

TYPICAL EMISSIONS OF ELECTRIC AND MAGNETIC FIELDS AT INTERMEDIATE FREQUENCIES BY HOUSEHOLD APPLIANCES

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Summary

Despite ample investigation of residential exposure to electric and magnetic fields in the extremely-low-frequency (ELF) and radiofrequency (RF) ranges, research on the intermediate-frequency (IF) range remains limited. We performed a comprehensive measurement survey on the typical levels of electric and magnetic IF fields emitted by a wide range of household appliances. It was found that the use of appliances at close distance (20 cm) can result in relatively high IF exposures, though none exceeded the ICNIRP2010 exposure summation rule. The observed emission spectra were either repeatable, containing harmonic signals with fundamental frequencies between 6 kHz and 293 kHz, or unpredictable, dominated by 50 Hz harmonics in the IF domain.

Introduction

In recent years, the number and variety of electric appliances in our households with electrical components working in the intermediate-frequency (IF) range (i.e., 300 Hz to 1 MHz) – such as induction cookers and compact fluorescent lighting – has increased significantly. Nevertheless, research efforts on characterizing electric fields (EF) and magnetic fields (MF) emitted by electric appliances have generally focused on the extremely-low-frequency (ELF) and radiofrequency (RF) ranges, and there is still only limited information available on the typical strength of the IF fields emitted by household appliances. Here, we present the results of a measurement survey spanning 279 appliances used in everyday circumstances in 42 households across three European countries (Belgium, Slovenia, and the United Kingdom).

Materials & Methods

In each of the 42 residences (11 in Belgium, 16 in Slovenia, and 15 in the UK), a uniform measurement protocol was followed to identify IF-emitting appliances and characterize their IF emission spectra. The identification was done by means of a compact handheld NFA-1000 meter (Gigahertz Solutions, Langenzenn, Germany) which was held close to the operational appliance under investigation and which measured the total electric- or magnetic-field strength between 2 kHz and 1 MHz. Proper characterization of the emitted fields up to a frequency of 400 kHz was then done at distances of 20 cm and 50 cm using a doublet of computer-operated narrowband probes: EHP-50 (300 Hz to 100 kHz) and EHP-200 (9 kHz to 400 kHz) (Narda Safety Test Solutions, Milan, Italy). During the measurements, the appliance under investigation was operated at settings *typical for the residents* and the probes were positioned in front of the face of the appliance closest to the user. The spectral measurement results were used to calculate for each appliance and measuring distance, the electric- and magnetic-field Exposure Quotients (EQ_E and EQ_H), following the summation rule of the International Commission on Non- Ionizing Radiation Protection (ICNIRP) [ICNIRP2010],

$$EQ_F = \sum_{i=1}^N \frac{F_{peak,i}}{F_{R,i}}$$

in which only the peak field strengths $F_{peak,i}$ higher than 5% of the corresponding reference level $F_{R,i}$ at frequency i were considered [IEC2005] (e.g., for i between 3 kHz and 150 kHz, $E_{R,i} = 83$ V/m and $H_{R,i} = 21$ A/m). An appliance was considered IF exposure-relevant if either EQ was above 0.05. It should be noted that, when $EQ > 1$, a more detailed assessment is required when to assure compliance with the ICNIRP basic restrictions [ICNIRP2010].

Results & Discussion

In total, IF-exposure measurements of 279 household appliances were performed (between two and nine appliances per residence, and seven on average). The appliances were classified into 65 categories, of which power tools and compact fluorescent lamps (CFLs) were the largest and thus most often present. Additionally, within three categories – refrigerators, laundry machines, and microwave ovens – IF emissions were observed at some of the appliances due to their use of inverter technology (IT), which offers better control (speed or temperature) and a higher energy efficiency. As IF emissions were completely absent at the other appliances in the same category, these categories were split in two. In the following, we present only the results of fourteen categories that were IF exposure-relevant (Table 1), i.e., for which at least one appliance had an EQ_E or EQ_H above the threshold of 0.05 at 20 cm.

Table 1: Exposure assessment of the IF exposure-relevant household appliance categories. n is the number of samples, E_{max} and H_{max} are the respective category's highest total electric- and magnetic-field values between 1 and 100 kHz (measured with EHP-50) at a distance of 20 cm, and EQ_E and EQ_H the EQ ranges at this distance, and f_{IF} indicates the frequency range in which fundamental frequencies were observed for this category.

Category	n	E_{max} (V/m)	EQ_E (-)	H_{max} (A/m)	EQ_H (-)	f_{IF} (kHz)
Battery charger	5	11.56	< 0.05 – 0.35	0.10	< 0.05	42 – 65
Cold-cathode fluorescent lamp (CCFL)	1	10.75	0.15	0.08	< 0.05	39
Compact fluorescent lamp (CFL)	28	37.27	< 0.05 – 1.00	0.11	< 0.05	27 – 62
Cathode ray tube (CRT) display	11	22.81	< 0.05 – 0.43	0.40	< 0.05	15 – 31
Electric-toothbrush charger	6	4.26	< 0.05 – 0.05	0.17	< 0.05	21 – 42
Fluorescent lamp	5	40.15	< 0.05 – 0.43	0.11	< 0.05	35 – 51
Induction cooker	12	41.48	0.08 – 0.64	3.71	< 0.05 – 0.19	19 – 70
Laundry machine IT	18	6.21	< 0.05 – 0.06	0.13	< 0.05	8 – 293
Liquid crystal display (LCD)	5	42.70	< 0.05 – 0.29	0.72	< 0.05	45 – 90
Microwave oven IT	5	2.47	< 0.05	1.43	< 0.05 – 0.08	---
Power tool	48	19.78	< 0.05 – 0.18	2.28	< 0.05 – 0.07	---
Refrigerator IT	1	13.03	0.19	0.10	< 0.05	6
Spotlight transformer	5	6.91	< 0.05 – 0.06	1.51	< 0.05	15 – 60
Welding machine	2	7.29	< 0.05 – 0.05	0.18	< 0.05	98

Within these categories, distinctive fundamental frequencies were usually observed in the electric- and/or magnetic-field spectra of the IF emissions (e.g., Figure 1). These frequencies varied between 6 kHz (refrigerator with IT) and 293 kHz (laundry machine with IT), with most of them in the 20-60 kHz range (Table 1), and they were often accompanied by harmonics further down the spectrum. In the case of power tools and IT microwave ovens (e.g., Figure 2), on the other hand, the emission spectra were elevated throughout the examined frequency range (sometimes up to 400 kHz).

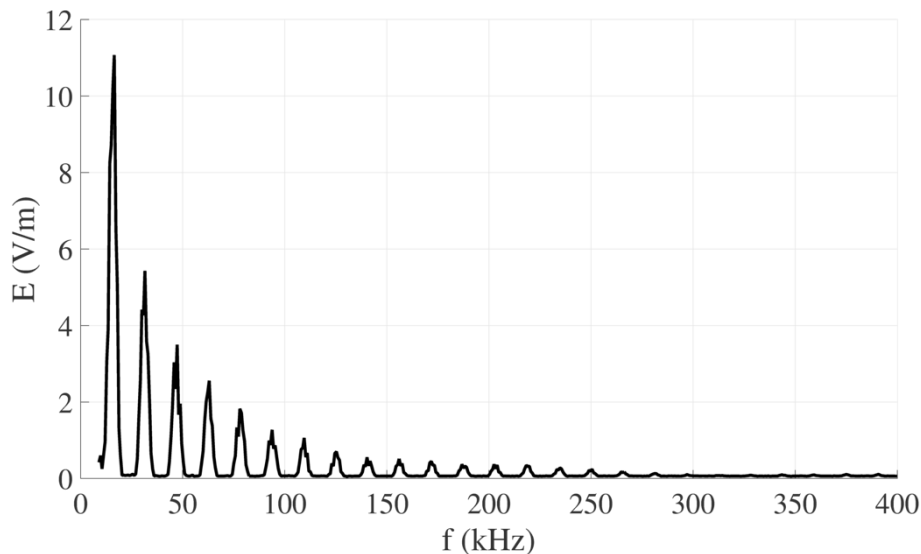


Figure 1: Electric-field spectrum (9-400 kHz) of a cathode ray tube (CRT) display, with fundamental frequency 15 kHz.

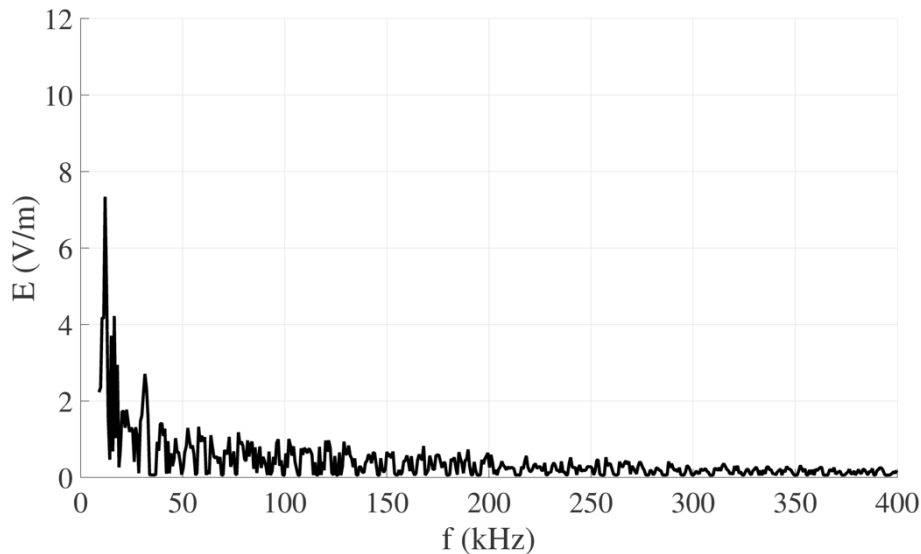


Figure 2: Electric-field spectrum (9-400 kHz) of a power tool (a chainsaw).

Furthermore, the maximum total electric- and magnetic-field strengths over the EHP-50 1–100 kHz frequency range (which in all cases except one contained all the relevant (i.e., F_{peak} higher than 5% of the corresponding reference level F_R) spectral components) were 41.84 V/m and 3.71 A/m, both measured for an induction cooker (Table 1). For the appliances with IT, the highest total field strengths were 13.03 V/m (refrigerator) and 1.43 A/m (microwave oven). Finally, none of the EQs exceeded the ICNIRP exposure summation rule (Table 1). The highest EQ_E at 20 cm (1.00) was observed for a CFL, the maximum EQ_H at 20 cm (0.13) for an induction cooker. At 50 cm, these decreased to 0.24 and < 0.05 , respectively. It should be noted that, even for these highlighted categories, many EQs were below the 5% threshold (Table 1).

Conclusions

Using a uniform methodology, we have gathered across three European countries a wealth of data on the typical emissions by household appliances of electric and magnetic fields at intermediate frequencies (IF) [Aerts2017]. IF exposure-relevant appliances, with a magnetic- or electric-field exposure quotient of at least 0.05, that were missing from the literature but were identified by this study include power tools, electric toothbrush and battery chargers, liquid crystal displays (LCDs), and appliances with inverter technology. Furthermore, our measurements of previously characterized appliances (induction cookers, CFLs, and CRTs) were in agreement with values reported in the literature [e.g., Mantiply1997]. In general, the observed IF emission spectra contained either harmonic signals, with fundamental frequencies between 6 kHz and 293 kHz, or much more capricious spectra, dominated by 50 Hz harmonics emanating far in the IF domain. Furthermore, at a measuring distance of 20 cm, the maximum observed electric-field (EQE) and magnetic-field Exposure Quotients (EQH) did not exceed the ICNIRP exposure summation rule. This study increases our knowledge on the typical human exposures to electromagnetic fields. Moreover, in combination with accurate data on appliance usage, the provided data can be valuable in future epidemiological studies assessing the impact of exposure to IF fields.

References

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