Radiofrequency Electromagnetic Fields from Mobile Devices Used for Learning and Working

T. Koppel[1], M. Ahonen[2]
[1] *Department of Work Environment and Safety, Tallinn University of Technology, Ehitajate tee 5, 19086 Tallinn, Estonia*
tarmo.koppel@ttu.ee
[2] *School of Information Sciences, University of Tampere, Kanslerinrinne 1, 33014 Tampere, Finland*
mikko.p.ahonen@uta.fi

***Abstract*—The relevance of this article can be described by two developments intrinsic to the digital age: the wide-spread use of the mobile devices with wireless connectivity and the exponential increase of radiofrequency electromagnetic fields in past years. The aim of this article is to determine the field strengths of popular mobile devices and to analyse their compliance in light of both legal safety limits and third-party precautionary limits. The importance of minimizing the exposure to the electromagnetic fields where possible is stressed by recent scientific evidence and also by the high level European bodies. The measurements are conducted using a novel 14-point measurement model, covering the entire body of the user. The measurement results show that the strongest fields are produced by a tablet PC, a smartphone and a netbook when they are connected to the network via EDGE or GPRS technologies. Significantly less exposure is obtained from the devices that utilize WLAN network connection or 3G within excellent network reception. At the same time, the least strong radiofrequency electromagnetic field is produced when using the e-reader or desktop PC. Based on the results, solutions are suggested to minimize the users' field exposure while retaining the network connectivity.**

***Index Terms*—Electromagnetic fields, WLAN, Wi-Fi, health, learning.**

I. INTRODUCTION

The mobile devices for learning or working are primarily defined as computers and other devices utilizing microprocessors which provide electronic alternative to traditional learning media, such as books, workbooks, etc. Mobile learning encompasses methods of implementing mobile technology into the learning process, but also learning in the era characterized by constant mobility of people and knowledge [1], [2].

The aim of this study is to rank most popular mobile learning devices – such as smartphone, tablet PC, e-reader, netbook PC, laptop PC – from the aspect of radiofrequency (RF) electromagnetic fields (EMFs) they produce.

The relevance of the subject is prescribed firstly by the exponentially increased use of mobile learning devices in the past few years, which in turn have increased the levels of RF EMFs at the learning environments. Secondly, the biological effects from the exposure to RF EMFs have become a heated debate amongst the scientific community and general public.

A number of studies have connected EMFs generated by the personal computers (PC) to certain after effects, whether cognitive or biological in nature. Sometimes these studies suffer from methodological flaws as for example the authors are not specific about the frequencies and intensities of the devices under research. Usually one mobile device generates a number of EMF frequencies – the focus should be in which of these have the ability to affect the human body. Different frequencies act differently on biological systems. Low frequencies (LF) have the ability to penetrate the body and by doing so they induce currents inside the body which might affect central or peripheral nervous system, affecting heart, muscles etc., if strong enough. Radiofrequencies are primarily absorbed by the skin or subcutaneous tissues and transformed into heat [3], [4].

Therefore a mobile device propagates a range of EMFs covering all – low, intermediate and high frequencies. Since the research on mobile learning devices has only begun, it is yet unclear which of these frequencies need most attention from the health perspective. Nevertheless, when the wireless connection is activated, radiofrequencies are prevalent over low and intermediate frequencies in field strength.

This study undertakes the measurements of RF EMFs generated by various mobile devices. The results of this paper allow both the scientists and the general public to assess the levels of EMFs generated by their mobile devices. The article also corresponds to the precautionary principle endorsed by the bodies of European Union addressing the environmental health issues: both business and private users are encouraged to reduce their exposure to the EMFs as low as reasonably possible.

A human being lacks sensory organs able to detect the presence of EMFs – this phenomenon can neither be heard, viewed nor sensed in any other manner, until it's too late and the adverse health effects have already taken place. Therefore the prior knowledge of EMF generating devices is of the essence in achieving the desirable level of protection.

In this article the authors also introduces a unique 14-point measurement protocol and a format of graphical representation, making the results easily understandable also to those not accustomed to the EMF health issues. Unlike the

Manuscript received January 29, 2013; accepted April 3, 2013.

typical measurement protocol, where only one (maximum) reading is taken from the user's position, the developed protocol allows better exposure assessment, providing a detailed view of varying exposure levels to various body regions, depending on the technology and antenna type. Such differentiation is important since for example the head (brain and the eyes) are especially vulnerable to the EMF's exposure.

A. Health effects associated with the radiofrequency electromagnetic fields

Although a majority of the studies on RF EMF induced health effects find no or little confirmation to effects taking place below the current safety limits, there still exists a significant number of studies which indeed establish the opposite. This has provided the scientists with a challenge – how can such discrepancy be explained. Explanations offered have pointed to varying genetic backgrounds of the subjects, suggesting different threshold levels for health effects, whereas some see such studies suffering from methodological deficiencies.

Whether and to what extent the RF EMFs below the current safety limits have an adverse effect on humans – is a question also rised by the high-level European bodies in the past few years. In 2009 the European Parliament issued a resolution where amongst other things was pointed out that 1) the public safety limits are outdated, 2) these limits don't take into account the developments in the info- and communication technology and 3) the limits don't consider such sensitive groups as pregnant women, newborns and children [5].

In 2011, after reviewing the updated scientific evidence, the committee of the Council of Europe issued a report naming wireless technology potentially harmful to humans. The report especially pointed out the threat to children and asked member states to take action so that the wireless networks (including WLAN and mobile communications) are removed from schools. In regard to the propagation of the electromagnetic fields the Council recommends to follow the precautionary principle of "as low as reasonably achievable", noting that failing to act now may humanly and financially become costly in the future [6].

Before the Council of Europe, the Russian National Commission of Non-Ionizing Radiation Protection had issued it's warning of a similar kind. Having reviewed the short- and long-term studies of children's mobile phone usage, they concluded that such chronic exposure may lead to psychosomatic disorders especially when a person starts the active use of mobile devices in their childhood. Probable health hazards were identified as follows: 1) in the nearest future (after starting the use) – memory problems, attention deficit, decline in learning and cognitive abilities, increasing irritability, sleeping problems, increased sensitivity to stress and increased probability of epileptic seizures; 2) at the age of 25–30yrs – brain tumours, acoustical and vestibular nerve tumours; 3) at the age of 50–60 yrs – Alzheimer's disease, dementia, depression and a variety of degenerative problems connected to the nerve structures of the brain [7], [8].

Reports from the western authorities are more reserved. The report from the European Health Risk Assessment Network on Electromagnetic Fields Exposure (EHFRAN) found that the scientific database from RF EMF exposure is yet inconclusive, and possible adverse health effects below the current safety limits are not well substantiated [9].

RF safety limits established by national legislation and international standards are still based on the thermal effect - according to which adverse health effects appear when the body tissue is heated more than about one degree (Celsius). This thermal effect is a basis for guidelines issued by the ICNIRP (International Commission for Non-Ionizing Radiation protection) [10].

Most of the scientists agree on the adverse health effects induced by the elevated body tissue temperature. When it comes to other – non-thermal health effects, scientists are divided into two camps. There exists a significant number of studies to substantiate the claims made by both parties. A group of researchers who issued a review on non-thermal effects, stated that LF and RF EMFs can cause changes in the DNA structure, proteins, lipids, nerve and muscle tissues [11], [12]. These changes are observed to take place at orders of magnitude lower field values than the thermal effect. The traditional dose-response-model has been debated because some of the research indicate frequency windows where a certain power/frequency combination may be more effective than another [13]

An official report, ordered by the European Commission, examined the existing scientific body of knowledge and found that many of the studies are biased (authors: the studies were not impartial or had other deficiencies) [14]. It must be noted that SCENIHR mainly looked for answers to if there is a link between the EMFs and the cancer – the link was not found for people who had used mobile phones for less than 10 years. At the same time, many of the researchers find that cancer is only one adverse outcome out of many.

The research on RF EMFs has provided controversial results. These studies attempt to establish a link in between EMFs and disorders of cognitive and behavioral nature. A large Danish study by Schüz et al found log-term mobile phone users to have more migraine and vertigo [1].

An extensive population study by MobilEe covered about 3000 persons, both adults and children. The study focused on the mobile communications (GSM, DECT, WLAN) and found that the average exposure to these RF EMFs amongst the general population is less than 1% of the public safety limits (ICNIRP 1998). It was established that the quartile with the highest exposure rate compared to the quartile with the lowest exposure (both adults and children), suffered more from behavioral disorders that were characterized as aggressive and destructive activities [15]. The authors however would like to point out that cognitive symptoms are not necessary considered as health symptoms.

At the same time, the EFHRAN report concluded that short term usage of mobile communications has no substantial effect on the ability to concentrate, on the memory performance or on the capability to work [9].

Many of the studies have identified the effect of RF EMFs on brainwaves – both when people are awake or asleep [14]. Although SCENIHR doubts the relevance of such effects, the authors find that, it can not yet be excluded that disturbed brainwaves interfere with the person's normal

physiological and mental functions. Such indirect effects would later be quite difficult to link to the previously disturbed brainwaves. At this point we do not know yet whether the sleeping under the influence of RF EMFs and with disturbed brainwaves is indeed a quality sleep, which allows a person's body to rest and recover fully.

SCENIHR also finds that the effect of RF EMFs on pregnant women needs further research and that it is yet too early to draw conclusions. Some of the research do point out implicit effects on pregnant people, but the scientific body of knowledge is scarce and not impartial [14].

A comprehensive Danish study reported that those 7-year old children, whose mothers had been using mobile phones before and after pregnancy, had more behavioral problems than others [14].

A hindering effect on reproductive organs and functionality of RF EMFs has also been established, but SCENIHR recognizes that studies provide controversial results and univalent conclusion can not be made; again methodological errors are pointed out [14].

Despite the controversy in the scientific body of knowledge, WHO IARC (World Health Organization International Agency on Research of Cancer) found that although the science does not allow to draw final conclusions, the research has established a significant case to motivate the raising the danger classification of EMFs to 2B – possibly carcinogenic [16]. The need for further studies was emphasized and the general public was suggested to reduce their exposure to the EMFs, until further evidence would point otherwise [16].

The aim of this study is to determine typical EMF exposure levels from devices used for mobile learning or working and to analyse these levels in light of 1) current legal safety limits and 2) precautionary safety limits produced by non-governmental organizations or groups.

II. METHOD

The authors used a 14-point measurement model, to record the levels of exposure from RF EMFs. Although measurements guidelines and standards offer a range of protocols they are often unnecessarily complex and are mostly described for persons standing up. Koppel's proposed model is a simplified measurements model customized for office workers or other workers operating computers (Fig. 1). Encompassing 14 point all over the body allows recording the EMF intensity variations with satisfactory spatial resolution. Performing the measurement, the entire body area is scanned with the meter, ensuring the detection of all the high intensity fields the body is exposed to. The model allows obtaining the readings in a relatively fast manner and at the same time providing an overview of EMF intensities across the body. The authors see it necessary to record such detailed data, since it might reveal links to adverse health effects and sensation in specific body areas, and also broaden the possibilities of the analysis done in the future. The EMFs have different effects when different body regions are exposed to them. Also, the threshold level for the adverse symptoms depends on the part of the body whereas head, eyes and reproductive organs are considered most vulnerable ones.

In order to obtain the highest reading, in each measurement point (14 points) the meter for horizontally rotated throughout the cross-section of the imaginary body. The directional antenna was aimed at the radiating antenna of the mobile device. Both the vertical and horizontal component of the field was checked.

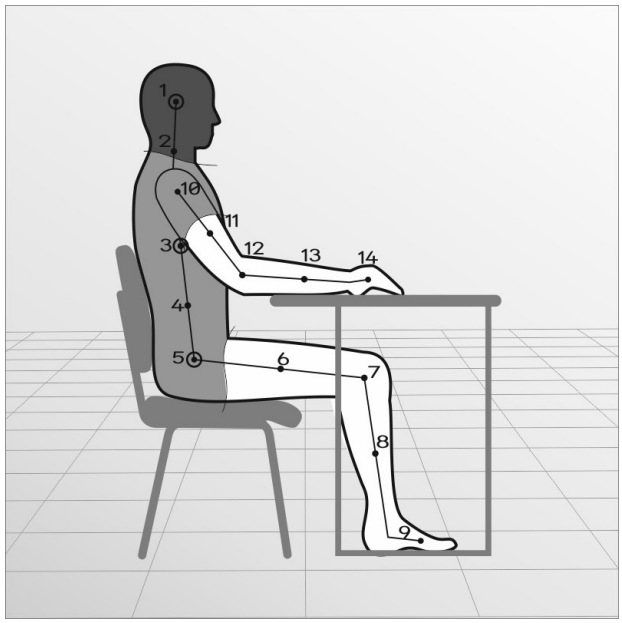

Fig. 1. 14-point measurement model used in this study (Koppel).

A wireless network connection was established to the mobile device under investigation; the device was put into constant upload mode (uploading a large file to a local server).

The instrument used, was a Gigahertz Solutions HF59B radiofrequency analyser, connected to a directional antenna HF800V2500LPE174 (Langenzenn, Germany) [17]. This setting allowed encompassing RF EMFs in the frequency range of 800–2500MHz, which includes all the RF activity of mobile learning devices observed by this study. The reading was recorded in whether in RMS-mode (root mean square) and applying the meter's normal or pulse-mode, intended especially for RF data transmission measurements. Unlike many others, this meter suits the task well, since wireless data transmission utilizes very short pulsing signals, which might be unnoticed or registered at much lower levels by other measurement devices, not customized for the pulse signals. Test measurements done with an omnidirectional antenna provided higher readings, indicating other RF EMF sources and reflections in the environment. Whereas omnidirectional antenna is suitable for overall exposure measurements, the task prescribed by this study (exposure from a single device) required a directional antenna.

III. RESULTS

The measurements were mainly conducted at the premises of Tallinn University of Technology, Tampere University but also at other research facilities. The room where the measurements took place was selected to have a low ambient level of RF EMFs, so that the evaluation of the measured device would be unaffected by neighbouring devices.

Altogether 36 mobile wireless solutions were analysed, including various device types from different manufacturers, utilizing a range of wireless adapters with different connection protocols. The sample can be divided into three groups: 1) smartphones, 2) tablet PCs, 3) netbooks/laptops. In addition the sample was enriched by measuring the devices under various connectivity conditions: both with good and poor reception areas, as some wireless adapters regulate the output power accordingly. The variety of wireless technology combinations allowed producing a comprehensive overview of modern mobile devices used for wireless learning and working activities.

Next, the measurement results of different mobile device types are analysed compared to each other and to the ambient background levels of RF EMFs. E-ink technology based E-reader was also included in the measurements but excluded from the results, since E-readers typically emit no RF EMFs and only radiate some intermediate frequency (IF) EMFs while the page is turned. The wireless data connection was established using widely used communication protocols: GPRS, EDGE, 3G, 3.5G, 4G and WLAN.

The main difference in the exposure levels resulted from the connection technology and protocol. Also, differences in exposure distribution were found to depend on the placement and the orientation of the wireless connection antenna on mobile device.

Table I summarizes the results of the measurements into the most commonly used combinations of mobile device type and wireless technology. It is important to present combinations of mobile devices and connections, as the exposure levels depend upon the way the user positions the device, the placement of the antenna and the wireless connection type.

TABLE I. MOBILE DEVICES PRODUCED RF EMF EXPOSURE.

Type of wireless connection and reception quality	**RF EMF power density (mW/m²) (MEAN / MAX)**		
	netbook, laptop	**tablet PC**	**smart-phone**
WLAN	0.52/7.80	0.19/3.03	0.12/0.81
EDGE (poor reception)	NA	NA	14.5/120
EDGE (good reception)	NA	NA	11.3/42.0
3G and 3,5G (poor reception)	8.26/27.1	20.1/53.0	7.20/53.0
3G and 3,5G (good reception)	1.55/17.8	15.2/40.3	3.60/20.0
4G (poor reception)	14.6/57.0	10.8/57.0	NA
4G (good reception)	6.88/57.3	3.2/22.0	NA
background reception	0.06 / 0.35		

The measurement results of the mobile devices are divided into subcategories according to the device type and wireless connection type. The MEAN power density levels are those averaged over the 14 points and then averaged over the subcategory. The MAX levels represent the highest of all the points in the subcategory.

As the connection types that depend on the vicinity of the cell phone tower usually regulate the output power of the corresponding wireless adapter, two types of measurements scenarios were created: 1) with good and 2) with poor reception quality. A good reception quality was established when at least ¾ of the best possible signal level was achieved. In order to obtain a poor signal quality the research facility's basement floor was used and the weakest workable signal level capable of corresponding connection type achieved.

The largest power intensity levels were created by the devices utilizing the technologies originally developed for the mobile phones. For example 3G internet USB-sticks can widely be used together with various mobile devices. The higher levels are easily explained as these devices need to establish a connection to the nearest cell tower, which could be kilometres away, whereas WLAN-adapter only needs to connect to the access-point, typically within 20 meters. Nevertheless 3G internet-adapters were also measured to have remarkably low radiating power levels, when the mobile devices were in an excellent reception area. However the output levels of 3G/4G adapters vastly differ from model to model: under good reception some of the models produced barely noticeable readings, whereas other models did not seem to care about the good reception and output a strong signal. Therefore the mean values calculated across the subcategory are distorted by the inconsistent behaviour of different wireless adapters.

Fig. 2–Fig. 5 represent samples of typical exposure situations while using popular mobile learning devices with wireless connection active.

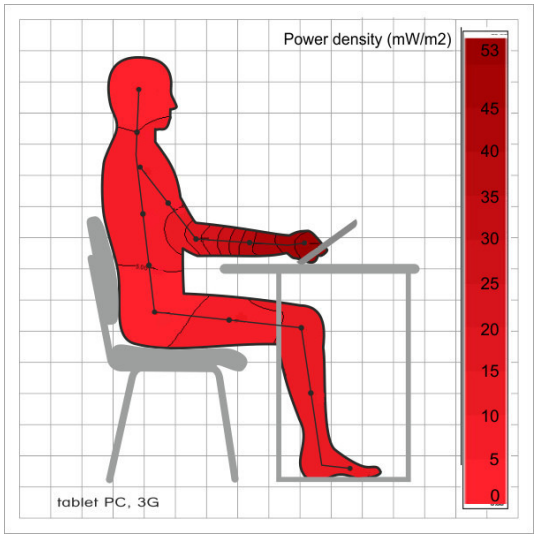

Fig. 2. Typical exposure levels from a tablet PC utilizing 3G wireless connection to a cell tower.

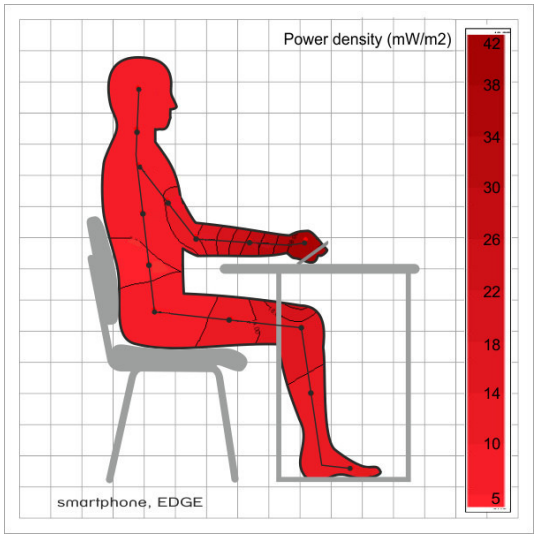

Fig. 3. Typical exposure levels from smartphone utilizing EDGE wireless connection to a cell tower.

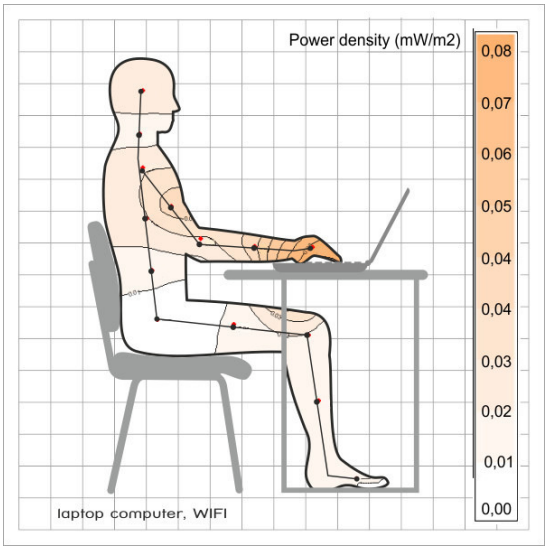

Fig. 4. Typical exposure levels from a laptop PC utilizing WLAN (antennas are placed on top edges of the monitor).

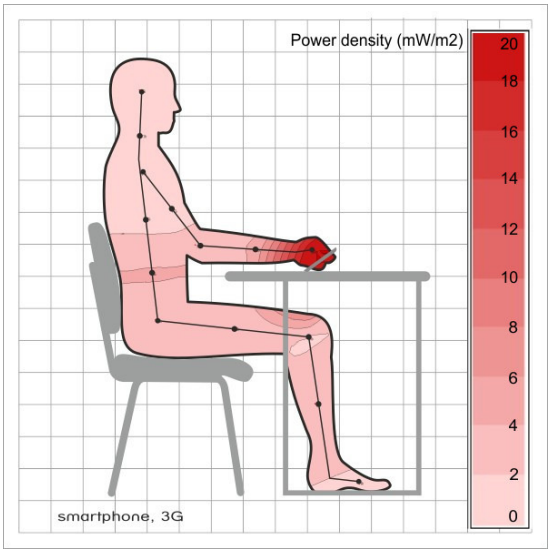

Fig. 5. Typical exposure levels from a smartphone utilizing 3G connection in a good reception area.

By examining the measurement results across the body, the largest exposure is taken by the palms (point 14), which are closest to the mobile device. This would apply to the stomach and genital area as well, if the device is held in the lap. As the measurement points recede from the device, so does decrease the power intensity level, which is also dependent on the irradiative characteristics of the antenna and the RF reflections occurring in the premises.

When taking a wider look into the array of mobile devices, the least exposure is provided by such classical solutions as a paper book and a workbook. Also a desktop PC when utilizing a LAN connection generates no RF EMFs. The same can be said to e-ink technology based e-readers. All of these devices do not utilize the wireless network and are therefore RF-free.

Fig. 6 represents different data transmission modes in EDGE, WLAN and 3G connections. One could clearly identify the different power intensity levels and the modes how the device is utilizing the connection.

Based on the experience in the field, the authors consider rapidly changing power intensity and extensive frequency-jumping, such as expressed by the tablet PC 3G connection activity – to be most influential on biological systems.

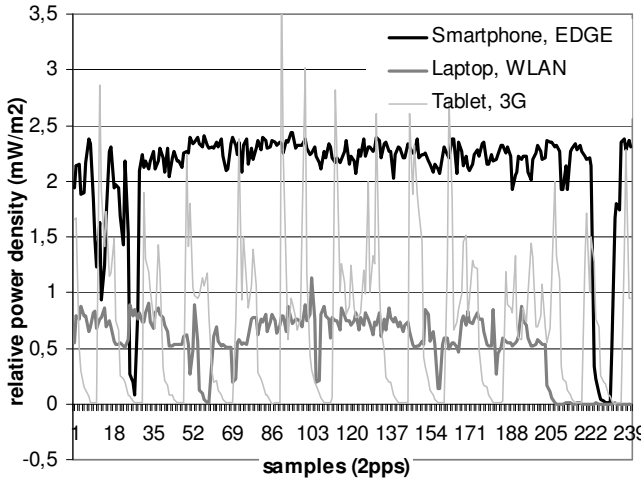

Fig. 6. Upload modes as characterized by connection type: EDGE, WLAN and 3G, sampled over 2min period.

IV. DISCUSSION

This study has provided RF EMF radiation characteristics for the currently most widely used wireless connection types. The results indicate high- and low-exposure solutions, by selecting amongst which, the precautionary principle can be followed of minimizing one's exposure to RF EMFs.

The emission levels of all the measured devices are well below the safety limits of the EMF public protection directive [18]. As discussed in this paper the current safety limits reside on the presumption that only adverse health effects are those of a thermal nature. Based on that conception the existing safety limit for RFs is 10W/m² [18], [10]. Although the argumentation for the non-thermal effects is not perfect, the authors see that failing to address the issue might become costly both humanely and economically in the future. For example, if and when the results from the long-term studies reveal themselves, confirming the current misconception (relaying on the non-thermal effects), then it would be too late for those people who have exposed themselves to excess RF EMFs for years.

Some third-party guidelines have suggested radically reducing the safety limits, for example to the level of 0,1 µW/cm² [11]. The newer version of the same report published in January 2013 has even suggested the precautionary limit to be 3–6 nW/cm² [12]. Although a general body of the scientists does not support such radical approach, important questions have bee raised by the Bioinitiative report which further research needs to address if consensus amongst the scientists is pursued. Meanwhile the precautionary approach should be entertained until further studies shade a light on the issue. The authors concur with the EU conception of the precautionary principle – to minimize the exposure to the EMFs where practically possible.

It must also be taken into account that such strict safety limits as endorsed by the BioInitiative report are unrealistic to implement into the national or even local legislation. The current form of our society and economy vastly depend on this newly implemented communications technology and such contra-technology actions would hinder the European

competitiveness on the global market.

Meanwhile as hindering the development of wireless technology is questionable and surely unpopular, the authors suggest that more effort should be made on educational work. The public should be fully made aware of the open questions in regard to the health effects, so that they take necessary actions in reducing their exposure, if so desired.

In looking at the exposure levels, based on the model used in this paper, most attention should be addressed to point 1 (head) and 5 (reproductive organs), since these organs seem to be most affected by the RF EMFs and the damage occurring there might take long time to reveal itself [19]–[21]. Next to RF EMFs mobile devices also emit other low and medium frequency EMFs which also contribute to the overall exposure budget, especially when the devices are held in close proximity to the body.

Attention should be paid on children's usage of mobile devices, as they are more vulnerable to the RF EMFs and are likely not to comprehend all the risks involved [1], [7], [8]. While the beneficial role of mobile devices in improving the learning process can not be undermined, the authors recognize the challenge in developing information technology with low exposure budget.

V. CONCLUSIONS

The results of this study illustrate a vast difference in exposure levels, dependent on the MLD and wireless connection type used. The authors summarize the findings of this study into following recommendations to be followed if the user would like to comply with the precautionary principle. The user can significantly reduce his/her exposure to the RF EMFs by:

1) Using the mobile device in an area with a good reception (in case of EDGE, 3G and 4G);

2) Preferring WLAN to other wireless solutions; but using cable LAN whenever available;

3) Creating more distance with the mobile device and the user. For example, when using wireless connection via USB-adapter, using an extension cord to position the USB-stick away from the body;

4) Switching the wireless transmitter and the antenna manually off, when the connection is not necessary;

5) Using advanced software design models to support synchronisation and replication to avoid constant, wireless cloud-based connection [22].

Besides to the above mentioned precautionary recommendations, the authors would like to point out the second-hand exposure of the nearby people i.e. not only the user of the MLD is exposed to the RF EMFs but also those surrounding him. As pregnant women and young children are identified as risk groups, special attention and responsibility should be exercised when generating RF EMFs around them.

REFERENCES

[1] J. Schüz, G. Waldemar, J.H. Olsen, C. Johansen, "Risk for central nervous system diseases among mobile phone subscribers: a Danish retrospective cohort study*". PLoS ONE,* vol. 4, e4389, 2009.

[2] M. Sharples, J. Taylor, G. Vavoula, *A Theory of Learning for the Mobile Age.* In *B. Bachmair (Ed.), Medienbildung in neuen Kulturräumen*. Wiesbaden: VS Verlag für Sozialwissenschaften, 2010, pp. 87–99. [Online]. Available: http://dx.doi.org/10.1007/978-3-531-92133-4_6

[3] A. S. Presman, *Electromagnetic Fields and Life.* New York: Plenum Press, 1970, pp. 34–59. [Online]. Available: http://dx.doi.org/10.1007/978-1-4757-0635-2

[4] H. B. Newton & F. A. Jolesz, *Handbook of Neuro-oncology Neuroimaging*, New York: Academic Press, 2008, pp. 164–165.

[5] "Report on health concerns associated with electromagnetic fields electromagnetic fields", EP- European Parliament Committee on the Environment, Public Health and Food Safety, (2008/2211(INI)), 2009.

[6] "The potential dangers of electromagnetic fields and their effect on the environment", CE-Council of Europe Parliamentary Assembly, Committee on the Environment, Agriculture and Local and Regional Affairs, 2011. [Online]. Available: http://assembly.coe. int/main.asp?link=/ documents/workingdocs/doc11/edoc12608.htm

[7] "Children and mobile phones: The health of the following generations isi n danger", RNCNIRP- Russian National Committee on Non-Ionizing Radiation Protection, Moscow, 2008.

[8] "Electromagnetic fields from Mobile Phones: Health Effect on Children and Teenagers", RNCNIRP- Russian National Committee on Non-Ionizing Radiation Protection, 2011.

[9] "Risk Analysis of human exposure to electromagnetic fields, report D2 of EHFRAN project 2010", EHFHRAN – European Health Risk Assessment Network on Electromgnetic Fields Exposure, [Online]. Available: http://efhran.polimi.it/docs/EFHRAN_D2_final.pdf

[10] "Guidelines for limit-ing exposure to time-varying electric, magnetic and electromagnetic fields", ICNIRP-International Commission of Non-Ionising Radiation Protection, 1998 [Online]. Available: http://www.icnirp.de/documents/emfgdl.pdf

[11] "A Rationale for a Biologically Based Public Exposure Standard for Electromagnetic Fields", BioInitiative Working Group, Bioinitiative report, 2007.

[12] "A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Radiation", BioInitiative Working Group, BioInitiative Report, 2012.

[13] C. F. Blackman, J. A. Elder, C. M. Weil, S. G. Benane, D. C. Eichinger, D. E. House, "Induction of calcium-ion efflux from brain tissue by radio-frequency radiation: Effects of modulation frequency and field strength", *Radio Sci*., vol. 14 no. 6S, pp 93–98, 1979, [Online]. Available: http://dx.doi.org/10.1029/RS014i06Sp00093

[14] "Health Effects of Exposure to EMF. European Commission Directorate-General for Health & Consumers", SCENIHR-Scientific Committee on Emerging and Newly Identified Health Risks, 2009.

[15] S. Thomas, S. Heinrich, A. Kühnlein, K. Radon, "The association between socioeconomic status and exposure to mobile telecommunication networks in children and adolescents", *Bioelectromagnetics*, vol. 31 no. 1, pp. 20–27. 2010.

[16] "IARC Classifies Radiofrequency Electromagnetic Fields as possibly carciogenic to humans", WHO International Commision for research on cancer, Press release no. 208, 2011. [Online]. Available: http://www.iarc.fr/en/media-centre/pr/2011/pdfs/pr208_E.pdf. 2011

[17] *Gigahertz Solutions HF59B radiofrequency analyser specifications*. [Online]. Available: http://www.gigahertz-solutions.de/de/Online-Shop/Messtechnik/Hochfrequenz/Messgeraete/HF59B.html

[18] EP-European Parliament, "Directive 1999/519/EC on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)", official Journal of the European Communities, vol. 30, no. 7, 1999.

[19] A. Agarwal, A. Singh, A. Hamada, K. Kesari, "Cell phones and male infertility: a review of recent innovations in technology and consequences", *International braz j urol,* vol. 37 no. 4, 2011. [Online]. Available: http://dx.doi.org/10.1590/S1677-55382011000400002

[20] N. Desai, K. K. Kesari, A. Agarwa, "Pathophysiology of cell phone radiation: oxidative stress and carcinogenesis with focus on male reproductive system", *Reprod Biol Endocrinol*, vol. 114 no. 7, 2009.

[21] J. Schüz, E. Böhler, G. Berg, B. Schlehofer, I. Hettinger, K. Schlaefer, J. Wahrendorf, K. Kunna-Grass, M. Blettner, "Cellular phones, cordless phones, and the risks of glioma and meningioma" (Interphone Study Group, Germany)". *Am J Epidemiol*, vol. 163, no. 6. 2006. [Online]. Available: http://dx.doi.org/10.1093/aje/kwj068

[22] M. Ahonen, T. Koppel, "Mobile Learning and Health-Risk Management of Pulsed Microwave Technologies", *in Proc. of the mLearn Conf.,* Helsinki, 2012.