RF EMF Exposure Sensing Network in a Smart-City Context

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SHORT ABSTRACT

Spatio-temporal radio-frequency (RF) electromagnetic field (EMF) exposure assessment is of interest for epidemiologists, governmental agencies dealing with environmental issues, and the general public. We designed low-cost EMF sensors and deployed an RF EMF exposure sensing network in the city of Antwerp (Belgium) consisting of eleven fixed EMF sensors and five mobile EMF sensors installed on the roof of postal vans. The EMF sensors were calibrated and validated in a lab environment and in the EMF sensor network in Antwerp using frequency-selective measurements. Such an EMF exposure network will enable long-term spatio-temporal exposure assessment on a local scale.

INTRODUCTION

Spatio-temporal radio-frequency (RF) electromagnetic field (EMF) exposure assessment [1] – [5] is of interest for epidemiologists, governmental agencies dealing with environmental issues, and the general public. However, spatio-temporal RF EMF exposure assessment is still a challenge as it requires a large amount of EMF sensors densely distributed over an area to realize accurate exposure maps on a local scale. Exposimeters for personal dosimetry are not suitable due to their high cost. Moreover, an exposimeter only takes a snapshot of the exposure in space and time and are battery-powered devices.

The advent of wireless sensor networks (WSNs) in the context of IoT, in recent years, enables the monitoring of environmental parameters, such as temperature, humidity, air quality, etc. The availability of relatively cheap sensors enables the deployment of dense wireless sensor networks in a smart city context allowing to monitor these parameters on a local scale. Another interesting environmental parameter is RF EMF. Within the context of City of Things in Antwerp, Belgium, we designed low-cost EMF sensors for WSNs and deployed an RF EMF exposure sensing network in Antwerp. This EMF sensing network currently consists of eleven fixed and five mobile – installed on vans of the local postal services – RF EMF sensors. The EMF sensors record the electric field in four frequency bands covering the main wireless communication bands.

The objective of this study was the design of the fixed and mobile EMF sensors and the deployment of an RF EMF Exposure Sensing Network within the City of Things program in the Smart Zone in the city of Antwerp, Belgium. Spatio-temporal EMF exposure mapping will be realized in this way.
MATERIALS AND METHODS

We designed the EMF sensor using off the shelf components to minimize its total cost. Further, we opted to use a single antenna and SAW filter per frequency band to increase the isolation between the frequency bands. Integrating the four antennas in a single device resulted in a size of the housing of the EMF sensor of 180 x 180 x 150 mm³ (l x w x h). Fortunately, the size of the sensor is less restrictive for a deployment in a smart city context (compared with exposimeters worn on a human body) as the fixed sensors will be attached to the wall of a building and the mobile sensors are put on top of the roof of a van. Figure 1(a) shows an EMF sensor node – connected through USB with the gateway – mounted on the wall of a building in the city of Antwerp. The total area covered by the EMF sensor network equals 0.11 km² and is shown in Figure 1(b). The current EMF sensor measure RF EMF exposure in 900 MHz, 1800 MHz, 2100 MHz, and 2450 MHz frequency bands. The sensitivity is 5 mV/m and the dynamic range is 70 dB. The probes are vertically polarized.

![Figure 1: (a) EMF sensor mounted on a building wall in Antwerp and (b) locations of EMF sensor nodes in an area of 0.11 km² in the city of Antwerp, Belgium.](image)

The EMF sensor nodes were calibrated in an anechoic room. Each EMF sensor was placed on a rotational platform in the far field of a horn antenna transmitting 50 mW of constant power. The EMF sensor registered the received power every two degrees when rotated in a horizontal plane. The procedure was performed for vertical and horizontal polarization of the horn antenna.

We also validated in-situ the EMF values from the EMF sensors with frequency-selective measurements in a lab environment as well as in the EMF sensor network in Antwerp.

RESULTS

In total, 22 fixed EMF sensors and 5 mobile sensors have been fabricated. Currently, only eleven fixed sensors and five mobile sensors are deployed in the city of Antwerp. The fixed sensors are located within an area of 0.11 km² in the city center. All the EMF sensors has been calibrated in an anechoic room. We also validated the EMF sensor in a lab environment and in the field with a spectrum analyzer connected to a R&S TS-EMF isotropic antenna and NARDA SRM-3006 connected to a NARDA 3501/03 isotropic antenna.
Figure 2 illustrates the 68% confidence interval (CI68) of the 22 nodes calibrated in free-space in an anechoic chamber. For 900 MHz a CI68 in the range of 6.9 dB to 10.3 dB (3.4 dB difference) is obtained and 8 nodes have a similar CI68. For 1800 MHz, the CI68 varies from 4.8 dB to 7 dB which is a difference of 2.2 dB. The minimum and maximum CI68 in the 2100 MHz band are 7.8 dB and 10.5 dB (2.7 dB difference), respectively. For WiFi-2G, this range changes to a minimum CI68 of 10.8 dB and a maximum CI68 of 12.6 dB which is a difference of 1.8 dB. The results show that nodes do not have a large difference in their CI68 values indicating the reliability of exposimeter fabrication and calibration measurements.

The in-lab validation showed that the measured RMS E field (only vertical polarization) deviated by -1.4 dB, 4.7 dB, -3 dB, and 6 dB from those of the isotropic antenna for the frequency bands 900 MHz, 1800 MHz, 2100 MHz and WiFi-2G, respectively. However, the measured total E-field is only 0.7 dB higher than the same field component measured using an isotropic antenna and SA, which is an excellent agreement.

As an example, Figure 3(a) shows the temporal variation of the measured received power in 900 MHz band by sensor EMF12 (see Figure 1(b)) in the EMF sensor network in Antwerp. We observe a clear diurnal variation of the measured exposure. Figure 3(b) shows the spatial received power measured by a mobile sensor installed on the roof a postal van. The red, blue color designates the highest, lowest received power values.
CONCLUSION

We designed low-cost EMF sensors and deployed an RF EMF exposure sensing network in the city of Antwerp, Belgium. The low-cost EMF sensors have been calibrated in an anechoic room (difference in 68% confidence interval of antenna apertures between the calibrated devices was below 3.4 dB) and validated with frequency-selective measurements in a lab environment (maximum deviation of 6dB) and in the deployed EMF sensor network. The deployed EMF sensor network consisted of eleven fixed and five mobile EMF sensors. The fixed sensors are located in an area of 0.11 km2. The mobile sensors are installed on the roof of the vans of postal services (bpost). Fixed sensor mainly provide data on the temporal behavior of RF EMF, whereas the mobile sensors provide mainly spatial data of RF EMF. Combining data from both type of EMF sensors will allow to assess RF EMF exposure on a local scale. Spatio-temporal exposure mapping is and will be realized using the smart EFM
sensor network.

**ACKNOWLEDGMENT**

This research is part of ‘DENCITY’, a VLAIO funded project. The fixed sensors have been installed in the Antwerp Smartzone. This is a Smart Zone in the Sint-Andries district in Antwerp. The City of Antwerp, imec and other partners are building a tightly woven mesh of smart sensors and wireless connections in and on buildings, along streets, in public squares and other objects you find in cities. The Smartzone represents a typical city neighborhood; narrow residential streets with lots of people, busy retail streets with delivery vans loading and unloading their goods, a (major) shortage of parking spaces and lots of busy city hustle and bustle going on all around. The mobile sensors were installed on B-post vans. They drive throughout the larger Antwerp area.

**REFERENCES**


