Field Survey of Power Frequency Magnetic Field under Living and Business Environments

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***Abstract*— This paper covers field survey results of power frequency magnetic field to which human body is exposed under living and business environments. Difference in the measured values for different occupations and different positioning of the measuring instrument were examined. Magnetic field produced by power substation facilities measured in a school building, and magnetic field in a hospital were also evaluated. And, an estimation of magnitude of the magnetic field multiplied by exposure duration based on the survey was conducted and then validated.**

Key words: magnetic field, power frequency, living and business environments

I. INTRODUCTION

Social interest in the effect of power frequency magnetic field on human body has been getting higher lately. Because of this, many epidemiological and cytological researches, and tests on living body at laboratory level have been widely reported. However, actual survey results under living and business environments are very limited. This paper covers field survey results of power frequency magnetic field to which human body is exposed under such environments. And, in this paper, magnetic field and magnetic flux density are treated as the same meaning.

II. MEASUREMENT OF POWER FREQUENCY MAGNETIC FIELD UNDER LIVING AND BUSINESS ENVIRONMENTS

A. Measuring method and subjected persons

As a measuring instrument, an EMDEX II, which was as per IEEE standard [1], was utilized so as to obtain the resultant magnetic fields of broadband range (40-800Hz) and harmonic range (100-800Hz). The instrument was generally equipped on a waist of person to be subjected during measurement from the hour of rising in the morning until bedtime. The magnetic field was continuously recorded every 3 seconds during measurement.

As the persons subjected to the measurement, collage students, office workers, electrical maintenance workers, house wives, and medical doctor were examined this time. Their major working or living space was in collage, offices, plants or hospital, and during transportation and in their houses.

B. Difference in magnetic field exposed due to occupation differences

Fig. 1 shows a time lapse of magnetic field (@40-100Hz) measured per day on electrical maintenance worker #1. The highest value of magnetic field of 43.9μT was recorded during field working in a plant. However, it was a very short time exposure of magnetic field and during the rest of time, mostly in office where the value was as low as approx. 0.4μT.

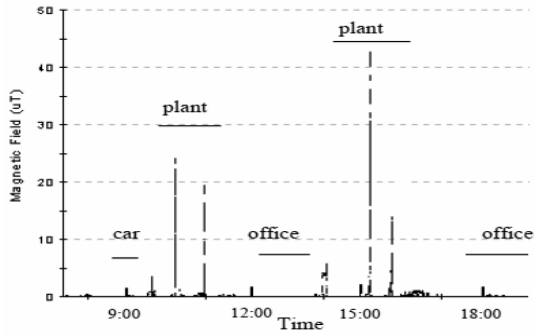

Fig. 1 A time lapse of magnetic field (at 40-100Hz) on electrical maintenance worker #1

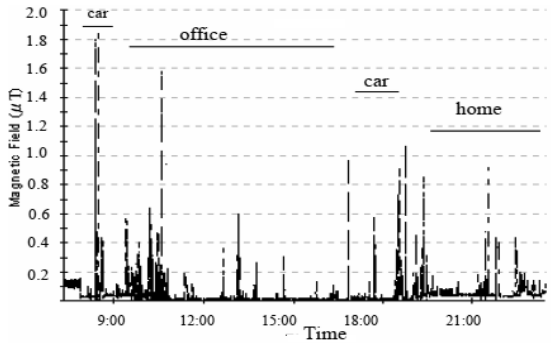

Fig 2 A time lapse of magnetic field (at 40-100Hz) on house wife #1

Fig. 2 indicates a time lapse of magnetic field (@40-100Hz) measured per day on house wife #1, who had a part-

time job as an office clerk. In her case, mostly 1.0μT was recorded including PC work except 1.9μT recorded during commuting by car.

The results on individual persons surveyed are summarized in Table 1. Although electrical maintenance workers had been subjected to higher maximum values than other groups, the average values and the medians were almost identical to others since exposure of such a higher magnetic field even on electrical maintenance workers were very short duration. Generally, magnetic field exposed in houses, during transportation and in plant was 0.3 - 4.8μT, 1.3 - 1.7μT, and 26 - 43.9μT, respectively. For medical doctor, any specific difference was not also seen unlike electrical maintenance workers.

TABLE I
SUMMARY OF MEASUREMENT RESULTS (μT)

Person tested	Min. value	Max. value	Ave.	Standard deviation	Median
S-1	0.001	1.232	0.024	0.022	0.018
S-2	0.001	4.130	0.040	0.131	0.021
S-3	0.001	2.410	0.054	0.109	0.024
S-4	0.001	4.870	0.052	0.096	0.028
OW-1	0.001	12.830	0.059	0.212	0.031
OW-2	0.001	8.550	0.054	0.155	0.023
EM-1	0.001	43.916	0.184	1.101	0.018
EM-2	0.001	31.390	0.408	1.696	0.048
EM-3	0.001	23.190	0.116	0.348	0.049
EM-4	0.001	15.970	0.048	0.221	0.023
EM-5	0.001	11.510	0.111	0.423	0.043
EC-1	0.001	1.3550	0.016	0.027	0.011
HW-1	0.001	1.890	0.042	0.062	0.026
HW-2	0.001	1.306	0.045	0.063	0.032
MD-1	0.001	1.190	0.074	0.082	0.057

Notes)
S: Student, OW: Office worker, EM: Electrical maintenance worker
EC: Electrical construction worker, HW: House wife,
MD: Medical doctor

C. Effect of measuring position

In most cases, a portable instrument has been equipped on a waist of person to be subjected when measuring magnetic field exposed. However, an effect of measuring positions might exist in data to be measured. According to a paper reported in USA [2], it said that the magnetic field on head was 20% higher than that on chest or waist. Since it seemed that head or chest was not suitable position to measure because of inconvenience through daily activity, two instruments were equipped on waist, setting them apart to right and left sides.

Fig. 3 shows a time lapse of magnetic field (@40-100Hz), which was measured per day according to the above mentioned way, on an electrical maintenance worker. For the electrical maintenance worker there was a large difference recognized between right and left sides of waist whereas there was no major difference seen on others. In other words, the difference in magnetic field recorded on the electrical maintenance worker was approx. 85μT as the maximum value between right and left sides. The statistically treated results are summarized in Table 2. As indicated in this table, a difference between electrical workers and others can be recognized not only in the maximum value but also in the average and the standard deviation.

However, all the values obtained here and in Clause II-B including the dada on electrical maintenance workers, are still far below the reference levels of 83μT for residence and 416μT for occupational at 60 Hz as per ICNIRP [3].

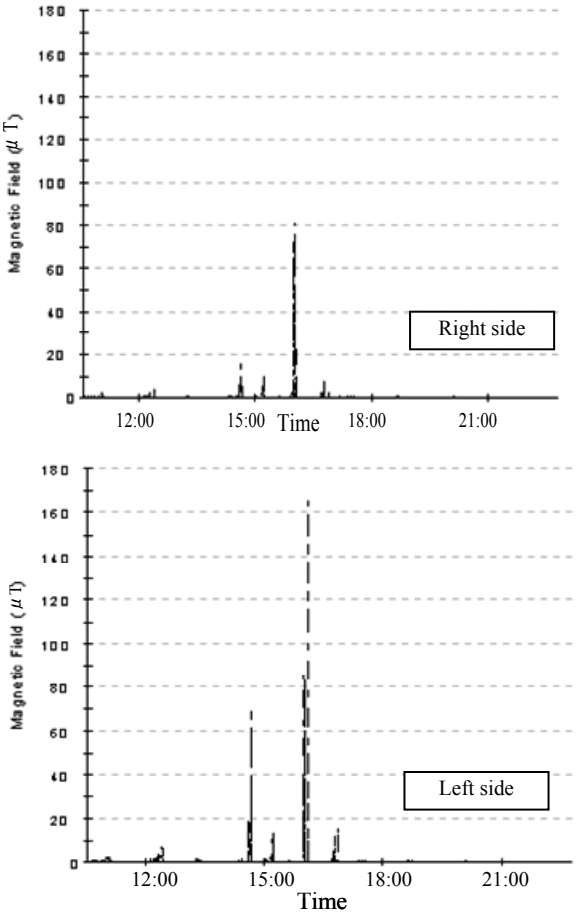

Fig. 3 A time lapse of magnetic field (at 40-100Hz) on electrical maintenance worker #1

TABLE 2
SUMMARY OF MEASUREMENT RESULTS (μT)

Person tested	Position of equipment	Min. value	Max. value	Ave.	Std. dev.	Medi -an
S-5, 1st day	Right side	0.001	1.274	0.038	0.052	0.023
	Left side	0.001	1.122	0.037	0.060	0.026
S-5, 2nd day	Right side	0.001	0.988	0.038	0.051	0.026
	Left side	0.001	1.021	0.038	0.052	0.024
S-5, 3rd day	Right side	0.001	1.267	0.054	0.084	0.024
	Left side	0.001	1.792	0.057	0.076	0.023
EM-1	Right side	0.001	80.80	0.213	1.671	0.036
	Left side	0.001	165.280	0.338	3.248	0.034

Notes)
S : Student, EM : Electrical maintenance worker
Std. dev.: Standard deviation

III. Survey of Power Frequency Magnetic Field in a Power Substation Located in a School

A. Measuring method

Magnetic field was measured in a 1,630kVA indoor substation located in a school building. The measurement was conducted with an EMDEX II in the morning with low demand and in day time with the peak demand.

B. Results

Figs. 4 and 5 show the measuring results in the morning and at the peak time of electricity demand, respectively. The highest magnetic field value was obtained at the peak time, indicating 14.5μT, which was approx.7μT higher than in the morning. And, the magnetic field measured in rooms adjacent to the power station room was 0.1 to 0.7μT, and enough below the value in the power station room.

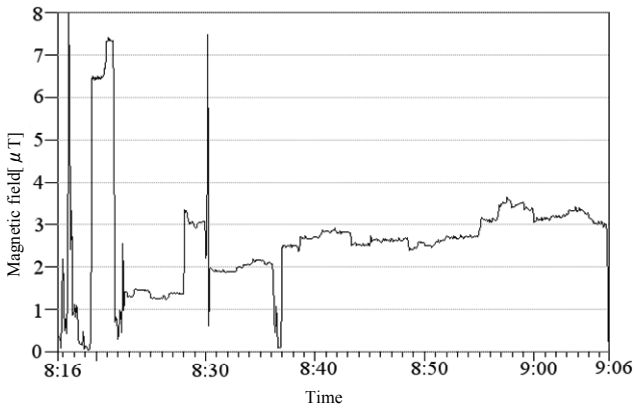

Fig. 4 A time lapse of magnetic field (at 40-800Hz) in power station room (in the morning)

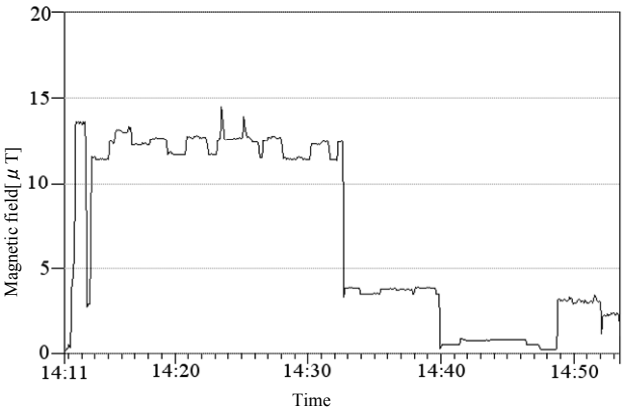

Fig. 5 A time lapse of magnetic field (at 40-800Hz) in power station room (at peak time)

IV. Survey of Power Frequency Magnetic Field in a Hospital

A. Measuring method and subjected persons

Magnetic field in a general hospital was also measured with an EMDEX II [4]. As the persons subjected for this study, medical doctors of roentgenology were chosen. The measurement was conducted during working hours within the hospital only.

B. Results

Fig.6 is a typical example of magnetic field measured in the hospital excluding MRI (Magnetic Resonance Imaging) zone. A comparison of cumulative probability curve of magnetic field between MRI zone and non-MRI zone is indicated in Fig.7. Although magnetic field in MRI zone was relatively higher than that in non-MRI zone, the level was enough lower than the reference level as per ICNIRP [3]. It is thought that this is due to magnetic shield treatment in MRI zone.

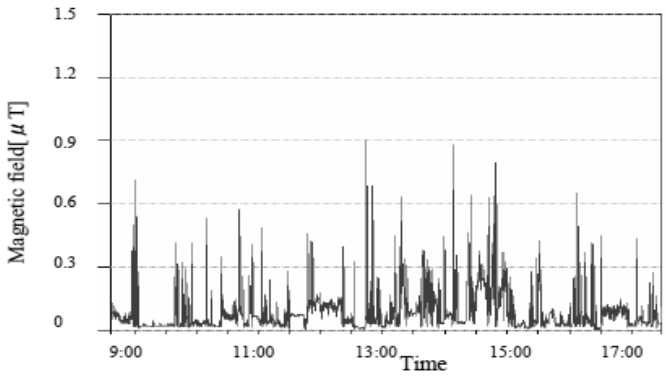

Fig. 6 A typical example of magnetic field (at 40-800Hz) measured excluding MRI zone

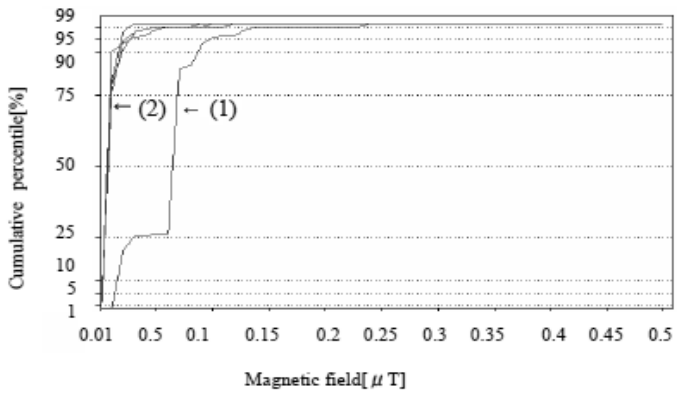

Fig. 7 Cumulative probability curve of magnetic field between MRI and non- MRI zones ((1) : MRI zone, (2) : non-MRI zone)

V. Discussion

A. Estimation of Magnitude of Power Frequency Magnetic Field to Human Body

Through 64 persons x days survey results accumulated, an estimation of magnitude of magnetic field multiplied by exposure duration was conducted. Table 3 shows the statistically treated summary, dividing into location categories having approx. 14,000 to 472,000 measured data each. And, Fig. 8 indicates its cumulative probability curve. It was found that more than 80 % of the measured values

were not greater than 0.2μT from this curve except in train and near appliances.

TABLE 3
SUMMARY OF MEASUREMENT RESULTS (μT)

	Location							
	A	B	C	D	E	F	G	H
Ave	0.026	0.195	0.024	0.298	0.050	0.230	0.087	0.044
Medi -an	0.020	0.104	0.014	0.043	0.023	0.134	0.061	0.018
Max	0.616	11.01	12.32	165.33	1.976	7.637	1.232	7.549
Val	0.000	0.085	0.002	3.123	0.005	0.139	0.008	0.009
Std. dev	0.021	0.291	0.045	1.767	0.073	0.373	0.092	0.097

Notes)
A : in house, B : near appliances, C : in office, D : in plant, E : in building, F : in train, G : in automobile, H : in open field, Val : variance, Std. dev. : standard deviation

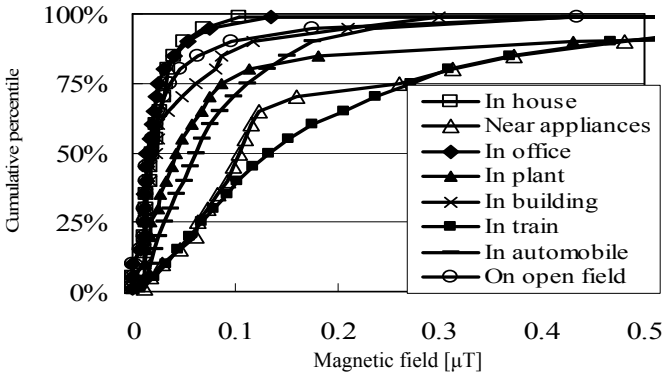

Fig. 8 Cumulative probability curve of magnetic field measured

TABLE 4
ESTIMATED AND MEASURED MAGUNITUDE OF MAGNETIC FIELD (μT-H)

Loca-tion*	Hour **	Estimated magnitude					Measured manuni-tude**
		10% value	25% value	50% value	75% value	100% value	
A	6.61	0.072	0.092	0.134	0.218	0.338	0.232
B	0.24	0.007	0.015	0.025	0.061	0.113	0.020
C	4.55	0.000	0.050	0.065	0.118	0.246	0.098
D	2.30	0.026	0.041	0.098	0.198	0.993	0.059
E	0.09	0.001	0.001	0.002	0.006	0.011	0.002
F	0.81	0.027	0.055	0.109	0.222	0.380	0.073
G	0.50	0.009	0.016	0.031	0.057	0.088	0.051
H	0.90	0.000	0.010	0.016	0.033	0.087	0.026
Total	16.01	0.142	0.280	0.479	0.913	2.256	0.562

Notes)
*: Refer to the notes of Table 3 for abbreviations.
**: A data from additional survey

Furthermore, in order to verify the validity of this curve, an additional survey of 11 persons x days was conducted again. Table 4 shows an example of calculations on the estimated magnitudes, which were obtained by multiplying 10-90 % values from curves in Fig. 8 with the hours from the additional survey, together with the magnitudes measured per locations. It is found that the measured values are within 10-90% range and 25-75% range for in house and other locations, respectively.

And, the same calculations were conducted on all the additional survey data. That is, number of samples matching to ranges of 25-75% and 10-90% probability on each location is summarized in Table 5. As a result, the validity of the estimated magnitudes can be confirmed since most measured magnitudes are within the estimated ranges.

TABLE 5
EVALUATION OF VARIDITY ON ESTIMATED MAGNITUDES

	A	B	C	D	E	F	G	H
No. of Sample	7	9	5	5	8	5	6	9
Range of 25 -75%	4 57.1 %	4 44.4 %	3 60%	2 40. %	5 62.5 %	5 100 %	4 66.7 %	5 55.6 %
Range of 10 -90%	6 85.7 %	8 88.9 %	5 100 %	4 80%	7 87.5 %	5 100 %	6 100 %	8 88.9 %

Note)
Refer to the notes of Table 3 for abbreviations.

VI. CONCLUSION

As the conclusions, followings can be summarized.

- The field survey for power frequency magnetic field exposed to human body was conducted on various occupations under living and business environments. And, effects of occupation and position of measuring instrument were examined.
- As a result, although electrical maintenance workers had been subjected to higher maximum values than other groups, the average values and the medians were almost identical to others since exposure of such a higher magnetic field even on electrical maintenance workers was a very short duration.
- For effect of measuring position, differences were recognized between electrical maintenance worker and others not only in the maximum value but also in the average and the standard deviation.
- However all the values obtained this time, including the dada on electrical maintenance workers were far below the reference levels of 83μT for residence and 416μT for occupational at 60 Hz as per ICNIRP.
- Magnetic field produced by power substation facilities measured in a school building, and magnetic field in a hospital were also evaluated. The results showed minimum exposure equivalent to other locations.
- An estimation of magnitude of the magnetic field multiplied by exposure duration was conducted by analyzing accumulated survey results. And the validity was verified with an additional survey.

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