Characterization of the exposure due to smart-home devices and other residential RF sources

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Summary

Current Internet-of-Things (IoT) trends such as home automation and smart metering may raise concerns about the human exposure to radiofrequency (RF) electromagnetic fields (EMF) due to new wireless devices installed in residences. As signals transmitted by smart devices are usually non-continuous, a new measurement methodology was developed to assess their exposure levels, using the spectrogram mode of a spectrum analyzer to capture changes in frequency and/or amplitude of the assessed signals over time. Here, the assessment of 94 residential RF sources is presented. It was found that, in the smart home, wireless access points, smartphones, and other personal communication devices continue to represent the bulk of our RF-EMF exposure.

Introduction

The work presented here addresses the issues concerning human exposure to radiofrequency (RF) electromagnetic fields (EMFs) that may arise from implementing the Internet-of-Things (IoT) approach ("everything is connected") in residences, including current trends such as home automation ("smart home") and energy grid monitoring ("smart grid"). Key components of the smart grid are so-called smart meters, which encompass a broad range of sophisticated sensors that constantly assess the state of the grid, the availability of power flowing into the grid, and the demand on the grid. However, as these devices are installed in the customer's residence and often communicate wirelessly using existing RF networks, members of the general public might feel saddled with these new technologies due to their proximity and visibility. In this study, a novel measurement method was designed to characterize in-situ residential sources of RF radiation (and in particular, IoT devices and smart meters), primarily with the use of the spectrogram mode on a spectrum analyzer. This method was then applied to a convenient sample of ten residences in Belgium and France containing various IoT devices, smart meters, and other residential RF-emitting sources.

Materials & Methods

As the signals transmitted by smart-home and other IoT devices are usually characterized by very short pulses – the number of which depends on the network topology, and sometimes on the user – for each smart apparatus the following were determined: (a) the transmission frequency, (b) the duty cycle DC, i.e. the proportion of the time the device is actually transmitting a signal, (c) the worst-case exposure level E_{max} (in V/m) – assessed at 0.2 m, 0.5 m, and 1 m – and (d) the actual (time-averaged) exposure E_{avg}, calculated as $E_{avg} = \sqrt{DC} * E_{max}$. The latter can be compared to the exposure guidelines issued by the Federal Communications Commission (FCC) in the USA (30-min time average) [FCC1997] and/or the International Commission on Non-Ionizing Radiation Protection (ICNIRP) elsewhere (6-min time average) [ICNIRP1998], by calculating the ratio R_S:

$$R_S = \left(\frac{E_{meas}}{E_{ref}}\right)^2,$$

with E_{ref} the reference level (issued by FCC/ICNIRP) corresponding to the frequency of the signal of the assessed device. As long as R_S is lower than 1, the assessed field complies with the guidelines.

All measurements were performed with a spectrum analyzer combined with a tri-axial antenna with frequency range 30 MHz - 3 GHz. Depending on the type of signal to be measured appropriate settings of the spectrum analyzer were needed. For example, as the RF signals emitted by IoT devices are typically non-continuous, the spectrogram mode of a Rohde & Schwarz FSVA40 spectrum analyzer was used to capturing the changes in frequency and/or amplitude of the assessed signal over time, which allowed to easily determine the device's duty cycle.

Results & Discussion

Example

Here, a specific smart-meter measurement is highlighted: the communications module (CoMo) of a smart electricity meter. In Belgium, it is usually the electricity meter that is equipped with a wireless communication link to the smart grid. Other smart meters possibly present in the home are connected to the CoMo using either a wired link or a wireless Meter-Bus or Wireless Fidelity (Wi-Fi) link. The CoMo usually communicated with the central system of the energy supplier through General Packet Radio Service (GPRS) technology, similar to GSM, transmitting in the GSM900 uplink band (in this case, at 904 MHz). The signal was measured in time using the spectrogram mode to obtain more detailed information about the rate of transmission, or in other words, about the duty cycle. In theory, a CoMo transmits once every 15 min. However, in our measurements, we observed durations between transmissions (denoted by T_{period} in Figure 1) as low as 43 s. Furthermore, each transmission (or pulse) consisted of a series of bursts sent over a 3.6 s interval (T_{pulse} in Figure 1). Combined with the transmissions technology's inherent duty cycle of 1/8 (just like GSM, GPRS uses time division multiple access or TDMA), the CoMo's theoretical duty cycle was 0.05%.

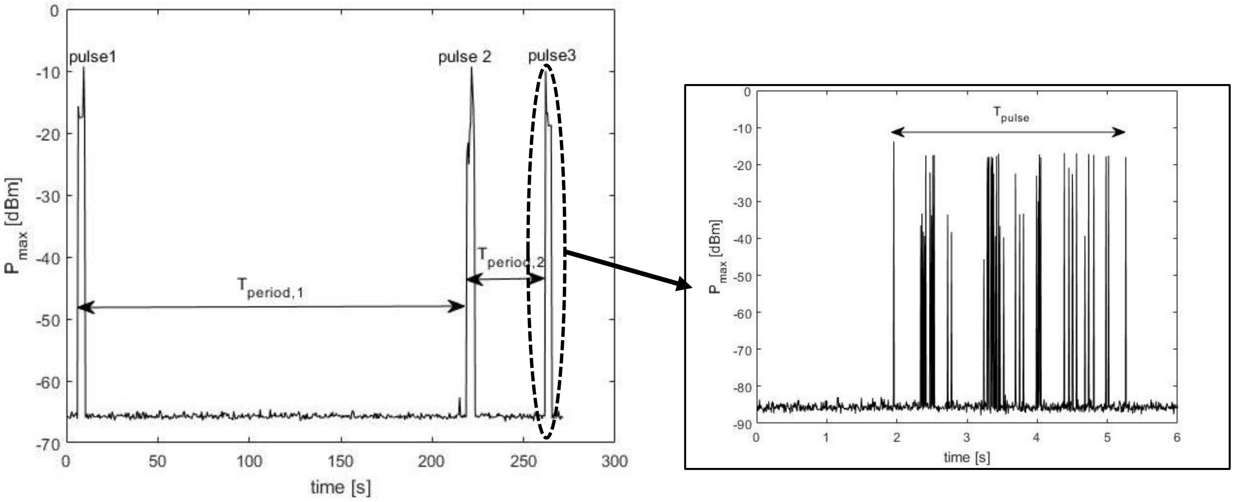
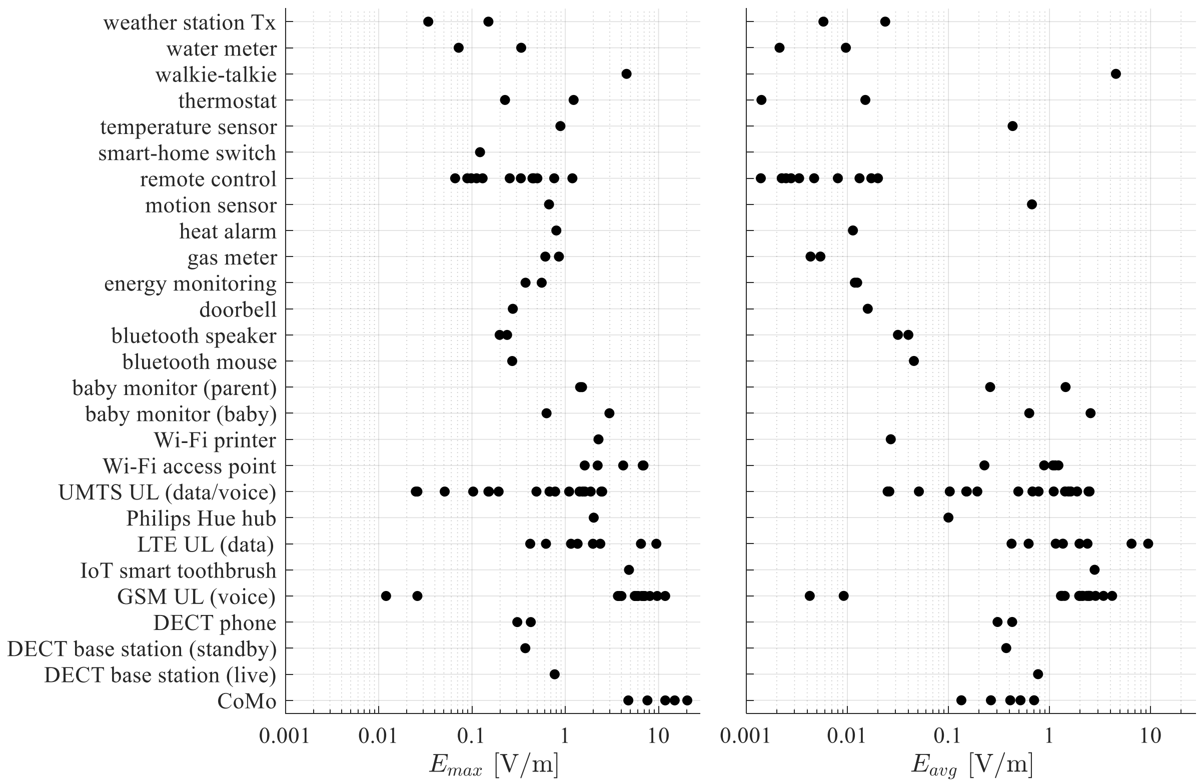


FIGURE 1: RF SIGNALS TRANSMITTED BY A SMART ELECTRICITY METER'S COMMUNICATION MODULE, MEASURED WITH THE SPECTROGRAM MODE OF A SPECTRUM ANALYZER SETUP.

Summary of the measurements

In total, the RF signals emitted by 53 in-home devices were characterized. In general, a distinction could be made between user-controlled devices (e.g. remote controls), independent devices with random or variable pulses (e.g. Wi-Fi routers), and independent devices with fixed pulses (e.g. most smart meters). In addition, o put the IoT measurements in a more familiar perspective, 41 measurements of the signals emitted by a mobile ('uplink') using three telecommunications technologies (Global System for Mobile Communications, Universal Mobile Telecommunications System, and Long Term Evolution) were performed at a distance of 0.5 m from the used phone. In Figure 2, the measurement results at 0.5 m are shown, with the assessed RF-emitting devices grouped per category.



(a) (b)

FIGURE 2: ELECTRIC-FIELD STRENGTHS AT A DISTANCE OF 0.5 M FROM VARIOUS CATEGORIES OF RF-EMITTING DEVICES: (A) THE MAXIMUM-HOLD VALUES MEASURED WITH THE SA MEASUREMENT SETUP, (B) THE TIME-AVERAGED FIELD VALUES, CONSIDERING THE ACTUAL 6-MIN DUTY CYCLE OF THE DEVICE UNDER TEST.

In Figure 2(a), the maximum measured electric-fields are compared. The highest field value was measured for a CoMo of an electricity meter (E_{max} = 20.319 V/m). In Figure 2(b), these values are time-averaged, using the duty cycle determined in a 6-min interval (in order to compare to the ICNIRP guidelines). The duty cycle of non-user-controlled devices, such as smart meters, was usually fixed. However, for user-controlled devices, the duty cycle was calculated based on a single action (e.g. push on a button) within six minutes; for smartphones, continuous use (voice or data transfer) during six minutes was assumed (i.e. DC = 100% for UMTS and LTE, and DC = 12.5% for GSM, due to the time-division multiplexing of its signal); and for Wi-Fi access points, the actually measured duty cycle of the dominant channel was used (overall, DC_{avg}= 6.9%).

All measurements satisfied the ICNIRP (and the FCC) guidelines. The highest R_S value (at 50 cm, and assuming a realistic duty cycle) for a non-smart or IoT device was 0.025 (six-minute call with a walkie-talkie), for a smart-home device 0.002 (smart toothbrush), and for a smart meter 0.0004 (CoMo of electricity meter, with theoretical DC). For uplink telecom signals, the highest R_S value found was 0.059 (LTE) – on average, UMTS uplink had the lowest R_S values of the telecom signals.

Conclusions

A novel measurement method was designed to characterize the RF-EMF exposure due to in-situ residential RF-emitting sources, which comes down to determining their transmission frequency, their peak emitted fields at various distances, and the percentage of time they transmitted (i.e. their duty cycle). This method was then applied to a convenient sample of ten residences in Belgium and France containing, in total, 53 IoT devices, smart meters, and other RF-emitting devices. The measured emissions were also compared to emissions by a mobile phone using three current telecommunications technologies (GSM, UMTS, and LTE), as well as to the ICNIRP guidelines for general public RF exposure.

In the smart home, wireless access points, smartphones, and other personal communication devices (e.g. DECT cordless phones, walkie-talkies) continue to represent the bulk of our exposure to RF-EMF due to their typically high emissions and use close to the body. However, smart-home and other IoT devices with high duty cycles (e.g. motion detector, baby monitor, toothbrush) can significantly heighten our exposure, if used close to the body. Smart meters, and in particular communications modules wirelessly linked to the utility company's central network, contribute only little to our RF-EMF exposure, regardless of their sometimes high emissions, due to their relatively rare transmissions. It should be noted that, as the specific physical environment in which RF sources are placed has a significant impact on the RF-EMF levels in a residence, the measurements presented here represent a sample cross-section in time of the assessed residential RF environments. However, the described results should be sufficient to illustrate a typical RF environment in our modern life, in which everything is connected.

Acknowledgment

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References

[FCC1997] Federal Communications Commission (FCC). "Evaluating Compliance with FCC Guidelines for Human Exposure to Radiofrequency Electromagnetic Fields", *OET Bulletin* 65, edition 97-01, August 1997.

[ICNIRP1998] International Commission on Non-ionizing Radiation Protection (ICNIRP). "Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up 300 GHz)," *Health Physics*, vol. 74, pp. 494-522, 1998.