MEASUREMENT OF EXTREMELY LOW FREQUENCY (ELF) MAGNETIC FLUX IN THE VICINITY OF THE OVERHEAD HIGH VOLTAGE TRANSMISSION LINE IN UNIVERSITI KEBANGSAAN MALAYSIA

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ABSTRACT

Electricity has become one of the necessities for human daily activities. The presence of electric current produces electromagnetic fields (EMF) at extremely low frequency (ELF). The problem arises when scientists suggests a possible connection between ELF exposure to human health and safety. Concerned about the safety and health of students and staff, Universiti Kebangsaan Malaysia (UKM) took the initiative to identify possible ELF sources and measure their exposure in various locations around the UKM main campus in Bangi. This paper reports the results obtained from the monitoring of the magnetic flux density at three identified locations in the vicinity of the overhead high-voltage transmission line which transverses the university compound and compare the maximum value results with the exposure limit suggested by the International Committee on Non Ionising Radiation Protection (ICNIRP) for ELF. Measurements were done with an (Extech) Three Axis Electromagnetic Field (EMF) Meter (Model 480826) to determine the magnetic flux density. The lateral profile method was applied as the standard measurement methodology. Results showed that the maximum value of the magnetic flux density was 12.5 mG, which is below the suggested ICNIRP public exposure limit of 1000 mG, or in percentage ratio, 1.25% of ICNIRP public exposure limit. Results from the statistical Kruskal-Wallis test showed that there is a significant difference in the distributions of the magnetic flux densities at the different locations ($P < 0.05$). In conclusion, the measured locations are still safe for people in short-term exposure. However, long-term exposure measurements still need to be done to provide concrete data on the ELF-emission levels in UKM.

ABSTRAK

Tenaga elektrik telah menjadi satu keperluan harian bagi manusia. Kehadiran arus elektrik akan menghasilkan medan elektromagnet (EMF) pada julat frekuensi lampau rendah (ELF). Masalah timbul apabila ahli sains mencadangkan bahawa terdapat hubungan di antara dedahan ELF dengan kesihatan *dan keselamatan manusia. Berdasarkan hubungan itu, Universiti Kebangsaan Malaysia mengambil langkah untuk mengenal pasti sumber dan mengukur dedahan ELF di lokasi-lokasi di kampus utama UKM di Bangi. Kajian ini melaporkan dapatan tinjauan ketumpatan fluks magnet di tiga kawasan berhampiran kabel voltan tinggi laluan atas yang merentasi kawasan UKM dan membandingkan nilai tertinggi yang diperoleh dengan had dedahan ELF yang dicadangkan oleh International Committee on Non Ionising Radiation Protection (ICNIRP). Alat (Extech) Three Axis Electromagnetic Field (EMF) Meter (Model 480826) digunakan untuk mengukur ketumpatan fluks magnet dengan kedudukan titik pengukuran ditentukan melalui kaedah profil sisi. Hasil menunjukkan bahawa nilai tertinggi ketumpatan fluks magnet adalah 12.5 mG, yang masih berada di bawah nilai had dedahan ICNIRP bagi orang awam iaitu 1000 mG, atau dalam nisbah peratus, 1.25% dari had dedahan ICNIRP. Ujian statistik Kruskal-Wallis menunjukkan terdapat perbezaan beerti dalam taburan nilai ketumpatan fluks magnet pada lokasi yang berlainan (P < 0.05). Berdasarkan hasil kajian, boleh disimpulkan bahawa lokasi yang dipantau masih selamat untuk orang awam dalam jangka-masa pendek. Walau bagaimanapun, kajian yang mengambil kira tempoh dedahan dengan masa yang lebih panjang perlu dilakukan untuk memberi maklumat tambahan untuk digunakan sebagai rujukan aras dedahan ELF di kawasan UKM.*

Keywords: Magnetic flux density, extremely low frequency (ELF), overhead high-voltage transmission lines, Kruskal-Wallis Test

INTRODUCTION

In 1979, Wertheimer and Leeper [1] reported the risk of leukemia amongst children living near high-voltage transmission lines. Thus, numerous epidemiological studies had been carried out to show the correlation between extremely low frequency (ELF) exposure and human health [2,3,4,5]. These epidemiological studies motivated several international bodies to develop guidelines and exposure limits for magnetic and electric fields. Some countries such as Taiwan [6,7], Denmark [8], France [9], Switzerland [10] and Canada [11] also carried out surveys on ELF magnetic field exposure among public generally and children particularly.

The International Commission on Non-ionizing Radiation Protection (ICNIRP) has published ELF standard exposure limits which taking into account the induction effects of electric current on the brain, which affects the central nervous system (CNS) and non-CNS or peripheral nervous system (PNS) [12]. Myelinated nerve fibers of the central nervous system (CNS) can be stimulated by electric fields induced during transcranial magnetic stimulation (TMS). In addition, effect on PNS may involve stimulation of muscle tissue such as the cardiac muscle tissue [12]. However, there is still no conclusive evidence, in terms of clinical or biological mechanisms, to support the relation between ELF exposures and human health. In fact, there are a number of epidemiological findings reported as inconsistent and contradictory [12].

World Health Organization (WHO) has divided ELF magnetic field effects toward human in two aspects: short-term and long-term effects. There are established biological effects from acute exposure at high levels (> 100 μT). It can be explained by recognized biophysical mechanisms which cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system. On the long-term effects, much of the scientific research has focused on childhood leukemia. However, the epidemiological evidence is still weak and there is yet to be an accepted biophysical mechanism that would suggest low-level exposures are involved in cancer development. A similar conclusion has also made by the International Agency for Research on Cancer (IARC), which classifies ELF magnetic fields as *possibly carcinogenic to humans,* indicating the limited evidence of carcinogenicity in human and tested animal [13].

As a safety precaution, the Malaysian Communications and Multimedia Commission (MCMC) has adopted the ICNIRP EMF exposure limits and WHO's recommendations for public and workers. Major public concern towards the possible health effects stimulated by ELF exposures convinced the Malaysian government to take several steps. One of them was the 'Surveillance Measurement on Exposures from Base Stations, Power Lines and Distribution Lines' [14]. Therefore, this paper presents the results of ELF monitoring and statistical analysis of the magnetic flux density at three identified locations in the vicinity of the overhead high-voltage transmission lines (OHVT) in Universiti Kebangsaan Malaysia (UKM). The results were compared with the suggested ICNIRP exposure limit.

MATERIALS AND METHOD

Selection of locations in the vicinity of the overhead high-voltage transmission lines

Locations near the 132 kV and 11 kV overhead high-voltage transmission lines located in UKM had been chosen as monitoring sites. After taking into consideration population occupancy, the three most critical monitoring areas were identified. Station D is in the vicinity of the power lines substation from (N02.92121, E101.77660) to (N02.92100, E101.77702), while Station C and Station E are directly under the OHVTs from (N02.92649, E101.77641) to (N02.92658, E101.77689) and (N02.92000, E101.77642) to (N02.92009, E101.77682), respectively. Figure 1 depicts the scheme of measurement location with the aid of the *GPS Geoplanar Online* device.

FIGURE 1. Identified locations of monitoring by GPS Geoplanar online software.

Measurements methods

The *Three Axis Electromagnetic Field (EMF) Meter (Model 480826)* was used to measure the magnetic flux density, with the minimum detection limit of 0.1 mG. The lateral profile method was utilized to determine the exact measurement points [15,16]. Points of measurement were set up by starting at an initial point exactly below the OHVTs or on the side of the power line substation. Then, subsequent measurement points were determined by extending the distance outwards by 2 meters consecutively to the left and right of the initial point, up to a maximum distance of 58 meters, as shown in Figure 2.

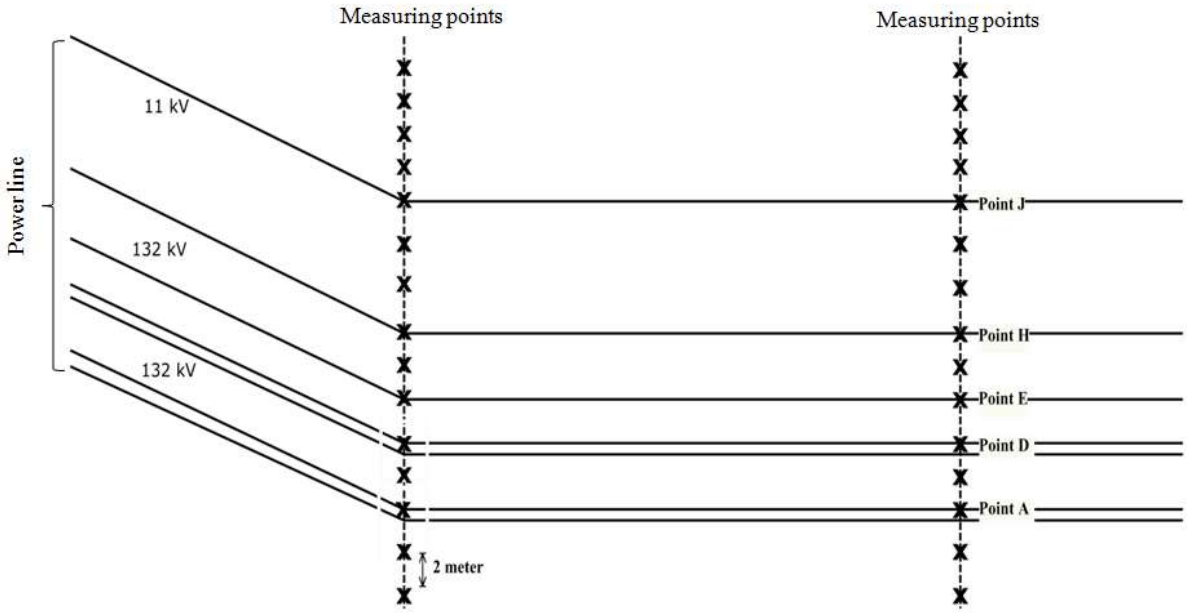

FIGURE 2. Schematic diagram of measurement points below OHVT from above angle

Three maximum readings were taken for every point of measurements at the same time everyday in the morning, noon and evening consecutively for 7 days at each location. The magnetic flux density was measured hourly from 7.00 a.m to 7.00 p.m. For locations in the vicinity of the OHVTs, measurements were taken at Point A till Point J, as shown in Figure 2.

The magnetic flux density was measured in three-dimensional directions of x, y and z simultaneously for every point of measurement. All three readings were then inserted in the formula shown in Figure 3 to calculate the magnitude of the magnetic flux density. To confirm that the direction of measurement was always parallel to the OHVTs, reading B_x was ensured to always be zero. The magnetic flux density data samples were analysed by using the SPSS software package version 19.

$$|\boldsymbol{B}| = \sqrt{\boldsymbol{B_x}^2 + \boldsymbol{B_y}^2 + \boldsymbol{B_z}^2}$$

B = magnetic flux [mGauss]

B_x = magnetic flux on x-dimensional [mGauss]

B_y = magnetic flux on y-dimensional [mGauss]
B_z = magnetic flux on z-dimensional [mGauss]

FIGURE 3. Formula to calculate total magnitude of magnetic field (B).

RESULTS AND DISCUSSION

A total of 1932 readings were collected, with the mean and median values for all three locations of 3.00 ± 2.09 mG and 2.54 mG, respectively. The highest reading ever recorded at all three locations was 12.5 mG. Figure 4 depicts the distribution of the magnetic flux density readings at all locations. The distribution shows that the magnetic flux density is skewed to the left, indicating that a predominant number of the readings were below 3.00 mG, with a standard deviation of ± 2.09 mG. This result displays the variation of the magnetic flux in accord to time and location of measurement, even though the source of the exposure is the same, as no other magnetic flux transmitter exists nearby.

The results also emphasize that the measured magnetic flux densities were still below the exposure limits suggested by the ICNIRP (which is also adopted by the MCMC) of 1000 mG [17]. Therefore, all the measured locations are still safe for people who spend a substantial part of the day exposed to magnetic field at these locations [18]. However, for long-term exposure levels is yet unjustify.

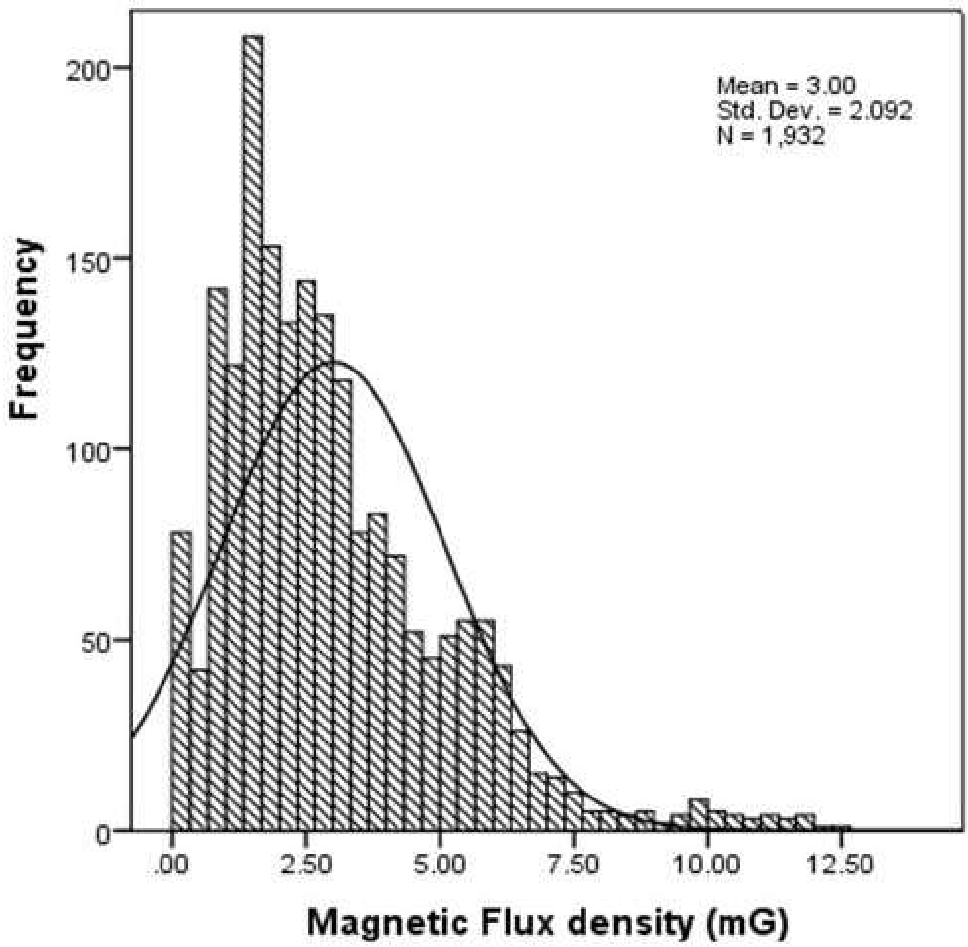

FIGURE 4. Frequency of magnetic flux densities for all locations.

Figure 5 depicts a graph of the varied mean values of magnetic flux densities for each measurement point according to their locations. Such variations may be attributed to the uneven topology of the study locations and non-uniform distance between the cables of the OHVTs. The result also shows that the magnetic flux density values decreases, as the measurement point is farther away from the OHVT. However, the reading from station C shows a dissimilar result, with the mean value of the magnetic flux densities between cables at point 5 and point 14 were escalated and higher compared to the other stations. This may be due to the cancellation process of the magnetic field at this point of measurement being less than at the other points [19,16].

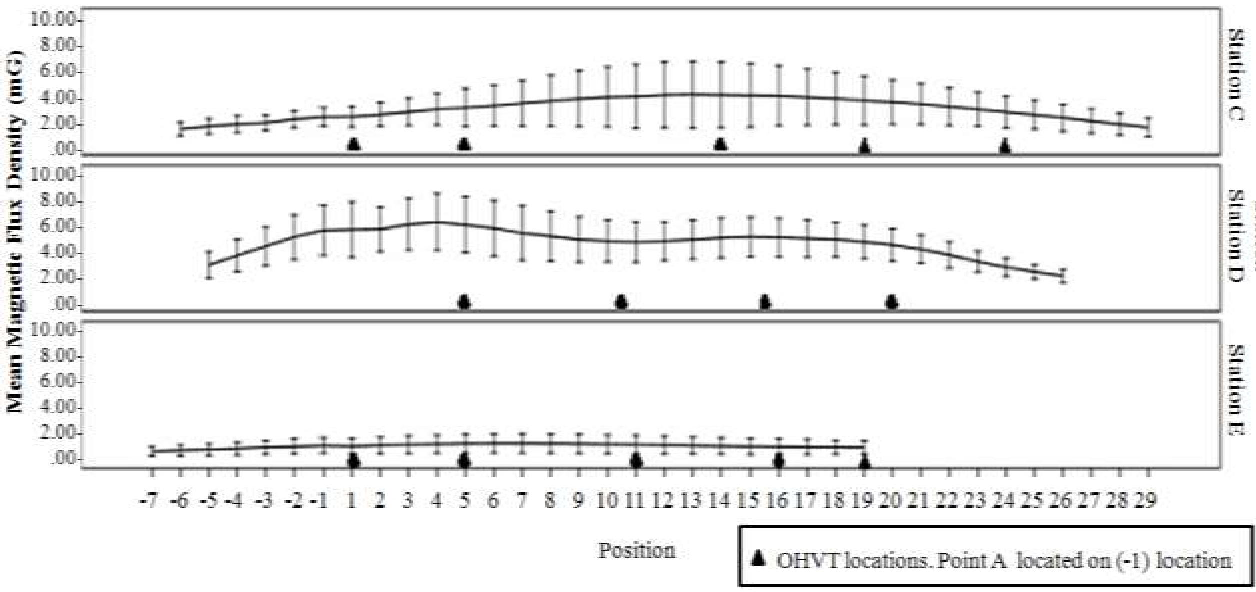

FIGURE 5. Average value of magnetic flux densities for all locations according to point of measurements.

Table 1 depicts the normal distribution test for the magnetic flux according to the respective areas. Results show that the data is not distributed normally (P<0.05) but skewed. Therefore, a non-parameter test must be applied to analyze the statistical data. We chose the Kruskall-Wallis statistical test specifically for the magnetic flux density values under the OHVTs for all three locations, with the results summarized in Table 2. A P value of less than 0.05 ($P < 0.05$) indicates that there is a significant difference in the distribution of the magnetic flux for all locations. The rank order mean provided in Table 3 shows that station D recorded the highest flux densities followed by station C and station E. However, the estimated distance between OHVT and point of measurements A at station D is the shortest followed by station C and E. Thus, it is suggested that the mean value of magnetic flux densities is inversely proportional to the distance between the magnetic flux transmitters and point of measurement. A post-hoc, Mann Whitney test was also done and the results are summarized in Table 4. A P<0.0017 (Bonferoni correction) value indicates that there is a significant difference in the distribution of magnetic flux densities for all locations.

TABLE 1. Normal Distribution test for magnetic field for each location.

Station	**Kolmogorov-Smirnov**		
	Statistics	**df**	**Significance**
C	0.139	188	0.000*
D	0.077	195	0.007*
E	0.152	195	0.000*

TABLE 2. Summary of Kruskal Wallis statistical test results.

Detail	Value

Chi-Square	478.417
df	2
Significance Level	0.000*

* There is a significant difference in the data distribution for all three locations (P<0.05)

TABLE 3. Rank order mean for the given locations and the distance between points of measurements to OHVTs.

Station	Rank order mean	Distance* (m)
Station C	1377.71	23
Station D	2143.49	16
Station E	410.93	27

* Estimated distance from point A to OHVT

TABLE 4. Mann-Whitney test results in median data for the given locations.

Significance level	Station C	Station D	Station E
Station C	--	0.000*	0.000*
Station D	0.000*	--	0.000*
Station E	0.000*	0.000*	--

* There is a significant difference in the median for all locations data (P < 0.017)

These results confirm that there are factors, which influence the magnetic flux densities other than the strength of OHVT's voltage capacity. Qin et al. [20] and Hamza [21] confirmed that the distances between the ELF source and point of measurements are capable of influencing the densities of the magnetic flux. In this study, we observed that the horizontal distances perpendicular to OHVT could also be influenced by several factors. Among them are the topology of the ground, the height of the OHVT, the configuration of the OHVT's towers and the configuration of the OHVTs itself [16].

The Mann-Whitney test result in Table 4 indicates that the value of the magnetic flux densities for every location is not correlated with each other. Thus, the measured densities at station C does not represent densities that was measured at station D and E. However, a conservative approach by measuring the value of the magnetic flux densities at each location, at the shortest distance between points of measurement and the OHVTs can be taken.

CONCLUSION

The magnetic flux densities from OHVTs were measured for all three locations. The maximum magnetic flux density value measured was 12.5 mG, 1.25% from the suggested ICNIRP exposure limits of 1000 mG for general public. Thus, the maximum value of the magnetic flux density was still far below the exposure limits suggested by ICNIRP. Statistical analysis shows that there is a significant difference in the distribution of magnetic flux densities for every location ($p<0.05$). This study also shows that magnetic flux densities vary along the OHVT, even though the magnetic flux is transmitted from the same source.

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