Residential exposure from extremely low frequency electromagnetic field (ELF EMF) radiation

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Abstract. ELF EMF radiation have received considerable attention as a potential threat to the safety and health of people living in the vicinity of high voltage transmission lines, electric distribution substations, power stations and even in close proximity to electronics and electrical household appliances. The paper highlights the study on the ELF EMF safety assessment performed at residences comprising of an owner-occupied house, a completed vacant house and an under construction condominium. The objectives of this study were to determine the ELF EMF radiation exposure level from the high voltage transmission line, electric distribution substation, power station and electrical household appliances in the residences, and to assess the potential exposure received by the occupants at the assessed locations. The results were logged in the electric and magnetic field strength with the units of volt per meter (V/m) and milliGauss (mG) respectively. The instrument setup and measurement protocols during the assessment were adopted from standard measurement method and procedures stipulated under the Institute of Electrical and Electronics Engineers (IEEE) Standard. The results were compared with the standards recommended in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines.

1. Introduction
As new applications and products are discovered in parallel to the technological advancement, the exposure to electromagnetic field (EMF) frequencies become increasingly significant. Notwithstanding of the fact that the colossal benefits of using electricity in everyday life are undeniable, the general public has become increasingly concerned about the potential adverse health effects of the exposure to electric and magnetic fields at extremely low frequencies (ELF) range. The exposures are mainly from the use of electrical energy at the power frequencies of 50 Hz.

Due to public concern, a study has been conducted to assess the extremely low frequency (ELF) radiations from the high voltage transmission line, electric distribution substation, power station and electrical household appliances in residences. This paper highlights the study on the ELF EMF safety assessment performed at residences comprising of an owner-occupied house, a completed vacant house and an under construction condominium. The objectives of this study were to determine the ELF EMF radiation exposure level from the high voltage transmission line, electric distribution substation, power station and electrical household appliances in the residences, and to assess the potential exposure received by the occupants at the assessed locations. The results were then compared with the standards recommended in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines.
2. Extremely low frequency (ELF) radiation

Extremely low frequency (ELF) radiation is a type of non-ionizing radiation (NIR) and is positioned at the low-energy end of the electromagnetic spectrum. Electric fields are produced by electric charges. The electric field strength is measured in units of volt per meter (V/m) or kilovolt per meter (kV/m) [1-3]. Magnetic fields are produced by moving charges and thus are proportional to electric currents in a system, irrespective of the voltage used. Their strength is measured in units of Gauss (G) and tesla (T) [1-3]. The maximum permissible exposure limits (PEL) was developed to protect workers and the general population from harmful exposure to ELF EMF. Based on scientific knowledge and information available at the moment, prolonged exposure at or below the levels recommended by these standard guidelines is considered as safe and acceptable for the purpose of protection of human health. The PEL for both workers and members of the public are excerpted from the ICNIRP and World Health Organization (WHO) guidelines. Based on these guidelines, the PEL for public, for electric and magnetic fields of ELF EMFs are 5,000 volt per meter (V/m) and 1000 miliGauss (mG) respectively for the frequency of 50Hz [1-5].

3. Methodology

The instrument setup and measurement protocols during the assessment were adopted from standard measurement method and procedures stipulated under the Institute of Electrical and Electronics Engineers (IEEE) Standard. Free body probes and ground reference instruments are the two methods used for electric and magnetic field measurement [1][4]. In this study, free body probe was used for the measurement of the fields because it does not require a known ground reference for measurements anywhere above the ground [1-4]. Measurements of the field strengths were carried out using PMM instrument Model 8053 with an attached probe Model PMM EHP-50C and EMDEX II attached with the Linear Data Acquisition System (LINDA) measurement wheel. The PMM Instrument Model EHP-50C can measure both electric and magnetic fields simultaneously and the EMDEX II attached with LINDA was used to measure the spatial distribution of the magnetic field. Readings were taken in volt per meter (V/m) for the electric fields and miliGauss (mG) for the magnetic fields.

4. Description of Assessment Site

The study comprised of ELF assessment on 3 different residential and locations specifically in an owner occupied house with primary exposure from high voltage transmission line and electrical appliances, a completed vacant house with primary exposure from electric distribution substation and an under-construction condominium with primary exposure from a power station. The 3 locations were classified as ELF1, ELF2 and ELF3 for the 3 different residential and locations. The layout of the measurement points are shown from figures 1 to 3 respectively.
Figure 1. Layout of the measurement points for location ELF1.

Figure 2. Layout of the measurement points for location ELF2.
5. Results and Discussion
For the first location (ELF1), the electric field strengths were found to vary from 0.100 V/m to 4.844 V/m. The highest averaged level of the electric field strengths was at 4.844 V/m measured at the car porch of the house, point 01. The value was about 0.10% or around 1032 times lower than that of the PEL recommended by ICNIRP for member of public (5000 V/m). The value is significant mainly due to the open space of the car porch without any shielding. In addition, the electrical field strength is influenced by the electrical cables and lighting points installed in that stated area. For areas inside the house, the highest averaged level of the electric field strengths was at 1.438 V/m measured at the first floor hall of the house. The value recorded at the location was about 0.03% or about 3477 times lower than that of the PEL. It should be noted that the electrical field strength value measured inside the house reduced drastically as the field strength from the transmission line was shielded by the walls of the house. For this particular condition, the electric field strength was influenced mostly by the electrical cables and electrical appliances in the house. It should be noted that at the points 03, 09, 12 and 17, the electric field strength was higher due to presence of electrical power points and electronic appliances such as television, desktop computers and in-built electronic alarm system. House wiring can produce electric fields, which are clearly strongest close to the wiring [1-5]. As for other points inside the house, the value remained constant at 0.100 V/m due to shielding by concrete walls, trees and was at a further distance from the internal and external ELF sources [1-5]. The plots of figure 4(a) indicate the electric field strength against distance and the point of measurement and their comparison with the PEL.

Figure 3. Layout of the measurement points for location ELF3.
Figure 4. Plot of ELF (a) electric field strength and (b) magnetic field strength, against distance and point of measurement for location ELF1 and their comparison with the PEL for public.

The averaged magnetic field strengths were found to vary from 0.100 mG to 0.823 mG. The highest averaged value was at 0.823 mG, which was measured outside of the property at the road (Point 02), with the distance from the transmission line at 20 meters. The value was about 0.08% or around 1215 times lower than the PEL recommended by ICNIRP for members of the public (1000 mG). This value is significant as the point of measurement was the nearest compared to the other points. Another significant value was recorded at point 03 with the value recorded was 0.803 mG, which was 57 meters from the transmission line. For this situation, the magnetic field strength was more influenced by the electrical wiring from the auto gate system for the house. Magnetic field strength increases with current, hence, a stronger magnetic field would be detected near an appliance when it runs on high compared when it runs on low [1-5]. Similar with electric field, the magnetic field strength at points 03, 09, 12 and 17 was higher due to presence of electrical power points and electronic appliances. As for other areas inside the house, the averaged magnetic field strength recorded was at 0.100 mG at all the points inside the house. The value recorded inside the house was about 0.01% or about 10,000 times lower than that of the PEL. The plots of figure 4(b) indicate the magnetic field strength against distance and the point of measurement and their comparison with the PEL for public.
The spatial distribution of the magnetic field strengths around the house was captured using the LINDA system. The magnetic field strength from the contour map around the selected area indicated that the highest magnetic field strength was 0.822 mG, recorded along the road near the house, indicated as L.1 in the layout map (Figure 1). The value was at 0.08% of the PEL for public or 1216 times lower compared to the limit. As mentioned earlier, this significant value was due to the close proximity of the measurement area to the transmission line.

For the second location (ELF2), the electric field strengths were found to vary from 0.100 V/m to 0.516 V/m. The highest averaged level of the electric field strengths was at 0.516 V/m measured 1 meter in front of the TNB electrical distribution substation, point 01. The value was about 0.01% or around 9689 times lower than that of the PEL recommended by ICNIRP for members of public (5000 V/m). The value was significant compared to other points mainly due to the close proximity to the stated distribution substation and was without any shielding. The other points at 1 meter distance from the electrical distribution substation were ranging from 0.201 V/m to 0.218 V/m. There was a reduction in value as the sides and back of the substation were shielded with shrubs and trees. The electric field strength reduced drastically as the distance increased from point 5 onwards. The electric field strength inside the house was from the range of 0.130 V/m to 0.163 V/m. The value was low compared to the first location (ELF1) as there were no electrical appliances installed inside the house.

The plots of figure 5(a) indicate the electric field strength against distance and point of measurement and their comparison with the PEL. The averaged magnetic field strengths were found to vary from 0.100 mG to 3.217 mG. The highest averaged value was at 3.217 mG, which was measured at a distance of 1 meter from the front of the TNB electrical distribution substation, point 01. The value is about 0.32% or around 310 times lower than the PEL recommended by ICNIRP for members of the public (1000 mG). This value was significant as the point of measurement was the nearest compared to the other points. Another significant value was recorded from points 02 to 04 which were at 1 meter from the substation. The values ranged from 3.005 mG to 3.155 mG. It should be noted that the trees that are planted at the sides and back of the substation does not provide shielding from the magnetic field and the field strength does not differ much from point 01 which was measured without any shielding. The magnetic field strength reduced drastically as the distance increased from point 5 onwards. The values remained constant at 0.100 mG throughout the points 05 to 13. The plots of figure 5 (b) indicate the magnetic field strength against distance and point of measurement and their comparison with the PEL for public.

The spatial distribution of the magnetic field strengths around the house was captured using the LINDA system. The magnetic field strength from the contour map around the selected area indicated that the highest field strength was at 3.118 mG, recorded around the electrical distribution substation, indicated as L.1 in the layout map (Figure 2). The value was at 0.31% of the PEL for public or 320 times lower compared to the limit. This value was significant compared to other areas due to the close proximity of the measurement area to the substation.
For the third location (ELF3), the electric field strengths were found to vary from 0.022 V/m to 0.250 V/m. The highest averaged level of the electric field strengths was at 0.250 V/m measured 120 meters in front of the TNB power station, point 01. The value is about 0.005% or around 20,000 times lower than that of the PEL recommended by ICNIRP for member of public (5000 V/m). The value is higher compared to other points of measurement mainly due to the close proximity to the stated power station. The electric field strength reduced drastically as the distance increased from point 2 onwards. The electric field strength inside the under-construction condominium was basically ranging from 0.022 V/m to 0.038 V/m. The value was low compared to the first location (ELF1) as there were no electrical wires and appliances installed inside the stated building. The plots of figure 6(a) indicate the electric field strength against distance and point of measurement and their comparison with the PEL for public. The averaged magnetic field strengths were found to vary from 0.100 mG to 0.700 mG. The highest averaged value was at 0.700 mG, which was measured 120 meters in front of the TNB power station, point 01. The value was about 0.07% or around 1428 times lower than the PEL recommended by ICNIRP for members of the public (1000 mG). This value was higher as the point of measurement was the nearest compared to the other points. The magnetic field strength reduced drastically as the distance increased from point 2 onwards. The values remained constant at 0.100 mG.
throughout the points 02 to 10. The plots of figure 6(b) indicate the magnetic field strength against distance and point of measurement and their comparison with the PEL for public.

![Graph showing electric field strength against distance](image)

**Figure 6.** Plot of ELF (a) electric field strength and (b) magnetic field strength against distance and point of measurement for location ELF3 and their comparison with the PEL for public.

The spatial distribution of the magnetic field strengths around the house was captured using the LINDA system. The magnetic field strength from the contour map around the selected area indicated that the highest field strength was 0.184 mG, recorded around the electrical distribution substation, indicated as L.1 in the layout map (Figure 3). The value is 0.02% of the PEL for public or 5434 times lower compared to the limit.

6. Conclusion

The assessment of the electric and magnetic field strength has identified the presence of ELF EMF radiation at the stated locations. The highest measured exposure was at 0.10 % and 0.08 % of the PEL for the electric and magnetic field respectively. The overall results indicated that the electric and magnetic field strengths were very much lower than the maximum PEL recommended by ICNIRP and WHO, hence will not lead to any significant exposure received by members of the public.
7. References

[1] World Health Organization 2007 *Environmental Health Criteria 238, Extremely Low Frequency Fields*.

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