DISCUSSION AND CONCLUSION

We found that some cellphone habits of adolescents, and their exposure to a WiFi transmitter near the bed or through the wall from the bed-head are related to some reduction in self-reported general wellbeing related to sleep and sleepiness, headaches and having a painful texting thumb. Some of our findings, while related to the phone, do not appear to be related to radio-frequency exposure. For instance, odds for headaches were higher with the phone by the bed than under the pillow. For others, while the cause may be RF exposure it may also be the type of use; for example, headache odds ratio increased when texting in bed as texting distance from the eyes decreased, but the headache may be due to eye-strain rather than increased RF exposure. There was one case where outcomes could be related to the RF exposure: having a WiFi transmitter near the bed.

Headaches at least weekly were remarkably common (37.7%), even higher than the 26.6 % reported by Gordon et al [8]. Our age group included younger children and considered fewer causal factors.

These results raise a question about reasons for giving precautionary advice about children's use of wireless phones. While there is some evidence supporting chronic effects on young people's well-being from exposure to radio frequencies and the way they are transmitted, there is a considerable body of evidence of effects on well-being from cellphone use. The reason for each effect is important, and requires further research to clarify this. In either case, it is relevant to recommend methods of reducing RF exposure from cellphones to safeguard young people's wellbeing. We suggest that one such step would be for parents to require their children's cellphones to be in another room overnight; this would remove both the (small) source of RF potentially from under the pillow and remove the risk of calls or texts causing broken sleep.

References

1. World Health Organisation: **Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference**. In: *Official records of the WHO.* 2 edn. Geneva: WHO; 1948: 100.

2. Heins E, Seitz C, Schuz J, Toschke AM, Harth K, Letzel S, Bohler E: **Bedtime, television and computer habits of primary school children in Germany**. *Gesundheitswesen* 2007, **69**(3):151-157.

3. Khorseva NI, Grigoriev YG, Gorbunova NV: **Psychophysiological indicators for child users of mobile communication. Message 2: Results of four-year monitoring**. *Radiation Biology Radiation Ecology* 2011, **51**(5):617-623.

4. Van den Bulck J: **Adolescent use of mobile phones for calling and for sending text messages after lights out: results from a prospective cohort study with a one-year follow-up**. *Sleep* 2007, **30**(9):1220-1223.

5. Heinrich S, Thomas S, Heumann C, von Kries R, Radon K: **The impact of exposure to radio frequency electromagnetic fields on chronic well-being in young people: A cross-sectional study based on personal dosimetry**. *Envrionment International* 2011, **37**(1):26-30.

6. Riddervold IS, Pedersen GF, Andersen NT, Pedersen AD, Andersen JB, Zachariae R, Molhave L, Sigsgaard T, Kjaergaard SK: **Cognitive function and symptoms in adults and adolescents in relation to rf radiation from UMTS base stations**. *Bioelectromagnetics* 2008, **29**(4):257-267.

7. Hillert L, Akerstedt T, Lowden A, Wiholm C, Kuster N, Ebert S, Boutry C, Moffat SD, Berg M, Arnetz BB: **The effects of 884 MHz GSM wireless communication signals on headache and other symptoms: an experimental provocation study**. *Bioelectromagnetics* 2008, **29**(3):185-196.

8. Gordon KE, Dooley JM, Wood EP: **Self-reported headache frequency and features associated with frequent headaches in Canadian young adolescents**. *Headache: The Journal of Head and Face Pain* 2004, **44**:555-561.

Session: O2
RF Dosimetry - Emissions I
June 18, 2012 • 11:30 - 12:50
Tesla Room
Chairs: Ken Joyner & Joe Wiart

O2-1 [11:30]
Surrogate modeling of base station exposure

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We propose a new method to accurately map RF-EMF exposure, using an algorithm that "learns" the exposure on-the-fly and sequentially proposes optimal locations real-time for the next measurements, based on the knowledge from previous measurements. The result is a surrogate model built as efficiently as possible from a limited data set. We have tested and validated this method in a small area for GSM900 radiation, and obtained very good results.

Long Abstract

INTRODUCTION

The World Health Organization (WHO) recently listed in its Research Agenda the need for quantification of the exposure to widespread as well as emerging radio frequency (RF) sources [1]. This information is valuable for both epidemiological research and governmental risk communication towards the general public. However, robust assessment of RF electromagnetic fields (EMF) is not yet possible in real-world situations, because in the current assessment approaches only a limited data set of exposure measurements is available at a given time. The objective of this paper is to conceptualize a new methodology to obtain an accurate and efficient exposure assessment, making it possible to make an accurate map of the exposure to RF-EMF in a certain area, despite an incomplete set of measurements and limited accuracy.

MATERIALS AND METHODS

Our procedure begins with a characterization of the area (determining two-dimensional geo-coordinates and dominant signals), after which a Latin hypercube distribution of the initial measurement locations is calculated. Measurements performed at these locations are used to build a first surrogate model (cubic spline interpolation), and to calculate a next batch of locations, using a sequential sampling algorithm. The measurements are thus performed iteratively: based on the knowledge that becomes available from the previous measurements, this algorithm "learns" the EMF exposure on the fly, and sequentially proposes optimal locations for future measurements. This way the procedure can be stopped at any moment in time, e.g. when a certain stopping criterion is fulfilled. The validation area of this study is a small suburban area (0.04 km^2) in Ghent, Belgium, where we have measured Global System for Mobile Communications base station radiation at 900 MHz (GSM900 downlink) using an EME-SPY120 exposimeter.

RESULTS

We measured the electric-field strength for 10 batches of 10 locations. After each batch, the surrogate model was updated. Table 1 summarizes the model parameters of models M_0 - M_9 (corresponding to 10-100 measurement locations) as well as the average of the sum of the absolute values of the relative deviations of the electric field levels predicted with model i with respect to the ones calculated with model i-1 ($\Delta(M_i,M_{i-1})$). Models M_0 and M_1 (Table 1) show a relatively constant electric-field distribution, with only slight variation, and maximum electric-field values below 0.20 V/m. In models M_2-M_4, several regions with electric-field levels above 0.25 V/m are identified, each time significantly changing the model, and no additional regions are found in the consecutive models. Once the main variations in the field are discovered, $\Delta(M_i,M_{i-1})$ drops below 5%. These results show that in this particular case 50 measurements locations are sufficient to obtain a valuable map of the GSM900 electric-field distribution , and 70 locations are sufficient to completely characterize the exposure. Fig. 1 shows the surface plot of the model built from 70 measurements (M_6).

Validating this model M_6 using 30 independent measurements, we obtained very good results. The mean relative error between model and validation measurements is just 1.5 dB, with more than 83% of the relative errors below 3 dB, as shown in Fig. 2. The correlation is also very good, with Pearson and Spearman correlation coefficients of 0.71 and 0.74, respectively, a linearly weighed κ of 0.51, and a sensitivity and specificity of 0.67 and 0.92, respectively.

CONCLUSIONS

A new, efficient measurement and modeling approach is proposed for the assessment of base station exposure, based on surrogate modeling and sequential design. The proposed method is applicable in real time and without a priori knowledge, making it interesting for epidemiologists, authorities and dosimetry research. The application of our procedure to both other signals as well as to a larger area will be the subject of future research.

ACKNOWLEDGMENTS

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REFERENCES

[1] World Health Organization. WHO research agenda for radiofrequency fields. 2010. Available online at http://whqlibdoc.who.int/publications/2010/9789241599948_eng.pdf

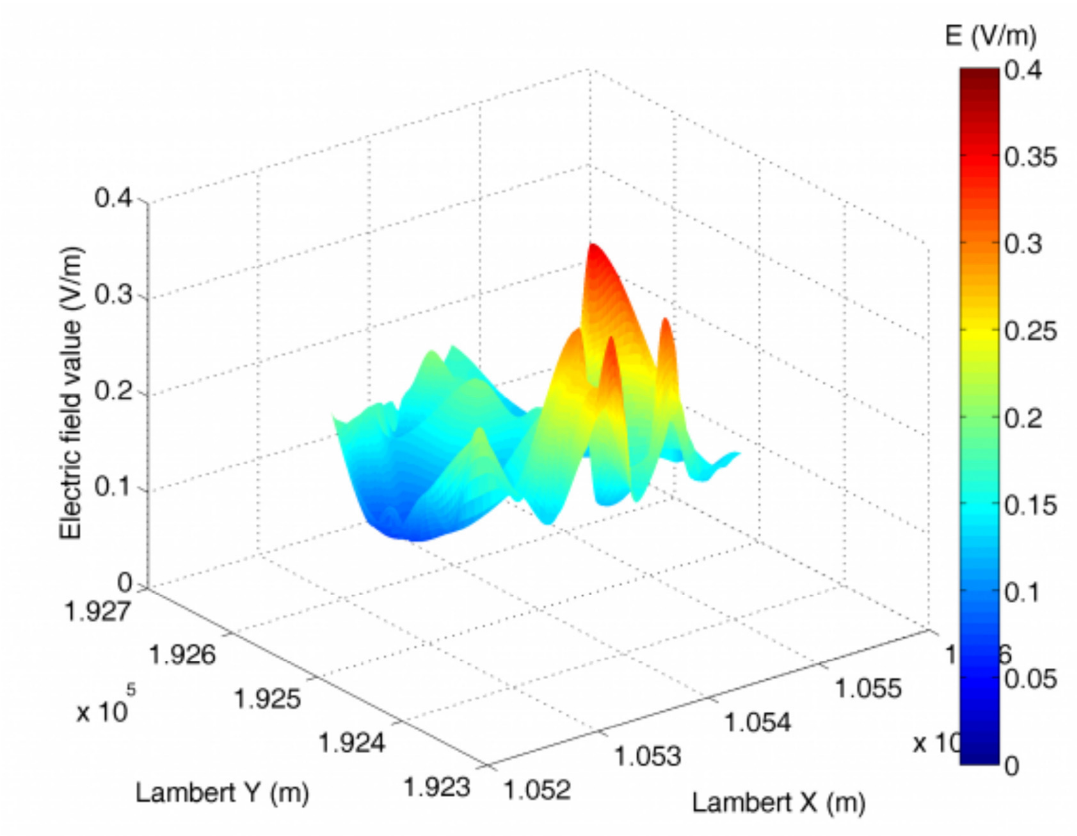


Figure 1. Surface plot of model of M_6 showing regions of high (peaks) and low (valleys) exposure. X and Y are Belgian Lambert 1972 coordinates.

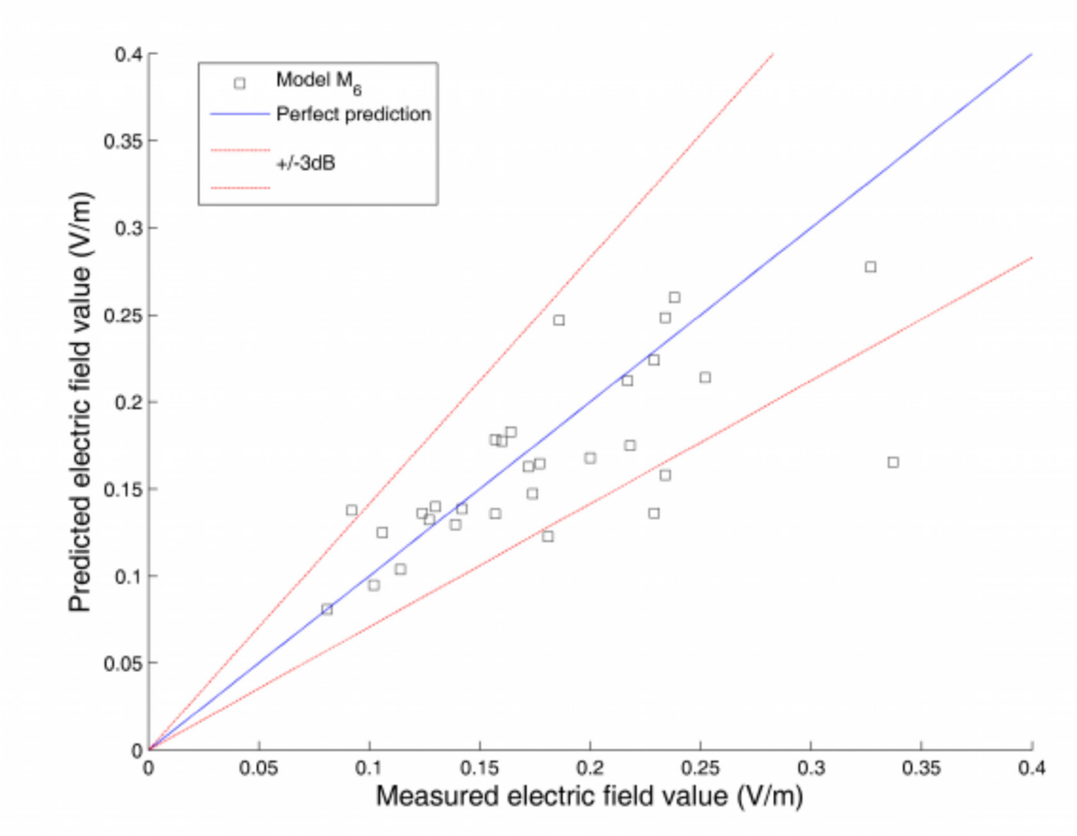
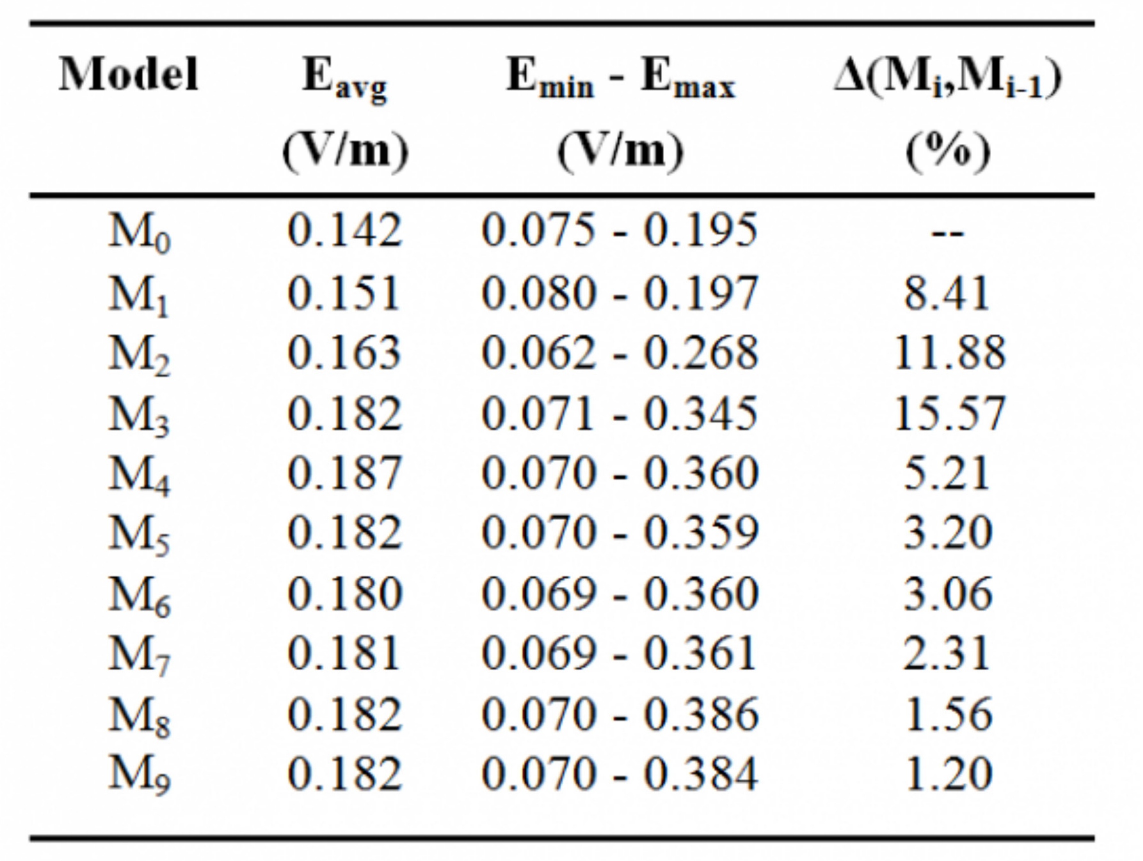


Figure 2. Comparison of measured and predicted (by model M_6) electric-field values. The full blue line depicts a perfect prediction; the dotted red lines define the region with errors below 3 dB.

Table 1. Electric-field parameters (mean and minimum-maximum) (V/m) of the subsequent interpolation models and the change of a model (%) compared to the previous one.



Model	E_{avg} (V/m)	E_{min} - E_{max} (V/m)	$\Delta(M_i,M_{i-1})$ (%)
M_0	0.142	0.075 - 0.195	--
M_1	0.151	0.080 - 0.197	8.41
M_2	0.163	0.062 - 0.268	11.88
M_3	0.182	0.071 - 0.345	15.57
M_4	0.187	0.070 - 0.360	5.21
M_5	0.182	0.070 - 0.359	3.20
M_6	0.180	0.069 - 0.360	3.06
M_7	0.181	0.069 - 0.361	2.31
M_8	0.182	0.070 - 0.386	1.56
M_9	0.182	0.070 - 0.384	1.20

E_{avg} is the average, and E_{min} and E_{max} are the minimum and maximum electric-field strengths of a certain model. $\Delta(M_i,M_{i-1})$ is the average of the sum of the absolute values of the relative deviations of the electric field levels predicted with model i with respect to the ones calculated with model i-1.

O2-2 [11:50]
LTE Exposure assessment and Extrapolation

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There is a need for the assessment of human exposure to electromagnetic radiation from emerging mobile network technologies. Long Term Evolution (LTE) is marketed as the fourth generation (4G) of radio technologies. A range of typical radio frequency (RF) exposure values and LTE contributions are provided for an urban environment in Reading, UK. Moreover, we determine the worst-case LTE values from instantaneous LTE exposure by an extrapolation method. The method is validated for various traffic loads and output powers.

Long Abstract

INTRODUCTION

There is a need for the assessment of human exposure to electromagnetic radiation from emerging mobile network technologies. Long Term Evolution (LTE) is a new mobile network technology marketed as the fourth generation (4G) of radio technologies [1]. The world's first publicly available LTE-service was started in 2009. In several countries, network operators are planning rollouts.

In this study, we provide a range of experimentally determined typical radio frequency (RF) exposure values in an urban environment and compare the LTE contribution with other sources. Moreover we determine the worst-case LTE values from instantaneous LTE exposure by an extrapolation method. In this way, LTE exposure is assessed for the maximal emission level when the base station is operating at full capacity. The method is validated for various traffic loads and output powers.

MATERIALS AND METHODS

The measurements were executed in February 2011 at 40 locations in the urban environment of Reading (UK), where a trial LTE network, consisting of 7 LTE base stations (BS) operating in an single frequency network (SFN) at 2.680 GHz with a