Archives of Environmental & Occupational Health
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/vaeh20

Exposure to Electromagnetic Fields From Laptop Use of “Laptop” Computers

C. V. Bellieni MD [a], I. Pinto MS [b], A. Bogi PhD [b], N. Zoppetti MS [c], D. Andreuccetti MS [c] & G. Buonocore PhD [a]

[a] Department of Pediatrics, Obstetrics and Reproduction Medicine, University of Siena, Siena, Italy

[b] ASL 7 (Local Health Agency), Prevention Department Physical Agents Laboratory, Siena, Italy

[c] CNR (Italian Research Council), Institute of Applied Physics (IFAC), Florence, Italy

Available online: 08 Feb 2012

Archives of Environmental & Occupational Health, Vol. 67, No. 1, 2012

Exposure to Electromagnetic Fields From Laptop Use of "Laptop" Computers

C. V. Bellieni, MD; I. Pinto, MS; A. Bogi, PhD; N. Zoppetti, MS; D. Andreuccetti, MS; G. Buonocore, PhD

ABSTRACT. Portable computers are often used at tight contact with the body and therefore are called "laptop." The authors measured electromagnetic fields (EMFs) laptop computers produce and estimated the induced currents in the body, to assess the safety of laptop computers. The authors evaluated 5 commonly used laptop of different brands. They measured EMF exposure produced and, using validated computerized models, the authors exploited the data of one of the laptop computers (LTCs) to estimate the magnetic flux exposure of the user and of the fetus in the womb, when the laptop is used at close contact with the woman's womb. In the LTCs analyzed, EMF values (range 1.8–6 μT) are within International Commission on Non-Ionizing Radiation (NIR) Protection (ICNIRP) guidelines, but are considerably higher than the values recommended by 2 recent guidelines for computer monitors magnetic field emissions, MPR II (Swedish Board for Technical Accreditation) and TCO (Swedish Confederation of Professional Employees), and those considered risky for tumor development. When close to the body, the laptop induces currents that are within 34.2% to 49.8% ICNIRP recommendations, but not negligible, to the adult's body and to the fetus (in pregnant women). On the contrary, the power supply induces strong intracorporal electric current densities in the fetus and in the adult subject, which are respectively 182–263% and 71–483% higher than ICNIRP 98 basic restriction recommended to prevent adverse health effects. Laptop is paradoxically an improper site for the use of a LTC, which consequently should be renamed to not induce customers towards an improper use.

KEYWORDS: electromagnetic, exposure, laptop, pregnancy

The use of laptop computers (LTCs) is wide and increasing in much countries; the general trend is to spread its use even among children. The word "laptop" means "a portable, usually battery-powered microcomputer small enough to rest on the user's lap,"[1] and this means that they are often used at close contact with the body in a very delicate area close to skin, bones, blood, genitals, and, in pregnant women, close to the fetus. LTCs have electrical circuits and power supplies that produce electromagnetic fields (EMFs), which has recently raised concern because they might "cause detectable impairment of the health of the exposed individual or of his or her offspring; a biological effect, on the other hand, may or may not result in an adverse health effect."[2] In fact, the physical interaction of EMF with the human body produces induced electric fields and circulating electric currents that can have biological effects.

EMFs can penetrate deeply into the body and induce electric currents. If the current density exceeds a certain threshold value, excitation of muscles and nerves due to membrane depolarization is possible.

C. V. Bellieni *and* **G. Buonocore** *are with the Department of Pediatrics, Obstetrics and Reproduction Medicine, University of Siena, Siena, Italy.* **I. Pinto** *and* **A. Bogi** *are with ASL 7 (Local Health Agency), Prevention Department Physical Agents Laboratory, Siena, Italy.* **N. Zoppetti** *and* **D. Andreuccetti** *are with CNR (Italian Research Council), Institute of Applied Physics (IFAC), Florence, Italy.*

The International Commission on Non-Ionizing Radiation (NIR) Protection (ICNIRP) provided “basic restrictions” in terms of current density inside the body. ICNIRP is an independent scientific organization that has the functions to investigate the hazards associated with the different forms of NIR, to develop international guidelines on NIR exposure limits, and to deal with all aspects of NIR protection. In particular, the ICNIRP publication entitled “Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)”[3] is the international guideline to be followed for limiting EMF exposure and to provide protection against known adverse health effects.[3] This document establishes “basic restrictions” to the exposure to time-varying electric, magnetic, and electromagnetic fields that are based directly on demonstrated health effects. Nevertheless, since the original report by Wertheimer and Leeper,[4] several epidemiological studies and meta-analyses on residential EMF (below the ICNIRP alarm threshold) and childhood leukemia have been published. Most of them report a positive association and a small but significant increase in risk[5] between EMF and leukemia. The risk threshold disclosed by these epidemiological investigation is 3 to 5 μT. In 2001, an expert group of the International Agency for Research on Cancer (IARC; an institution under the World Health Organization [WHO]) reviewed reports on the carcinogenicity of extremely low frequency (ELF) low-intensity magnetic fields. Weighting the evidence from cellular, animal, and human studies (especially from epidemiological studies on childhood leukemia), they classified these fields as “possibly carcinogenic to humans.”[6]

The present study has 2 aims: to investigate if and in what conditions (a) EMF and (b) induced currents produced by common LTCs exceed values that might be considered risky for the users.

METHODS

We considered 5 common laptops of different firms, which in the present study we named with letters from A to E. Experiments were performed after having previously measured the background EMF level and having disclosed that it was lower than 0.01 μT.

Emission measurement

Magnetic fields have been measured in the 1 Hz to 400 kHz frequency range, using a NARDA ELF 400 electromagnetic field measuring system, equipped with a 3-axis magnetic NARDA field probe with a 100 cm^2 cross-sectional area (NARDA, Hauppauge, NY, USA). The probe has a frequency response that is constant from 1 Hz to 400 kHz. The unfiltered analog signal from the instrument has been input into an Agilent U2531A analog to digital converter (sample rate 200 kSa/s) and downloaded to a PC (Agilent, Santa Clara, CA, USA).

Measurements have been carried out according to EN 62233:2008-04 standard. We performed measurements of the magnitude and the spatial distribution of magnetic flux density on the LTC surface of 5 different models of computers examined.

We scanned each of the 5 laptops above their front and back surfaces, along the entire laptop external surface. We detected the point of highest emission at the back surface of the laptop.

We detected the dominant frequency of the EMF, and measured the level of EMF emissions for that frequency.

A computer program developed in C++ language was used to appropriately process the continuous signals, for nonoccupational exposures.[7]

Dosimetric calculation

The voxel model used to calculate intracorporal electric current density distributions was the whole-body human database of Japanese average pregnant woman, jointly developed by the National Institute of Information and Communications Technology and Ciba University, which represents a pregnant woman at the 26th week of gestation. In this model, mother and fetus tissues are defined according to NICT (National Institute of Information and Communications Technology) pregnant female voxel phantom. Dielectric properties of mother tissues are calculated using the parametric model developed by C. Gabriel and colleagues[8] that reproduces the tissue conductivities in a wide range of frequencies. The following 3 tissues are defined for the fetus: eyes, brain, and body. Their conductivities are derived using the conductivities of eyes and brain and a weighed average over all the tissues conductivities of the Virtual Family children voxel phantom.[9–12]

The algorithm we used is a reformulation of the scalar potential finite difference (SPFD) in the time domain, whose basics are presented in the following paragraphs.

The magnetic field in proximity of laptop computers has complex waveform and polarization.

The application of dosimetric methods is aimed at the evaluation of basic internal quantities, and has been carried out according to the following steps:

1. Representation of the spatial inhomogeneity of the impressed magnetic field
2. Representation of a complex time dependence of field components
3. Assessment of compliance with basic restrictions values of ICNIRP, considering their frequency dependency

In this article the attention was focused on points 2 and 3, whereas the spatial distribution was simplified by adopting a “worst-case” approach. In particular, a uniform field distribution was assumed and its time trend is the one measured at close contact with one of the laptops.

In the case of uniform field, the time dependence of the field is the same in all the points of the exposed subject and it is easy to show that, at low frequencies, the dosimetric problem can be split into 3 independent problems with homogeneous field distribution and linear polarization, parallel to each one of the 3 Cartesian axes of the reference system chosen for the analysis.

The measured magnetic field $\mathbf{B}(t)$ (Tesla), considered to be constant in the entire exposure scenario, is expressed by Equation 1, where t is the time and $\mathbf{r}$ is the position vector.

$$\mathbf{B}(\mathbf{r}, t) = \mathbf{B}(t) = B_x(t) \cdot \hat{x} + B_y(t) \cdot \hat{y} + B_z(t) \cdot \hat{z} \quad (1)$$

It is easy to demonstrate that the current density $\mathbf{J}(\mathbf{r}, t)$ (A/m^2) can be expressed by the following Equation 2:

$$\mathbf{J}(\mathbf{r}, t) = \frac{dB_x(t)}{dt}\mathbf{j_1}(\mathbf{r}) + \frac{dB_y(t)}{dt}\mathbf{j_2}(\mathbf{r}) + \frac{dB_z(t)}{dt}\mathbf{j_3}(\mathbf{r}) \quad (2)$$

where $\mathbf{j_1}(\mathbf{r})$ (Am^{-2}sT^{-1}) is a vector representing the spatial dependency of the impressed field.

Equation 2 allows us to calculate the current density in a generic instant once that the 3 solutions $\mathbf{j_1}(\mathbf{r})$, $\mathbf{j_2}(\mathbf{r})$, and $\mathbf{j_3}(\mathbf{r})$ of Equation 2 were found. This method can be applied only at low frequency, under the so-called "quasistatic" conditions hypothesis, where both the effects of field propagation and the dielectric proprieties of biological tissues can be neglected.

The main approximation "hidden inside" Equation 2 is related to the fact that the conductivities of biological tissues are known as a function of the frequency. The choice of a reference frequency in the case of a not sinusoidal impressed field leads to an approximation that is well verified only in case of narrow band waveforms. In any case, the *reference frequency* can be chosen in such a way to minimize the error or to overestimate the current density in order to apply a "worst-case" approach.

According to the ICNIRP statement on complex waveform,[11] a first-order filter, whose frequency response represents the inverse of basic restrictions on current density, can be applied to Equation 2 to obtain a "weighted peak" exposure index that is less or equal to the unity in case of compliance of basic restriction (the index can be also expressed in percentage scale). Equation 3 defines the index WPJ for current density. In this expression Γ_J is the mathematical functional that represents the application of the first-order filter defined in the ICNIRP statement.[13]

$$\mathrm{WPJ}(\mathbf{r}) = \max_t \left| \Gamma_J \left\{ \frac{dB_x(t)}{dt} \right\} \mathbf{j_1}(\mathbf{r}) + \Gamma_J \left\{ \frac{dB_y(t)}{dt} \right\} \mathbf{j_2}(\mathbf{r}) + \Gamma_J \left\{ \frac{dB_z(t)}{dt} \right\} \mathbf{j_3}(\mathbf{r}) \right| \quad (3)$$

In order to chose the orientation of the impressed field, the instant in which the maximum intensity of the field holds can be considered. Alternatively, the 3 components $\mathbf{j_1}(\mathbf{r})$, $\mathbf{j_2}(\mathbf{r})$, and $\mathbf{j_3}(\mathbf{r})$ can be considered separately, according to the moment the impressed field reaches its maximum while it is parallel to one of the coordinate axes.

In this particular case, the calculations were performed as follows:

Preprocessing: EMFs were processed to calculate the percent of exposure with reference to exposure limits given by ICNIRP in the frequency measurement range, and maximum spectral component was determined.

Processing: We considered a magnetic field intensity uniform in the volume of the model. The calculus was made for an input magnetic field of 1 T intensity and a frequency correspondent to the frequency obtained in preprocessing. In order to take into account the possible field orientation, a calculus was made for a field oriented along the x-, y-, and z-axis.

Postprocessing: Intracorporal electric current densities distribution was obtained within the different fetus' and mother's tissues, following these steps:

- Current distribution were rescaled in order to obtain a value corresponding to the maximum magnetic field exposure measured.
- For each point the modulus of the current density distribution was evaluated.
- For each body tissue the maximum, minimum and average current density were evaluated.
- According to the normative an average of the current density over 1 cm^2 was made and new statistical values of the averaged current density were evaluated for each body tissue.

We estimated the induced currents produced by the power supply.

The estimation of induced current in the mother's brain have been carried out assuming that power supply was very close to the mother's head (eg, on a socket positioned near the headboard), whereas induced currents in the fetus have been calculated considering that the power supply may be put close to the mother's womb (Figure 1). The choice of these positions is called "worst-case approach."[14] A worst-case challenge is defined as executing a process under a set of conditions that leads toward process or product failure yet does not result in failure. The worst-case approach is attractive in that it allows examination of all of the critical process variables together, thus ensuring that additive effects and interactions are tested for. In this case, we have considered the laptop with the highest emission, with the power supply close to the woman's body, and we have calculated induced currents in her brain if the power supply was close to the head, and the fetus's induced currents if the power supply was close to the womb.

RESULTS

In the 5 laptops we examined, EMF levels for their dominant frequency ranges from 1.8 to 6 μT, whereas those

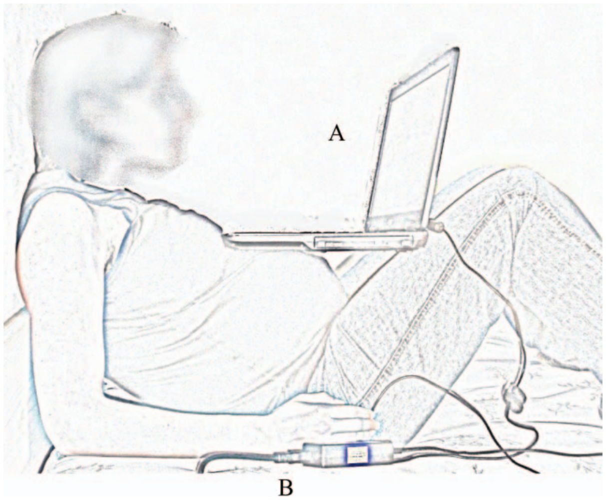

Fig. 1. A laptop (A) on the womb of a pregnant woman and the power supply (B) close to her body (color figure available online).

produced from the power supply ranges from 0.7 to 29.5 μT (Tables 1 and 2).

Applying the "worst-case approach" and considering intracorporal currents induced by the higher emission laptop (laptop A), we found that power supply produces strong intracorporal electric current densities in the fetus and in the mother, higher than ICNIRP 98 basic restriction recommended to prevent adverse health effects,[15] whereas currents induced in the mother's body or in the fetus by the laptop do not exceed these limits (see Tables 1 and 2 for details).

COMMENT

In the present study we found that mother and fetus are exposed by LTC to EMFs higher than exposures that can be found in the proximity of high-voltage power lines and transformers[15] or of domestic video screens.[16] EMF values that we found in the present study were also higher than the values recommended by 2 recent guidelines for computer monitors magnetic field emissions, MPR II and TCO[18,19] (Table 3), and higher than those considered risky for the development of blood tumors.[20]

It is true that laptop induced currents and EMFs are in ICNIRP limits, but we must consider the possibility that actual EMFs that reach the body are higher than those we detected, since the detector in the tool we used was at 5 cm from the laptop; this means that EMFs (and consequently the induced currents that we extrapolated) were of course higher at direct contact to the laptop, as the EMFs decrease with the square of the distance.

Although LTC-induced currents fit the broad ICNIRP limits, concern about the safety of any level of induced currents has been raised,[21] even in the case of few hours of exposure.[22] It is clear that both laptop and power supply are not always at close contact with the body, but in several cases the distance is not guaranteed and the possibility that the laptop is used on the laps, and that the power supply is in a narrow range with the body, is high. This is why we used the "worst-case approach" for our study.

Table 1.—EMF Emissions From Laptops (Laptop) and From Power Supply (p.s.) Investigated

Model	Bmax (μT)	Frequency (Hz)	WPJ (%)
A laptop	3.8	1, 000	27
A p.s.	29.5	750	175
B laptop	6	17, 960	23
B p.s.	20	750	112
C laptop	2.8	1, 025	14
C p.s.	10.5	550	87
D laptop	2.4	360	12
D p.s.	3.58	550	29
E laptop	1.8	800	8
E p.s.	0.7	100	4

Note. Laptop and power supply EMFs measured at the dominant frequency (third column), expressed as percent value of the ICNIRP reference values for the population. Maximum values obtained for each equipment are reported in the column B_{max}.

Table 2.—Induced Currents as Percentage of ICNIRP Limit for Population From Equipment A

Body tissue	Source	Orientation *x*	*y*	*z*
Fetus	Laptop	34.20	49.80	36.70
Fetus	Power supply	182.0	263.7	195.2
Mother Brain grey matter	Power supply	167.2	168.1	124.1
Mother Brain white matter	Power supply	71.5	72.9	78.6
Mother cerebellum	Power supply	144.3	96.5	126.7
Mother cerebrospinal fluid	Power supply	346.7	483.5	394.4
Mother muscle	Power supply	173.9	228.3	153.5

Note. Induced current on the fetus and on the mother body due to the exposition to laptop A electromagnetic emission expressed in terms of percent of ICNIRP 98 basic restriction for the population.

Table 3.—EMF Emission Limits Prescribed by MRP II and TCO

Magnetic filed	MPR II	TCO
ELF (5 Hz to 2 kHz)	$<0.25\ \mu T$	$<0.2\ \mu T$
VLF (2 to 400 kHz)	$<0.025\ \mu T$	$<0.025\ \mu T$

Note. The recommendations for EMF emission limits prescribed by MRP II and TCO are exceeded in the case of laptop emissions, as results from our measurements show.

Possible low-level EMF exposure risks

All these data demand the adoption of safety guarantees in the production and use of LTCs. In facts, though some studies have failed to find a link between exposure to low-intensity EMF and tumors,[23,31–33] others have reported adverse effects.[25–33] The Engineering in Medicine and Biology Society (EMBS) Committee on Man and Radiation[8] has defined a security limit of 1 μT; Ahlbom[25] indicates an almost 2-fold risk for subjects exposed to more than 0.4 μT. Other authors[24] give a safety limit of 0.2 μT. Magnetic flux density values in some of our LTCs are much higher. In recent double-blind laboratory investigations, exposure to electromagnetic fields was found to reversibly reduce the normal variability of heart rate.[34] A recent study performed on adult subjects suggests that exposure to 1-μT EMF alters sleep by reducing total sleep time, sleep efficiency, stage 3 to 4 slow-wave sleep, and slow-wave activity.[35] EMFs, even those produced by electric blankets, may inhibit the production of melatonin.[36–39] A number of epidemiological studies have investigated possible association of adverse pregnancy outcome with the use of video display terminals during pregnancy.[40–45] In general, these studies have not suggested increased risks for spontaneous abortion, low birth weight, preterm delivery, intrauterine growth retardation, or congenital abnormalities. However, most of the studies did not include any measurements of EMF field exposure: the average exposure of a video display operator is typically low (around 0.1 μT), so these studies are not informative for assessing possible effects associated with higher exposures. Lindbohm et al.[46] carried out measurements of the field emissions of displays used by the study subjects, and observed an increased odds ratio (3.4; 95% confidence interval [CI]: 1.4–8.6) for spontaneous abortions among women who used the few video display terminal types that had unusually high-ELF magnetic field emissions ($>$0.9 μT peak-to-peak value). Another study that included ELF field measurements[47] did not report any association with field exposure.

The precautionary principle

EMF exposure is not the only concern raised by the laptop use of LTCs. An increase in genitals temperature[48] has been described as well as posture alterations,[49,50] but also the posture produced by holding the PC on a lower site than the table level can be harmful, producing bad posture and back pain and vision fatigue.[51] Nevertheless, it is paradoxical that adult workers who should operate in front of a PC have well-stated guarantees, whereas those working with a LTC, and namely pregnant workers, have not the same guarantees. A precautionary principle states that prudent action should be taken when "there is sufficient scientific evidence (but not necessarily absolute proof) that inaction could lead to harm and where action can be justified on reasonable assessment of cost-effectiveness ratio," and that the number of possibly affected persons as well as the benefits of EMF usage should be taken into consideration.[52] Taking into account such principle, several recommendations on further limitation of exposure to electromagnetic fields—well below the limits of the ICNIRP guidelines—have been produced by several national boards and institutions.[53,54] In particular, the following recommendations are given by the WHO[2]: "Changes to engineering practice to reduce ELF exposure from equipment or devices should be considered . . . . Local authorities should enforce wiring regulations to reduce unintentional ground currents when building new or rewiring existing facilities, while maintaining safety. . . . National authorities should implement an effective and open communication strategy to enable informed decision-making by all stakeholders; this should include information on how individuals can reduce their own exposure." In this light, our results are a strong claim for further caution and guarantees in the use of portable computers.

In conclusion, our data show that the laptop is paradoxically an improper site for the use of a LTC, which consequentially should be renamed to not induce customers towards an improper use. The use of the word "laptop" is thus misleading, because evidence shows that an incorrect use of the LTC can cause an increased EMF body exposure. Users should be aware about such risk: recommendations for safe use of laptop should avoid close contact between laptop, power supply, and user, in particular during pregnancy.

****

For comments and further information, address correspondence to Carlo V. Bellieni, Neonatal Intensive Care Unit, University of Siena, Viale M. Bracci, 53100 Siena, Italy.
E-mail: cvbellieni@gmail.com

****

References

1. Dictionary.com. Available at: http://dictionary.reference.com/browse/laptop. Accessed January 2, 2012.
2. WHO. Extremely low frequency fields. Environmental Health Criteria Monograph No. 238.
3. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). International Commission on Non-Ionizing Radiation Protection. *Health Phys*. 1998;74:494–522.
4. Wertheimer N, Leeper E. Electrical wiring configurations and childhood cancer. *Am J Epidemiol*. 1979;109:273–284.
5. Kheifets L, Shimkhada R. Childhood leukemia and EMF: review of the epidemiologic evidence. *Bioelectromagnetics*. 2005;26 (Suppl 7):51–59.
6. WHO. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Volume 80. Non-Ionizing Radiation Part I: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields. WHO; 2002.
7. Nagaoka T, Togashi T, Saito K, Takahashi M, Ito K, Watanabe S. An anatomically realistic whole-body pregnant-woman model and specific absorption rates for pregnant-woman exposure to electromagnetic plane waves from 10 MHz to 2 GHz. *Phys Med Biol.* 2007;52:6731–6745.
8. Gabriel S, Lau RW, Gabriel C. The dielectric properties of biological tissues: III. Parametric models for the dielectric spectrum of tissues. *Phys Med Biol*. 1996;41:2271–2293.
9. Christ A, Kainz W, Hahn EG, et al. The Virtual Family—development of surface-based anatomical models of two adults and two children for dosimetric simulations. *Phys Med Biol*. 2010;55:N23–N38.

10. Cech R, Leitgeb N, Pediaditis M. Fetal exposure to low frequency electric and magnetic fields. *Phys Med Biol*. 2007;32:879–888.
11. Davey KR, Cheng CH, Epstein CM. Prediction of magnetically induced electric fields in biological tissue. *IEEE Trans Biomed Eng*. 1991;38:418–422.
12. International Commission on Non-Ionizing Radiation Protection. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). *Health Phys*. 1998;74:494–522.
13. Guidance on determining compliance of exposure to pulsed and complex non-sinusoidal waveforms below 100 kHz with ICNIRP guidelines. *Health Phys*. 2003;84:383–387.
14. Gardner AR, Smith TM, Robert G. Gerber RG, Zabriskie DW. Worst-case approach to validation of operating ranges. In: Kelley BD, Ramelmeier RA, eds. *Validation of Biopharmaceutical Manufacturing Processes*. American Pharmaceutical Society; 1998:69–79.
15. The Council of the European Union. Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) Available at: http://www.anacom.pt/streaming/1999-519-CE.pdf?categoryId = 31136&contentId = 33252&field = ATTACHED_FILE. Accessed January 2, 2012.
16. Swanson J. Power frequency fields in the environment. *IEEE Digest*. 1994;96:1–2.
17. Kaune WT, Miller MC, Hatch EE, et al. Children's exposure to magnetic fields produced by U.S. television sets used for viewing programs and playing video games. *Bioelectromagnetics*. 2000;21:214–227.
18. FMS. The Swedish standards. Available at: http://80.59.18.72/electron/franjagl/sit/apuntes/MPRII-TCO.htm. Accessed January 2, 2012.
19. INTERTEK. TCO certification. Available at: http://www.intertek.com/it-equipment/tco-certification./ Accessed January 2, 2012.
20. Feychting M, Ahlbom A. Magnetic Fields and cancer in children residing near Swedish high-voltage power lines. *Am J Epidemiol.* 1993;138:467–481.
21. Martínez-Búrdalo M, Sanchis A, Martín A, Villar R. Comparison of SAR and induced current densities in adults and children exposed to electromagnetic fields from electronic article surveillance devices. *Phys Med Biol*. 2010;55:1041.
22. Hossam-Eldin A, Youssef K, Karawia H. Investigations of induced currents in human bodies due to exposure to EMF from low voltage appliances. In: *Power Systems Conference, 2006. MEPCON 2006. Eleventh International Middle East*; December 19–21 2006.
23. COMAR. Possible health hazards from exposure to power-frequency electric and magnetic fields—a COMAR Technical Information Statement. *IEEE Eng Med Biol Mag.* 2000;19:131–137.
24. Gurney JG, Mueller BA, Davis S, Schwartz SM, Stevens RJ, Kopecky KJ. Childhood brain tumor occurrence in relation to residential power line configurations, electric heating sources, and electrical appliance use. *Am J Epidemiol.* 1996;143:120–128.
25. Ahlbom A. Electromagnetic fields and childhood cancer. *Lancet*. 1993;343:1295–1296.
26. Possible health hazards from exposure to power-frequency electric and magnetic fields—a COMAR Technical Information Statement. *IEEE Eng Med Biol Mag*. 2000;19:131–137.
27. Gurney JG, Mueller BA, Davis S, Schwartz SM, Stevens RG, Kopecky KJ. Childhood brain tumor occurrence in relation to residential power line configurations, electric heating sources, and electric appliance use. *Am J Epidemiol*. 1996;143:120–128.
28. Linet MS, Hatch EE, Kleinerman RA, et al. Residential exposure to magnetic fields and acute lymphoblastic leukemia in children. *New Engl J Med*. 1997;337:1–7.
29. Wilson BW, Stevens RG, Anderson LE. Neuroendocrine mediated effects of electromagnetic-field exposure: possible role of the pineal gland. *Life Sci*. 1989;45:1319–1332.
30. Ahlbom A, Day N, Feychting M, et al. A pooled analysis of magnetic fields and childhood leukemia. *Br J Cancer*. 2000;83:692–698.
31. Michaelis J, Schutz J, Meinert R, et al. Combined risk estimates for two German population based case-control studies on residential magnetic fields and childhood acute leukemia. *Epidemiology*. 1998;9:92–94.
32. Feychting M, Forssen U, Rutqvist LE, Ahlbom A. Magnetic fields and breast cancer in Swedish adults residing near high-voltage power lines. *Epidemiology*. 1998;9:392–397.
33. Feychting M, Schulgen G, Olsen JH, Ahlbom A. Magnetic fields and childhood cancer-a pooled analysis of two Scandinavian studies. *Eur J Cancer*. 1995;31A:2035–2039.
34. Bellieni CV, Acampa M, Maffei M, et al. Electromagnetic fields produced by incubators influence heart rate variability in newborns. *Arch Dis Child Fetal Neonatal Ed*. 2008;93:F298–F301.
35. Sastre A, Cook MR, Graham C. Nocturnal exposure to intermittent 60 Hz magnetic fields alters human cardiac rhythm. *Bioelectromagnetics*. 1998;19:98–106.
36. Karasek M, Woldanska-Okonska M, Czernicki J, Zylinska K, Swietoslawski J. Chronic exposure to 2.9 mT magnetic field reduces melatonin concentrations in humans. J Pineal Res. 1998;25:240–244.
37. Juutilainen J, Stevens RG, Anderson LE, et al. Nocturnal 6-ydroxymelatonin sulphate excretion in female workers exposed to magnetic fields. *J Pineal Res*. 2000;28:97–104.
38. Liburdy RP, Sloma TR, Sokolic R, Yaswen P. ELF magnetic fields, breast cancer, and melatonin: 60 Hz field block melatonin's oncostatic action on ER+ breast cancer cell proliferation. *J Pineal Res*. 1993;14:89–97.
39. Wilson BW, Wright CW, Morris JA, et al. Effects of electric blanket use on human pineal gland function: a preliminary report. Presented at DOE/EPRI Contractor Review; October 30–November 3, 1988; Phoenix, Arizona.
40. Brent RL. Reproductive and teratologic effects of electromagnetic-fields. *Reprod Toxicol*. 1993;7:535–580.
41. Delpizzo V. Epidemiological studies of work with video display terminals and adverse pregnancy outcomes (1984–1992). *Am J Ind Med*. 1994;26:465–480.
42. Juutilainen J. Effects of low-frequency magnetic fields on embryonic development and pregnancy. *Scand J Work Environ Health*. 1991;17:149–158.
43. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. *Non-ionizing Radiation, Part 1: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields*. Lyon: IARC; 2002
44. Parazzini F. Video display terminal use during pregnancy and reproductive outcome a meta-analysis. *J Epidemiol Community Health*. 1993;47:265–268.
45. Shaw GM. Adverse human reproductive outcomes and electromagnetic fields: a brief summary of the epidemiologic literature. *Bioelectromagnetics*. 2001;22(Suppl 5):5–18.
46. Lindbohm ML, Hietanen M, Kyyrönen P, et al. Magnetic fields of video display terminals and spontaneous abortion. *Am J Epidemiol*. 1992;136:1041–1051.
47. Schnorr T, Grajewski B, Hornung R, et al. Video display terminals and the risk of spontaneous abortion. *N Engl J Med*. 1991;324:727–733.
48. Niederberger C. Increase in scrotal temperature in laptop computer users. *J Urol*. 2005;20:452–455.
49. Straker L, Jones KJ, Miller J. A comparison of the postures assumed when using laptop computers and desktop computers. *Appl Ergon*. 1997;28:263–268.
50. Pfister J, Schönbächler J, Gerber H. Laptop meralgia. *Clin Rheumatol*. 1995;14:593–594.
51. Grossman M. Computer eye strain: how to relieve it. Available at: http://www.visionworksusa.com/computereyestrain.htm. Accessed January 2, 2012.
52. Kheifts LI. The precautionary principle and EMF. Presented at WHO Meeting on EMF Biological Effects and Standards; October 22–24 2001; Seoul, South Korea.
53. Ahlbom A, Bridges J, de Seze R, et al. Possible effects of electromagnetic fields (EMF) on human health—opinion of the scientific committee on emerging and newly identified health risks (SCENIHR). *Toxicology*. 2008;246:248–250.
54. Schüz J, Ahlbom A. Exposure to electromagnetic fields and the risk of childhood leukaemia: a review. *Radiat Prot Dosimetry*. 2008;132:202–211.