_{R,i} = 21$ A/m).

III. Results

In total, measurement data were collected for 281 household appliances. They were divided into 65 categories, of which, based on the 5% threshold of the exposure summation rule of Eq. (1), fourteen were considered exposure-relevant (Table I).

Of the exposure-relevant categories, *power tools* and *compact fluorescent lamps (CFLs)* were the most present in residences. Furthermore, three categories—fridges, laundry machines, and microwave ovens—had been split in two because of the presence of IF fields caused by the use of inverter technology (IT), which offers better control (speed or temperature) and a higher energy efficiency.

The maximum wideband electric- and magnetic-field strengths (measured over the range 1–100 kHz) were 41.84 V/m and 3.71 A/m, both for *induction cookers*. For the appliances with IT, the higest field strengths were 13.03 V/m (refrigerator) and 1.43 A/m (microwave oven). When calculating the Exposure Quotients (Fig. 1), on the other hand, the highest EQ_E (1.00) was found for *CFLs*, while the maximum EQ_H (0.13) was again found for *induction cookers*.

TABLE I

IF EXPOSURE-RELEVANT HOUSEHOLD APPLIANCE CATEGORIES. n = THE TOTAL NUMBER OF SAMPLES, E_{max} AND H_{max} ARE THE CATEGORY'S HIGHEST ELECTRIC- AND MAGNETIC-FIELD STRENGTHS (WIDEBAND VALUES BETWEEN 1 AND 100 KHZ) MEASURED AT A DISTANCE OF 20 CM, AND f_{IF} SIGNIFIES THE FREQUENCY RANGE IN WHICH IF FUNDAMENTAL FREQUENCIES WERE FOUND.

category	n	E_{max} (V/m)	H_{max} (A/m)	f_{IF} (kHz)
battery charger	5	11.56	0.10	42–65
cold-cathode fluorescent lamp (CCFL)	1	10.75	0.08	39
compact fluorescent lamp (CFL)	28	37.27	0.11	25–65
cathode ray tube (CRT) display	11	22.81	0.40	15–31
electric toothbrush charger	6	4.26	0.17	21–45
fluorescent lamp	5	40.15	0.11	32–50
induction cooker	12	41.84	3.71	18–45
laundry machine IT	18	6.21	0.13	8–61
liquid crystal display (LCD)	5	42.70	0.72	45–90
microwave oven IT	5	2.47	1.43	—
power tool	48	19.78	2.28	—
refrigerator IT	1	13.03	0.10	6
spotlight transformer	5	6.91	1.51	15–60
welding machine	2	7.29	0.18	98

Furthermore, in most of these 14 categories, the appliance emissions had fundamental frequencies in the electric- and/or magnetic-field spectrum between 6 kHz (*refrigerator with IT*) and 98 kHz (*welding machine*) (Table I)—often accompanied by harmonics further down the spectrum—though in two cases (*power tools* and *IT microwave ovens*), the appliances' spectra were elevated throughout the examined frequency range.

IV. DISCUSSION & CONCLUSIONS

Using a standardised protocol, a measurement survey spanning three countries resulted in a wealth of data on the typical emissions of electric and magnetic fields at intermediate frequencies by household appliances. IF exposure-relevant appliance categories identified in this study that were not yet described in the literature include liquid crystal displays (LCDs), electric toothbrush and battery chargers, power tools, and appliances with inverter technology (which could become increasingly important in the future). For previously assessed categories (in e.g., [5]), i.e., induction cookers, CFLs, and CRTs, the measurements were in line with the reported values.

Overall, emissions in the IF range contained either harmonic signals, with fundamental frequencies between 6 and 100 kHz, or much more capricious spectra, possibly dominated by 50 Hz harmonics emanating far in the IF domain; and at a measuring distance of 20 cm, the maximum observed electric- (EQ_E) and magnetic-field Exposure Quotients (EQ_H) did not exceed the ICNIRP exposure summation rule.

The information provided by this study fills a gap in knowledge on typical human exposures to electromagnetic fields, and, in combination with appliance usage data, can be valuable in future epidemiological studies assessing the impact of exposure to IF fields.

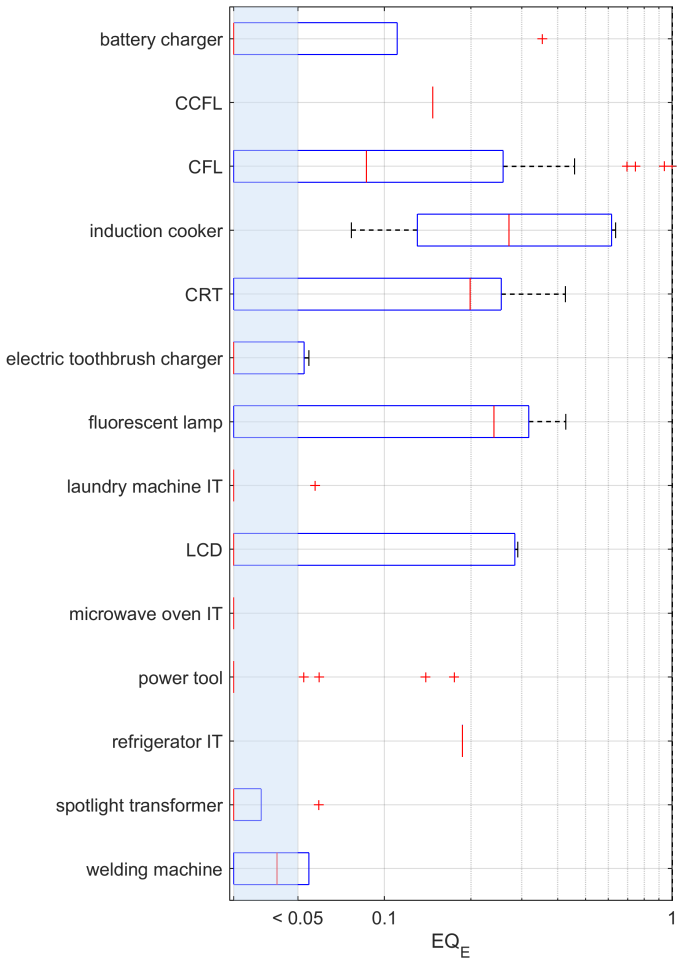

Fig. 1. Electric-field EQ boxplots at 20 cm calculated following guidelines in Ref. [4] for the exposure-relevant categories. All other categories only had EQs < 0.05. EQs in the gray area are < 0.05. Red crosses are outliers.

ACKNOWLEDGMENT

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement no 603794 – the GERONIMO project.

REFERENCES

[1] N. Leitgeb, R. Cech, and J. Schrättner, "Electric emissions from electrical appliances," Radiat. Prot. Dosimetry, vol. 129, no. 4, pp. 446–455, 2008.

[2] G. Vermeeren, I. Markakis, F. Goeminne, T. Samaras, L. Martens, and W. Joseph, "Spatial and temporal RF electromagnetic field exposure of children and adults in indoor micro environments in Belgium and Greece," Prog. Biophys. Mol. Biol., vol. 113, no. 2, pp. 254–263, 2013.

[3] E. Litvak, K. R. Foster, and M. H. Repacholi, "Health and Safety Implications of Exposure to Electromagnetic Fields in the Frequency Range 300 Hz to 10 MHz," Bioelectromagnetics, vol. 23, no. 1, pp. 68–82, 2002.

[4] International Commission on Non-Ionizing Radiation Protection (ICNIRP), "Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz)," Health Phys., vol. 99, no. 6, pp. 818–836, 2010.

[5] E. D. Mantiply, K. R. Pohl, S. W. Poppell, and J. A. Murphy, "Summary of measured radiofrequency electric and magnetic fields (10 kHz to 30 GHz) in the general and work environment," Bioelectromagnetics, vol. 18, no. 8, pp. 563–577, 1997.