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Pilot Study of Residential Power Frequency Magnetic Fields in Melbourne (2005)

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NOTICE

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Abstract

Several epidemiological studies have reported an association between prolonged exposure to power frequency magnetic fields greater than 4 mG and an increased risk of childhood leukaemia, although other scientific evidence, including cell and animal studies, does not support this hypothesis. Previous studies have shown that the percentage of children exposed to levels above 4 mG for prolonged periods is approximately 1% in the UK and 3% in the USA but there is little information on magnetic field levels in Australian homes. With a view to conducting a comprehensive study of exposures in Australia, ARPANSA carried out a pilot study of power-frequency magnetic field levels in private residences in the metropolitan area of Melbourne, Australia. The aim of the pilot study was to investigate different issues regarding the implementation of a larger survey such as the sampling and recruitment of homes, suitability of the measurement methodology and possible bias in the selection of homes. Measurements were conducted in 26 homes. Average magnetic field levels were approximately 0.9 mG with 10th and 90th percentiles of 0.2 mG and 5.1 mG, respectively. The pilot survey identified situations where levels were likely to be above 4 mG, including inner suburban homes and homes near high-voltage transmission lines. Three of the residences, approximately 12% (95% CI = 1% - 30%) had levels greater than 4 mG in the nominated youngest child's bedroom. This result was higher than expected although it cannot be taken to be indicative of the true population proportion due to the small sample size.

Contents

1. Introduction

Several epidemiological studies have reported an association between prolonged exposure to power frequency magnetic fields at levels above what is normally encountered (> 4 mG) and an increased risk in childhood leukaemia (Matthes *et al*, 2003). Other scientific evidence, including cell and animal studies, does not support this finding, and many of the epidemiological studies themselves suffer from problems, including inadequate exposure assessment (WHO, 2000). Based on the epidemiological findings of childhood leukaemia, the International Agency for Research on Cancer (IARC) has classified power frequency magnetic fields as a 2B or “possible” carcinogen (IARC, 2002). This possibility has caused considerable controversy in the scientific community and has received great attention in the media and among the general public (d’Amore *et al*, 2001).

The issue of magnetic fields and health has presented significant challenges for those responsible for implementing policy on public health and safety (Nuttall *et al*, 1999). The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) is currently developing a standard for extremely low frequency (ELF) fields that will include protection limits for exposure to power-frequency magnetic fields. Although current epidemiological evidence does not provide a sound basis for the derivation of exposure limits, a precautionary strategy could be considered (Grandolfo and Vecchia, 1996). According to such a precautionary approach, it is important to have knowledge of the exposure potentially related to the possible risk. That is, one should know what proportion of the population, and in particular children, are exposed to time-averaged levels above 4 mG.

Previous studies have shown that the percentage of children exposed to levels above 4 mG for prolonged periods is approximately 1% in the UK (Ahlbom *et al*, 2000) and 3% in the USA (Greenland *et al*, 2000) (differences in power-supply voltages, distribution methods and house wiring practices, together with differences in housing types make variation in exposures from one country to another very likely). Magnetic field levels within the home are large contributors to children’s overall exposure. However, there is little information available on power-frequency magnetic fields in residences in Australia (Loy, 2000). With a view to conducting a comprehensive study of exposures in Australia, ARPANSA conducted a pilot study of power-frequency magnetic field levels in private residences in the metropolitan area of Melbourne, Victoria, Australia. The pilot study was intended to:

- investigate different methods of residence sampling and recruitment of willing householders;
- examine the issue of self-selection and other biases in the selection and recruitment of homes;
- determine a method for the measurement of residential power-frequency magnetic field levels;
- obtain preliminary results on the distribution of average magnetic fields in homes and the proportion of homes with average fields exceeding 4 mG.

It is important to note that the pilot study did not address the issue of whether magnetic fields are associated with any health effects.

2. Methods

2.1 Sample size

The sample size required for a full survey was calculated to be approximately 300 homes (Appendix I). This is the minimum number of homes that would provide the survey with enough statistical power to achieve its objectives. For the pilot study, a sample size of 30 residences, or 10% of the sample size of a full survey, was chosen.

2.2 Sampling and recruitment

Three methods of sampling and recruitment were investigated with the aim of recruiting 10 homes for each method:

2.2.1 *Area-based sampling with face-to-face recruitment*[1]

This sampling method followed a three stage procedure. In the first stage, 10 suburbs[2] from the Melbourne metropolitan area were randomly chosen. In the second stage, a street was randomly chosen in each suburb. In the final stage, a residence was randomly chosen in each of the 10 streets. Recruitment of the houses was performed by a team comprising a male and a female staff member from ARPANSA over two weekend days in order to increase the likelihood of the residents being at home. If a resident declined to participate then the residents in successive houses in ascending street number order were approached. In two cases, residents later declined to participate and this prompted a third weekend day of recruitment.

2.2.2 *Telephone directory sampling with mail-out recruitment*[3]

A selection of 100 addresses was made randomly from the 2003/2004 White Pages (Sensis Pty Ltd) and letters were posted to these inviting the resident to participate in the pilot survey. Reminder letters were sent 2 weeks from the date of the original letters to addresses from which no response to the original invitation had been received. Although only 10 homes were required, it was decided to include all of the homes that chose to participate.

2.2.3 *Random-digit-dialling sampling and recruitment*[4]

This sampling method followed a two stage procedure. In the first stage, 10 suburbs from the Melbourne metropolitan area were randomly chosen. In the second stage, 50 telephone numbers for each suburb were randomly chosen. Numbers were called at various times between 9am to 6pm to account for people being at home at different times.

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[1] The sampling method used was simple random sampling without replacement.
[2] As defined by the Australian Bureau of Statistics in "Statistical Geography: Volume 1 - Australian Standard Geographical Classification", 2003.
[3] The sampling method used was systematic sampling.
[4] The sampling method used was simple random sampling without replacement.

2.3 Measurements

The residences were visited for measurements between 18 June and 16 August 2004. All measurements were performed by appointment during weekdays by a technically trained ARPANSA staff member, who happened to be male, accompanied by a female staff member for assistance and to help unaccompanied female householders feel more at ease. Power-frequency magnetic fields were assessed by conducting spot-measurements and by logging two specific locations over approximately 24 hours. The spot measurements were made under low and high power conditions[5] at several locations throughout the house and surrounding property at the time of the first visit. Long term averages over approximately 24 hours, based on single measurements recorded every 30 seconds, were taken in the living room and the youngest child's bedroom (or nominated substitute). Fields at distances of 30 cm, 1 m and 2 m from selected appliances were also measured. Magnetic fields were measured using an EMDEX II triaxial meter. The meter measured the root mean square (rms) magnetic field intensity in each of three orthogonal directions and recorded the resultant magnitude. . The protocol for the measurements generally followed the methodology described by Karipidis (2002). It is important to note that for the 24-hour measurements the meters were placed at convenient locations away from electrical sources and not on 1-metre stands in the middle of rooms as described by Karipidis (2002). In addition to the measurements, a record was made of the existence of any electrical facilities (power lines, transformers and/or substations) in the vicinity of each residence.

2.4 Communication Strategy

Following recruitment, all residents were provided with literature outlining the state of scientific knowledge of the possible health effects of magnetic fields[6]. All spot and appliance field measurements were provided[7] to the resident on the day the measurements were performed. Whenever measurements indicated widespread levels above 4 mG, the ARPANSA officer explained the likely reasons behind these levels and provided advice on ways of reducing the resident's exposure, where possible. At a later date, the residents received a measurement report which included the 24-hour measurements as well as an optional questionnaire. The questionnaire asked questions about the execution of the survey as well as the resident's views on the issue of magnetic fields and health.

2.5 Measurements to Estimate Self-Selection Bias

In order to investigate the issue of self-selection bias, a random sample of homes that declined to participate from the mail-out recruitment was chosen. The number of homes was equal to the number of homes recruited by this method that did participate. Measurements were performed at the front-gate, without entering the property, and surrounding features, such as the existence of power lines and substations, were noted. A comparison of measurements at the front gate was then made between the homes surveyed and those that refused.

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[5] The low and high power conditions are obtained by turning off or on most of the electric-power-consuming systems including lights and electrical appliances.

[6] Information on magnetic fields and health can be found on http://www.arpansa.gov.au/rad_health.htm.

[7] All information collected in the pilot study is subject to the provisions of the *Privacy Act 1988*.

2.6 Data Analysis

The results were analysed using Excel and SPSS software.

2.6.1 Descriptive statistics

The measurements were summarised with the following statistics: mean, median, standard deviation (SD), minimum value (min) and maximum value (max). In order to estimate a more representative exposure of a hypothetical child resident, descriptive statistics were also calculated for the time periods between 3pm-10pm for the living room and 10pm-8am for the child's bedroom.

2.6.2 Fields above 4 mG

Although the limited statistical power of the pilot study was recognized, the distribution of homes with time-averaged fields above 4 mG was characterized by calculating the percentage of such homes. In addition, the 95% confidence interval (CI) for the percentage of homes above 4 mG was calculated using the Wald method (Newcombe, 1998). Furthermore, the percentage of time, based on individual 30 second measurements, for which the fields were above 4 mG, was calculated for the living room and child's bedroom of each house.

2.6.3 Measurement comparisons

Low power spot measurements were compared with high power spot measurements for all the measurement locations using the paired-samples T test[8]. Twenty-four-hour measurements were compared with spot measurements for the living room and the child's bedroom using the Wilcoxon Signed Rank test [9]. The measurements at the front gate of the homes successfully recruited by mail were compared with those of the sample of homes that refused using the Mann-Whitney test[10]. Linear relationships between different measurements were investigated using Spearman's (ρ) correlation coefficient[11].

3. Results

3.1 Recruitment of homes

3.1.1 Area-based sampling with face-to-face recruitment

A total of 59 residences were visited with 9 (15.2%) agreeing to participate in the survey. Of the 50 non-acceptances, 36 were due to the residents not answering the door, so the participation rate when actually speaking to someone was 38.5%.

[8] The paired-samples T test is used when the differences between two sets of related data follows a normal distribution.
[9] The Wilcoxon Signed Rank test is used when comparing two sets of related data that follow a log-normal distribution.
[10] The Mann-Whitney test is used when comparing two sets of independent data that follow a log-normal distribution.
[11] Spearman's (ρ) coefficient is used when investigating the linear relationship between data that follow a log-normal distribution.

3.1.2 Telephone directory sampling with mail-out recruitment

Of the 100 first-contact letters that were sent, 23 replies were received; 15 accepting and 8 refusing. Six letters were returned unopened, due possibly to incorrect or insufficient address information. Following the reminder letters, there were 19 further replies; 6 wishing to participate and 13 declining. Out of the total of 21 that indicated they wished to participate, 4 changed their mind at a later stage, leaving a total of 17 participating homes. The overall recruitment success was therefore 17%.

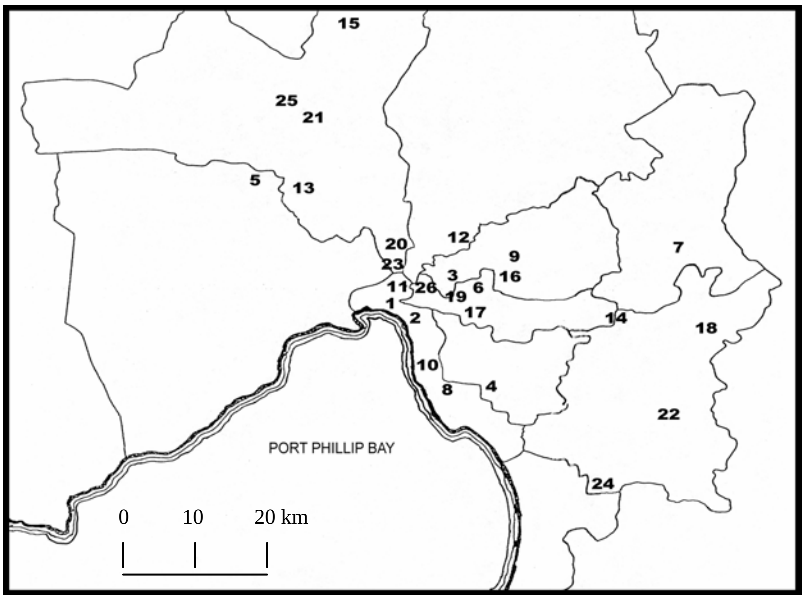
3.1.3 Random-digit-dialing sampling and recruitment

Initially 25 telephone numbers for one suburb were called, several times if necessary, without any acceptance. A further 15 numbers from another suburb were called also without success. This recruitment method was subsequently abandoned.

3.2 Homes that were surveyed

A total of 26 homes were surveyed in the suburbs: (1) Port Melbourne, (2) Elwood, (3) Canterbury, (4) East Bentleigh, (5) Sydenham, (6) Surrey Hills, (7) Mooroolbark, (8) Highett, (9) East Doncaster, (10) North Brighton, (11) Richmond, (12) West Heidelberg, (13) Kings Park, (14) Wantirna, (15) Mickleham, (16) Ormond, (17) Glen Iris, (18) Tecoma, (19) East Malvern, (20) Brunswick, (21) Coolaroo, (22) Doveton, (23) Parkville, (24) North Narre Warren, (25) Roxburgh Park, (26) Camberwell. Their locations are shown in Figure 1.

Figure 1. Location of the 26 residences in the Melbourne metropolitan area



3.3 Measurements

3.3.1 Spot measurements

The results of the spot measurements taken in the 26 homes under low and high power condition are given in Appendix II. The magnetic field levels measured under the high power condition were not markedly higher than those measured under the low power condition (mean difference between low and high power measurements at all locations was 0.17 mG, $p<0.005$) and were occasionally lower, although this was probably due to the second measurement being taken at a slightly different location. The measurements showed a log normal distribution, as expected (Matthes *et al*, 2003). Table 1 shows the descriptive statistics for selected locations under the low power condition as well as the percentage of homes for which each level exceeded 4 mG (and 95% CI).

Table 1. Descriptive statistics for magnetic field spot measurements at selected locations in the 26 homes under low power condition as well as the percentage of homes for which the level exceeded 4 mG (and 95% CI) at that location.

Location	No.	mean (mG)	median (mG)	SD (mG)	min (mG)	max (mG)	% of homes above 4 mG	95% CI (%)
Front gate	25	3.34	2.0	3.19	0.20	11.6	28	14 – 48
Front yard	23	1.83	1.40	1.61	0.20	6.9	9	1 – 28
Front door	26	1.58	0.95	2.18	0.20	11.2	8	1 – 26
Living room	26	1.22	0.80	1.50	0.10	5.8	8	1 – 26
Kitchen	26	1.07	0.60	1.23	0.10	5.0	4	<.01 – 21
Master bedroom	26	1.39	0.75	1.94	0.10	9.2	12	3 – 30
Child's bedroom	26	1.51	0.80	2.12	0.10	9.9	12	3 – 30
Study	14	1.47	0.70	1.97	0.10	5.9	14	3 – 42
Back yard	25	0.97	0.50	1.40	0.10	6.8	4	<.01 – 21

Table 1 shows that the median level for each location was below 1 mG apart from the front gate and the front yard. The higher values at the front of the houses are to be expected since these areas are generally closest to the distribution lines that run outside most houses. Amongst the spot measurements there were 4 homes with fields greater than 4 mG in several locations or throughout the house. These included an inner suburban house (Richmond) with distribution wiring close to the front of the house, a house with a 3-phase service drop adjacent to the child's bedroom (Narre Warren), a house near a high voltage transmission line (Roxburgh Park) and a house for which the source was not obvious (Kings Park). In this latter case, the uniform trend within the house suggested that the normal distribution line at the front of the house was carrying an unusually high current. Details on these homes are presented in Appendix III.

3.3.2 Appliance fields

Magnetic fields from appliances generally showed great variation from house to house for the same sort of appliance. The fields from each type of appliance were typically normally distributed (apart from the hair dryers) with microwave ovens having the highest levels. Table 2 shows descriptive statistics for selected appliances.

Table 2. Descriptive statistics for magnetic fields from selected appliances measured at a nominal 30 cm separation.

Appliance	No.	mean (mG)	median (mG)	SD (mG)	min (mG)	max (mG)
television	26	10.1	9.9	5.7	1.4	25.4
microwave oven	22	97.1	106.0	54.5	7.7	188.0
kettle	22	5.3	4.7	3.2	1.7	13.8
clock radio	22	4.8	4.5	2.5	1.4	9.6
hair dryer	9	25.3	9.5	31.8	2.6	99.0
computer	17	2.3	2.3	1.2	0.6	5.2

3.3.3 Twenty-four-hour measurements

Figure 2 shows examples of the temporal variation of the magnetic field level and the distribution of the measured levels taken at 30 sec intervals over 24 hours for the living rooms of the houses in a) Richmond and b) Kings Park, and the child's bedroom in c) Narre Warren and d) Roxburgh Park. The individual 30 sec measurements collected over 24 hours for all of the 26 homes in the pilot study were similar to these examples and, in general, normally distributed so the mean is an appropriate measure for the average magnetic field over that period. The 24-hour means for the living room and the child's bedroom, the means for the living room over the 3pm-10pm period and the means for the child's bedroom over the 10pm-8am period for the 26 homes, are shown in Appendix IV. Also shown in Appendix IV are the percentages of time that the levels exceeded 4 mG. In 3 homes the living rooms had a mean magnetic field level above 4 mG (Richmond, Kings Park, Roxburgh Park). In 3 homes, the child's bedroom had a mean level above 4 mG (Richmond, Narre Warren, Roxburgh Park). In 2 homes the mean levels exceeded 4 mG in both the rooms. The descriptive statistics of all the means are shown on Table 3. Also shown in Table 3 is the percentage of homes with the 24-hour mean above the 4 mG level (and 95% CI).

Table 3. Descriptive statistics for the living room and child's bedroom 24-hour measurements as well as the 3pm-10pm and 10pm-8am time periods for the living room and the child's bedroom, respectively.

	mean (mG)	**median (mG)**	**SD (mG)**	**min (mG)**	**max (mG)**	**% of homes with mean above 4mG**	**95% CI (%)**
Living room 24 hours	1.47	0.94	1.57	0.21	6.09	12	3 - 30
Living room 3pm-10pm	1.68	1.13	1.69	0.22	6.06	12	3 - 30
Child's bedroom 24 hours	1.74	1.10	2.32	0.12	9.71	12	3 - 30
Child's bedroom 10pm-8am	1.61	0.86	2.18	0.11	8.02	12	3 - 30

The difference between the spot measurement medians and the medians of the 24-hour measurement means for the living room and the child's bedroom is shown in Table 4. The spot measurements generally underestimated the 24-hour measurements slightly with a statistically significant[12] median difference of 0.15 mG for the living room and 0.13 mG for the child's bedroom although the differences in the two measurement types were generally not large.

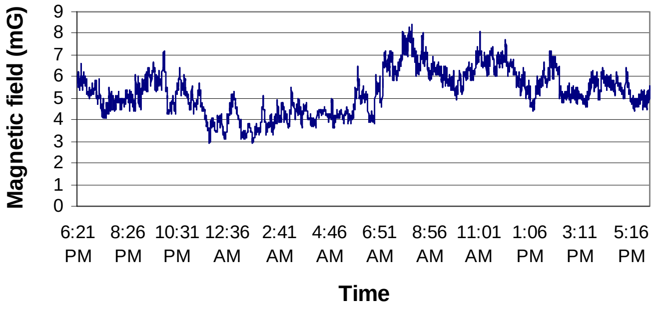
Table 4. Comparison of the median of the 24-hour means with the median of the spot measurements for the living room and the child's bedroom of the 26 homes.

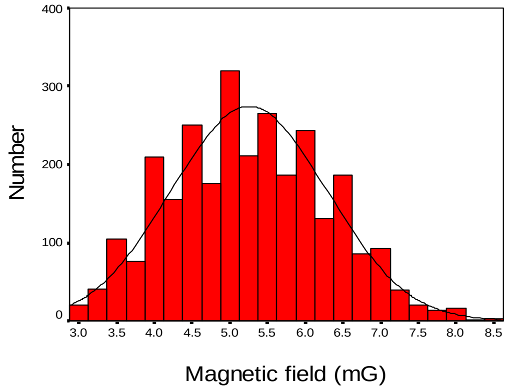
	Median magnetic field(mG)	**min (mG)**	**max (mG)**	**median of differences (mG)**
Living room 24h	0.94	0.21	6.09	0.15
Living room Spot measurement	0.80	0.10	5.8	(p = 0.012)
Child's bedroom 24h	1.10	0.12	9.71	0.12
Child's bedroom spot measurement	0.80	0.20	9.90	(p = 0.042)

[12] Statistical significance in terms of the pilot population and not the population of Melbourne homes in general.

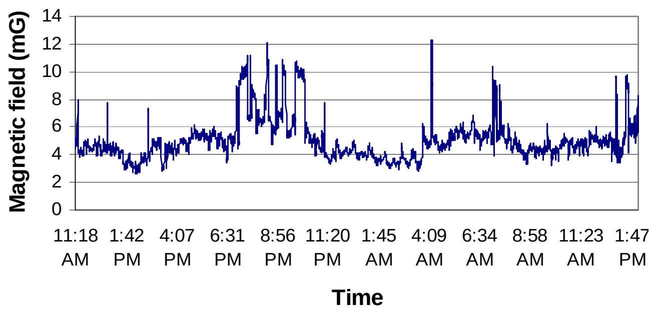
Figure 2. Temporal variation of the magnetic field level taken at 30 sec intervals over 24 hours for the living room of the houses in a) Richmond and b) Kings Park, and the child's bedroom in c) Narre Warren and d) Roxburgh Park as well as the distribution of the measured levels.

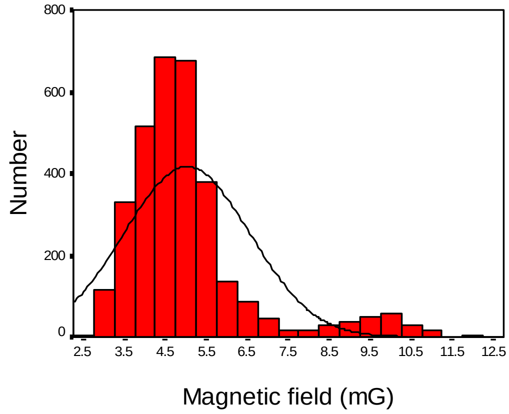
a) Richmond



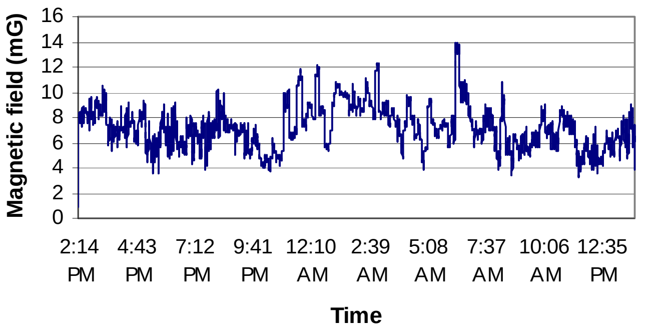


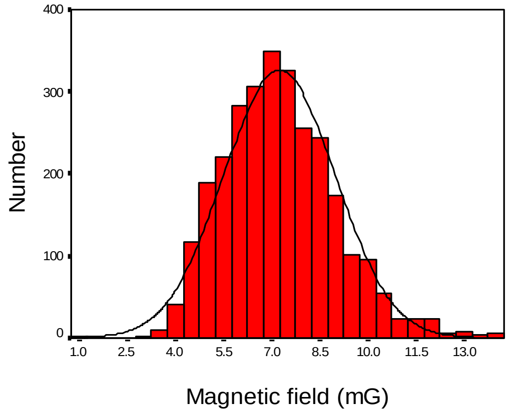
b) Kings Park



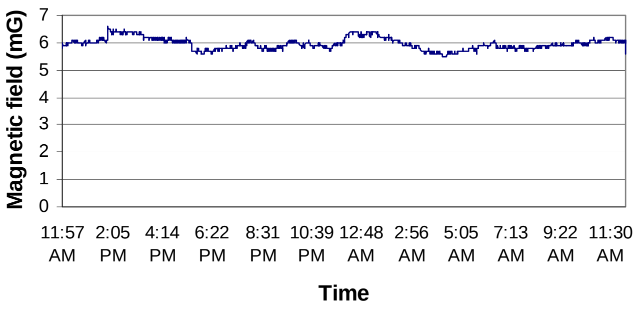


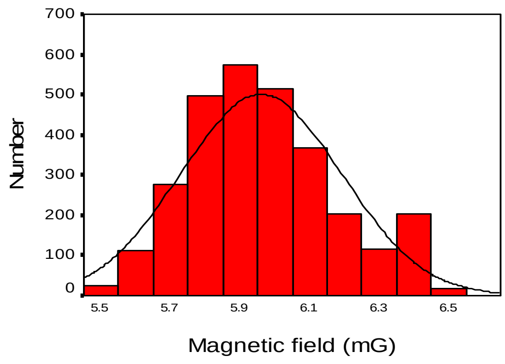
c) Narre Warren





d) Roxburgh Park





3.3.4 Measurements at front-gate of non-participating homes

The front gate measurements for the random sample of 17 homes that declined to participate following recruitment by mail are shown in Table 5.

Table 5. Front gate measurements from a random sample of mail-out recruitment homes that declined to participate.

Suburb	Time of measurement	Magnetic field (mG)
East Doncaster	10:15	0.9
East Doncaster	10:30	4.4
Burwood	10:50	1.2
Glen Waverley	11:10	1.3
Berwick	11:10	2.4
Boronia	13:50	0.8
Lilydale	14:20	0.5
Research	14:55	0.2
Diamond Creek	15:10	0.3
Mill Park	15:40	1.1
St Albans	16:10	2.5
Bundoora	16:40	1.1
East St Kilda	11:40	8.1
Prahran	12:30	9.1
East Malvern	13:15	2.2
Kew	14:00	0.8
Richmond	14:15	1.3

The front gate measurements for mail-out homes that did not participate were similar to mail-out homes that did take part in the survey. The descriptive statistics of the two are compared in Table 5. Although there was a difference of 0.8 mG in the medians of the two samples the difference was not statistically significant (p=0.39).

Table 6. Descriptive statistics for the front gate measurements of the non-participation homes compared to the mail-out homes that did participate in the survey.

	Homes not participating	Participating homes
Mean	2.25	2.78
median	1.20	2.0
SD	2.60	2.56
min	0.20	0.20
max	9.10	9.50

3.4 Correlations

Table 7 shows the correlation matrix for selected measurements in the study. The measurements in the living room were highly correlated with all other measurements, including the 24-hour and 3pm-10pm averages and low and high power spot measurements. For the child's bedroom there was a strong correlation between the 24-hour and 3pm-10pm averages. The low and high power spot measurements in the child's bedroom were also highly correlated. The correlation between the low power and high power spot measurements was high for both the living room and the child's bedroom and, although not shown in Table 7, low and high power spot measurements were highly correlated for every room measured in all the residences.

Table 7. Correlation matrix of selected measurements in the study.

	Living 24h (median)	**Living 3-10 (median)**	**Child's Bed 24h (median)**	**Child's Bed 10-8 (median)**	**Living low-power (spot)**	**Living high-power (spot)**	**Child'sBed low-power (spot)**	**Child'sBed high-power (spot)**	**Front Gate (spot)**
Living 24h (median)	1								
Living 3-10 (median)	0.99	1							
Child's Bed 24h (median)	0.85	0.84	1						
Child's Bed 10-8 (median)	0.83	0.83	0.99	1					
Living low-power (spot)	0.81	0.84	0.82	0.81	1				
Living high-power (spot)	0.87	0.88	0.84	0.82	0.98	1			
ChildBed low-power (spot)	0.75	0.77	0.76	0.77	0.97	0.88	1		
ChildBed high-power (spot)	0.66	0.68	0.64	0.64	0.93	0.84	0.84	1	
Front Gate (spot)	0.40	0.40	0.56	0.53	0.64	0.61	0.62	0.58	1

3.5 Questionnaire

Out of the 26 questionnaires that were sent out together with the measurement report, 11 were completed and returned. The results of the questionnaire are shown on Table 6.

Table 8. Questionnaire results.

QUESTION	**RESPONSE**		
1) Was the issue of magnetic fields and health of any concern to you prior to this survey?	No it wasn't 5 (45%)	I've never thought about it 2 (18%)	Yes it was 4 (36%)
2) How intrusive did you find the survey?	Not at all 10 (91%)	Slightly intrusive 1 (9%)	Very intrusive 0
3) How would you describe the manner of the ARPANSA staff members conducting the survey?	Discourteous 0	Did not notice 0	Courteous 11 (100%)
4) Was the procedure of the survey sufficiently explained?	No it wasn't 0	Not entirely 1 (9%)	Yes it was 10 (91%)
5) Were you provided with adequate information on the issue of magnetic fields and health?	No I wasn't 1 (9%)	Not entirely 0	Yes I was 10 (91%)

4. Discussion

4.1 Sampling, recruitment and bias

Area-based sampling with face-to-face recruitment has been shown in other surveys (Magnani, 1997) to produce the most accurate results in terms of bias when sampling homes. Studies have also shown this method of recruiting to have higher participation rates. In the pilot study the participation rate for this recruitment method was 15% for all of the homes surveyed although many residents were not at home during the recruitment. The participation rate was 39% when a resident was actually spoken to. Another advantage of this recruitment method was the fact that the field officers were able to better explain the project and could also answer any questions that the resident may have had. The main disadvantage of this method is that it is much more costly than the other recruitment methods. There are costs involved in time and travel to reach the homes. The cost of this method was more than double that of the mail-out recruitment in the pilot study. Another disadvantage of this method might be that some residents may decline to participate due to the recruiter's appearance or demeanor. While obviously very difficult to detect, there was no obvious sign of this effect during the pilot study.

Telephone directory sampling with recruitment by mail requires less time, effort and resources than face-to-face recruitment and therefore has a lower cost. Previous studies (Magnani, 1997) have cited this method as having a lower participation rate than face-to-face recruitment although this wasn't shown in the pilot study. The participation rate in the pilot study for recruitment by mail was 17%. An advantage is that this method does not depend on the recruiter's skill to recruit homes. Some residents may feel more comfortable not speaking to a person either face-to-face or via the telephone. The main disadvantage of this method is that omission of telephone numbers (silent numbers) from the White Pages coupled with the incomplete population coverage of telephones, results in possibly important sub-groups of the population being omitted and increases the likelihood of bias.

Some of the potential bias of telephone directory sampling should be eliminated by means of random-digit-dialing, due to its random nature and the fact that, theoretically, every person with a telephone has a chance of being selected. However, the participation rate for random-digit-dialing in the pilot study was poor with all residents from the 40 numbers that were called declining to participate. This sampling method was subsequently abandoned.

A very important potential source of bias, which is relevant to all sampling and recruitment methods, is self-selection bias. Residents may choose to participate because they live in the vicinity of highly visible electrical installations such as power lines, transformers and substations. This would clearly bias the sample of homes chosen and probably increase the average fields observed. In an attempt to quantify this source of bias, measurements were taken at the front-gates of a random sample of homes from the mail-out that declined to participate. These results were compared with similar measurements from the houses from the mail-out that did participate. The two sets of measurements had similar descriptive statistics and although there was a difference of 0.8 mG in the medians of the two samples the difference was not statistically significant ($p=0.39$). It is interesting to note that two of the homes from the sample of refusals had visible transmission lines within the vicinity of the residence (one at 50 m and the other at 200 m). This would suggest that although the existence of electrical facilities may have urged some residents to participate, this was not universal.

One problem that was encountered in the recruitment of homes was that of withdrawals. There were 6 residents who agreed to participate and then changed their mind at a later date. The possibility of withdrawals will have to be considered in the design of a larger survey, particularly given the likelihood of longer time periods being involved.

4.2 Measurements

In the pilot study, power frequency magnetic fields were assessed by conducting spot-measurements and long term (24-hour) measurements as well as performing measurements near various appliances. The small sample size (26 homes) of the pilot study means that the measurements were not representative of the true population. However, the pilot study has answered many questions about methodology and the protocol described by Karipidis (2002), with minor modifications, was shown to be suitable for a larger survey.

The spot measurements, when taken together, followed a log-normal distribution. There was no great difference between low and high power condition measurements. The median for the spot measurements was below 1 mG for most locations (0.8 mG for both the living room and the child's bedroom). There were 2 homes with fields greater than 4mG throughout the house. Three of the homes or approximately 12% (95% CI = 1% - 30%) had fields above 4 mG in areas where children are likely to spend large amounts of time (ie their bedroom and the living room).

The 24-hour measurements for each house were, in general, normally distributed whereas the 24-hour means for the 26 homes followed a log-normal distribution as seen by the distribution histograms. The medians of the 24-hour means for the living room and the child's bedroom were 0.94 and 1.1 mG, respectively. The medians of the 24-hour means for the living room and the child's bedroom were slightly higher than the spot measurements means with a statistically significant difference of 0.15 mG for the living room and 0.13 mG for the child's bedroom although the differences in the two measurement types were generally not large (Spearman's ρ correlation coefficient between the two measurement types was 0.81 for the living room and 0.76 for the child's bedroom). The median of the means for the 3pm-10pm time period for the living room was slightly higher at 1.13 mG, which is to be expected since there is likely to be higher electricity use during the afternoon and evening. The median for the 10pm-8am time period means for the child's bedroom was slightly lower at 0.86 mG, which is also to be expected due to lower electricity use during the night. In terms of childhood exposure there was an obvious gap between 8am-3pm, which could be investigated by assessing magnetic field exposure in schools or child care facilities in a future survey.

For the 24-hour measurements there were 2 homes with average levels above 4 mG in both the living room and the child's bedroom. There was one additional house with fields above 4 mG in each of the living room and the child's bedroom (ie a proportion of 15% of homes with at least one of either the living room or the child's bedroom exceeding 4 mG). It must be noted that there were some houses in which the levels exceeded 4 mG at certain times of the day, although they did not have overall average levels above 4 mG (see Appendix 4).

The magnetic fields near appliances showed great variation from house to house for the same sort of appliance type. Fields were typically normally distributed with microwave ovens having the greatest levels (mean 97 mG). It is questionable whether appliance fields need to be measured in a larger survey unless they impact directly on the long term exposure of the residents as, for example, in the case of an alarm clock next to a bed head.

There were no major problems in performing the measurements. Minor problems included residents not being at home at the arranged time and difficulties of performing outside spot measurements at night and in the rain. The residents in all of the houses surveyed were hospitable and, judging from the questionnaire, the residents were also satisfied with the behavior of the ARPANSA officers conducting the survey. Although two officers attended all homes in the pilot study, this could be reduced to one officer for a larger survey unless two are specifically requested by the resident.

5. Conclusions

In this study we investigated different issues regarding the implementation of a survey of power frequency magnetic fields in an urban environment. The participation rates in the sampling and recruitment of homes were similar for area sampling with face-to-face recruitment and telephone directory sampling with recruitment by mail. However, the mail-out method was substantially cheaper to implement. Random-digit-dialing was considered by ARPANSA to be the most intrusive on people's privacy and it showed poor initial recruiting and was subsequently abandoned. The issue of selection bias is very important in the recruitment of homes and will have to be investigated further in a larger survey.

The measurements confirmed the methodology described by Karipidis (2002) as suitable for the purposes of a larger survey, although some minor modifications are warranted. Average magnetic field levels were approximately 0.9 mG with 10th and 90th percentiles of 0.2 mG and 5.1 mG, respectively. The pilot survey identified situations where levels were possibly likely to be above 4 mG, including inner suburban homes and homes near (high-voltage) transmission lines. Approximately 12% (95% CI 1% - 30%) of the homes had levels above 4 mG in areas where children are likely to spend large amounts of time. This result was higher than expected but cannot be taken to be indicative of the true population due to the small sample size of the pilot study. A larger survey is required to answer some of the underlying questions regarding power frequency magnetic field exposure in Australia.

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Appendix I

Calculation of sample size

One of the objectives of the survey is to estimate the average magnetic field in Melbourne homes. Wilson *et al* (1994) conducted power frequency magnetic field measurements in 47 residences located throughout the Melbourne metropolitan area in Victoria, Australia in 1987 and repeated these measurements in 1993. The data was collected using the 24-hour and spot measurement method under 'low' and 'high' power conditions. The authors show that a lognormal distribution fits the data reasonably well. The 1987 and 1993 summary statistics (arithmetic and geometric means, medians and standard deviations) of the home-average magnetic flux density for the 47 residences are shown below.

Statistical data on magnetic flux densities (mG) in Victorian homes

	Observation (N)	Arithmetic Mean	Standard Deviation	Median	Geometric Mean
Low power					
1987	47	0.7	0.9	0.4	0.5
1993	37	0.8	0.9	0.5	0.5
High power					
1987	47	1.8	1.3	1.3	1.4
1993	37	1.4	1.3	0.9	0.9

The precision of a sample mean in estimating the population mean is given by the standard error of the mean (Lemeshaw *et al*, 1990):

$$SEM = \frac{\sigma}{\sqrt{N}}$$

where

SEM= standard error of the mean,
σ = standard deviation, and
N= sample size.

The sample size is therefore given by:

$$N = \left(\frac{\sigma}{SEM}\right)^2$$

Using a standard deviation of 0.9 mG as shown by the measurements of Wilson *et al* (1984) for the low power condition we get a range of sample sizes and their corresponding precision:

Sample Size (No. of homes)	Precision (%)
8,100	1
1,296	2.5
324	5
144	7.5
81	10

The confidence interval of the population mean is given by

$$CI = m \pm Z(SEM)$$

where

CI= confidence interval

m= population mean

Z= the number of standard deviation units away from the mean (for a 95% confidence interval Z=1.96)

From the table above we are 95% confident that a sample size of approximately 300 homes would provide an estimate for the mean magnetic field in homes with an uncertainty of ± 0.1 mG.

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APPENDIX II

Spot measurements taken at different locations in the 26 homes under low and high power condition

House	Time	FG(L)	FG(H)	FD(L)	FD(H)	LR(L)	LR(H)	K(L)	K(H)	MB(L)	MB(H)	CB(L)	CB(H)	B3(L)	B3(H)
Port Melbourne	1400	1.6	3.2	1.6	3.2	1	1.4	0.5	1.7	1.1	2.2	1.2	1.9	0.9	1.1
Elwood	900	5.3	5.9	1.8	2.2	0.8	1.6	0.6	1	2.6	3	N	N	N	N
Canterbury	1100	1.5	1.5	0.9	1.1	1.4	2.2	0.4	0.5	0.7	0.7	1.2	1.2	1.1	5
East Bentleigh	1700	0.8	0.7	0.7	1.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	N	N
Sydenham	1900	0.6	0.6	0.4	0.6	0.3	0.5	0.4	0.9	0.4	0.7	0.2	0.5	0.3	0.3
Surrey Hills	1200	1.4	3	0.8	2.2	1.6	2.4	1	2.4	1.2	2.2	1.3	2.1	N	N
Mooroolbark	1100	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.5	0.2	0.2	0.3	0.3	0.3	0.3
Highett	1200	5.1	5.1	1.5	1.3	1.7	1.5	1.2	1.1	1.4	1.2	1.2	1.2	N	N
East Doncaster	1400	1	2.6	0.2	0.8	0.2	0.2	0.7	1	0.2	0.5	0.3	0.7	0.2	0.9
North Brighton	1100	2.3	2.3	0.8	1	0.8	0.7	0.6	0.7	0.6	1	0.6	0.9	N	N
Richmond	1800	11.6	12.4	11.2	10.8	5.8	5.9	4.5	5	9.2	9.9	N	N	N	N
West Heidelberg	1100	2	2	0.5	1.1	0.6	1	0.6	0.8	0.6	1.1	0.5	0.9	N	N
Kings Park	1100	10.1	11.2	2.8	3.3	3.6	4.9	3.1	3.8	4.6	4.5	2.4	2.4	2.7	2.2
Wantirna	1100	2	0.7	0.2	0.3	0.1	0.2	0.8	1.3	0.1	0.3	0.1	0.2	N	N
Mickleham	1500	N	N	0.3	0.3	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.6	0.2	0.7
Ormond	1330	0.9	1.1	2.4	3.9	0.6	0.5	0.6	0.6	1	1	0.8	0.2	0.8	0.7
Glen Iris	930	0.8	0.8	1.2	1.2	0.7	0.8	0.4	0.4	0.5	0.5	0.3	0.3	0.3	0.4
Tecoma	1200	0.4	0.4	0.2	0.4	0.1	0.2	0.1	0.8	0.1	0.4	0.1	0.4	0.1	0.3
East Malvern	1100	5.9	5.7	1.4	1.4	0.9	0.8	0.7	0.7	1.7	1.8	1.2	1.3	0.7	0.6
Brunswick	1400	2	1.6	1.4	1	0.8	0.6	0.4	0.4	1.1	0.8	0.8	0.7	0.5	0.5
Coolaroo	1000	6.3	6.3	1.9	1.9	1.3	1.8	1.6	1.5	1.2	1.9	1	1.6	0.9	1.4
Doveton	1600	1.7	0.8	0.8	0.5	0.5	0.4	0.7	0.9	0.6	0.6	0.4	0.4	0.3	0.5
Parkville	1100	2.8	2	0.9	0.5	0.4	0.4	0.6	0.4	0.6	0.5	0.5	0.3	0.6	0.3
Narre Warren	1400	9.5	9.5	1	1	0.9	0.8	1	1.6	0.8	0.9	4.3	4.7	1.1	1.1
Roxburgh Park	1200	4	4.1	4.4	4.5	5.6	5.7	5	5.1	4.1	4.2	5.1	4.7	4.7	5.5
Camberwell	1000	3.6	3.6	1.7	1.8	1.2	1.5	1.3	1.4	0.8	1.9	1.7	1.5	N	N

NOTE – All measurements are in mG

Abbreviations
L – low power condition, H – high power condition, FG – front gate, FD – front door, LR – living room, K – kitchen, MB – master bedroom, CB – child's bedroom, B3 – bedroom 3, N – residence did not have this location

APPENDIX II - continued

House	S(L)	S(H)	DL(L)	DL(H)	FY(L)	FY(H)	BY(L)	BY(H)	M(L)	M(H)	WM(L)	WM(H)
Port Melbourne	0.7	1.5	5.6	5.7	N	N	0.8	0.9	6.8	7.2	1.7	1.9
Elwood	N	N	6.5	6.6	3.7	3.8	0.4	0.4	22.2	19.6	4.4	4.2
Canterbury	0.7	1.3	1.3	1.3	1.4	1.4	0.7	0.7	22.8	26.3	4.7	4.7
East Bentleigh	N	N	3.8	3.8	0.7	0.7	0.4	0.4	21	22.4	0.8	1.1
Sydenham	N	N	N	N	0.6	0.6	0.2	0.2	19.8	49	0.7	1
Surrey Hills	0.9	2	10.2	10.2	1.5	2.3	2.1	2.6	10.5	14.8	2.3	4.2
Mooroolbark	0.3	0.3	N	N	0.2	0.3	0.2	0.2	53.8	45.2	0.2	0.3
Highett	N	N	5.1	5.1	3	3.2	0.9	0.6	12.4	19.6	11.4	11.1
East Doncaster	0.2	0.5	1	1	0.8	1.5	0.2	0.2	43	65.2	0.7	5.6
North Brighton	1	0.9	1.8	1.8	1	1	0.4	0.4	115	178	1.6	2
Richmond	N	N	12.6	12.4	N	N	2.9	2.5	33.6	38.2	9.8	10
West Heidelberg	0.9	1.1	2.2	2.2	1	1.5	0.7	0.7	7.8	10.8	1.5	1.8
Kings Park	2.6	2.5	11.2	11.6	6.9	5.8	2.2	2.2	54.2	54.6	6.7	9.2
Wantirna	N	N	N	N	0.3	0.2	0.1	0.1	26.4	31.6	0.7	0.4
Mickleham	0.2	0.3	N	N	N	N	N	N	15.3	16.7	N	N
Ormond	N	N	1.3	1.3	1.3	1.4	0.7	0.7	10.7	10.6	4.2	3.7
Glen Iris	N	N	0.8	0.8	0.9	0.9	0.2	0.2	42.2	49.2	2.3	2.3
Tecoma	0.1	0.3	0.4	0.4	0.2	0.2	0.1	0.1	20.4	28.8	0.4	0.5
East Malvern	N	N	6.4	6	3.3	3.1	0.4	0.4	8.6	11.3	4.9	4.7
Brunswick	0.7	0.5	2.1	2	1.5	1.4	0.6	0.6	58.6	51	1.1	1
Coolaroo	N	N	7	7.3	2.1	2.1	1.1	1.1	6.1	6.1	7.5	7.5
Doveton	N	N	2.5	2.5	0.8	0.6	0.4	0.4	13.6	19.8	2.4	3.7
Parkville	0.5	0.4	5.7	4.7	1.4	0.8	0.2	0.2	272	215	4	2.3
Narre Warren	5.9	6.4	10.9	10.9	3.1	3.1	1	1	56.4	56.4	8.8	8.8
Roxburgh Park	5.9	6	N	N	4.5	4.9	6.8	6.8	26	27	4	4.2
Camberwell	N	N	3.5	3.5	1.9	1.9	0.5	0.5	25.6	38	4.1	4.1

NOTE – All measurements are in mG

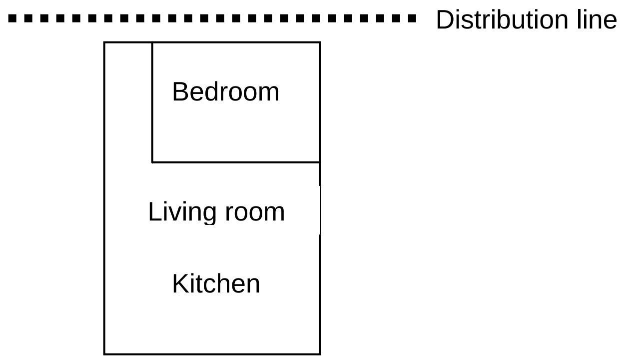
Abbreviations
L – low power condition, H – high power condition, S – study, DL – distribution line, FY – front yard, BY – back yard, M – meter box, WM – water meter, N – residence did not have this location

APPENDIX III

Houses with background fields above 4 mG

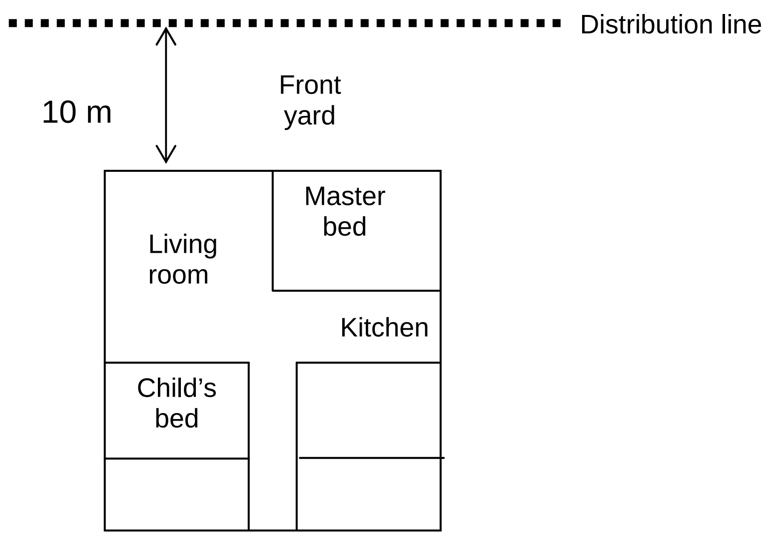
Richmond

This was an inner suburban older home with no front yard where the distribution line was a few metres from the front of the house. The spot measurements indicated levels greater than 4 mG throughout the house. The levels were higher in the master bedroom (which was at the front of the house) and decreased moving towards the back of the house and away from the distribution line. It is conceivable that many residences in inner suburban Melbourne will be similar. It seems likely that such houses could be readily identified with reasonable accuracy by inspection and spot measurement in publicly accessible locations.



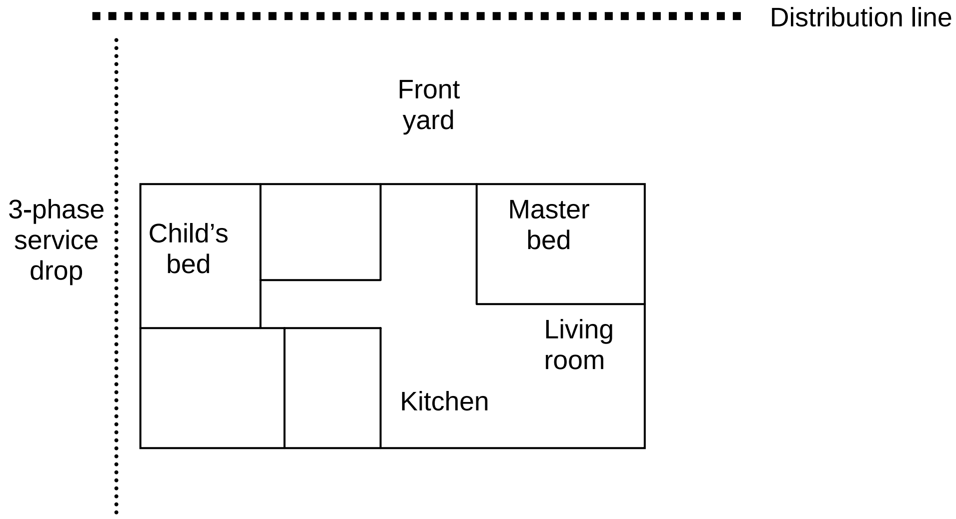
Kings Park

This is an example of an outer suburban home where the distribution line seemed to cause fields above 4 mG at the front of the house where the living room, kitchen and master bedroom were located. The fields fell below 4 mG at the back of the house where the child's bedroom was located. The rooms with the high fields were a considerable distance from the distribution line suggesting that the line may have been carrying a high current.



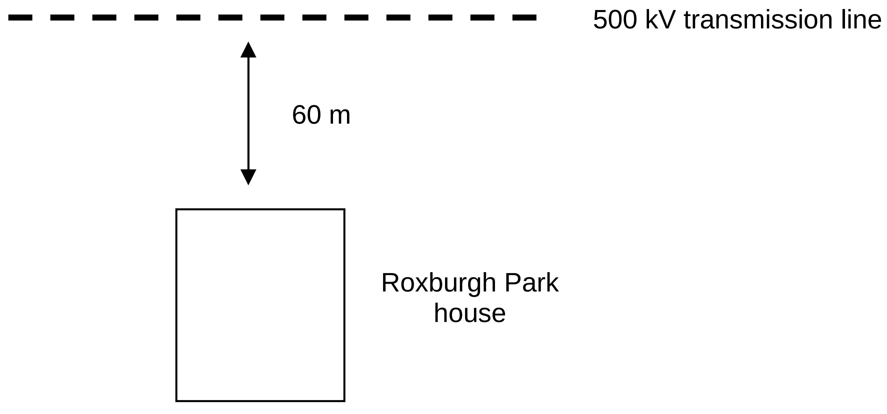
Narre Warren

This is another example of an outer suburban home where the levels were low throughout most of the house apart from one side of the house where the child's bedroom and another bedroom were situated. Levels in those rooms were greater than 4 mG. The resident indicated that he had installed a three-phase service drop adjacent to those rooms.



Roxburgh Park

This house had a 500 kV transmission line running adjacent to the back fence at approximately 60 m distance. Levels were consistently above 4 mG throughout the house.



APPENDIX IV

The 24-hour mean for the living room and the child's bedroom as well as the 3pm-10pm and 10pm-8am time period means for the living room and the child's bedroom for the 26 homes, respectively. Also shown is the percentage of time above 4 mG.

House	Living room 24h mean (mG)	% time above 4mG	Living room 3pm-10pm mean (mG)	% time above 4mG	Child's bedroom 24h mean (mG)	% time above 4mG	Child's bedroom 10pm-8am mean (mG)	% time above 4mG
Port Melbourne	2.29	10.9	3.17	33.7	1.44	0	1.29	0
Elwood	1.37	0	1.54	0	1.72	0.8	1.61	2
Canterbury	1.8	3	2.2	3.7	2.48	24.8	1.91	11.3
East Bentleigh	0.52	0	0.49	0	0.61	0	0.6	0
Sydenham	1.17	0	1.19	0	0.53	0	0.53	0
Surrey Hills	1.44	0	1.57	0	1.31	0	1.38	0
Mooroolbark	0.3	0	0.46	0	0.33	0	0.24	0
Highett	0.76	0	0.8	0	0.7	0	0.73	0
East Doncaster	0.3	0	0.37	0	0.41	0	0.51	0
North Brighton	0.67	0	0.76	0	0.74	0	0.62	0
Richmond	5.26	86.8	5.33	100	9.71	100	7.88	100
West Heidelberg	0.8	0	0.85	0	0.79	0	0.69	0
Kings Park	5.02	77.7	6.04	94.9	2.52	0.1	2.27	0
Wantirna	0.51	0.9	0.65	0.7	0.12	0	0.11	0
Mickleham	0.21	0	0.24	0	0.24	0	0.23	0
Ormond	0.97	0	1.12	0	1.15	0	1.03	0
Glen Iris	1.74	1.2	2.26	4.2	1.38	0	1.26	0
Tecoma	0.22	0	0.22	0	0.16	0	0.13	0
East Malvern	0.93	0	1.13	0	1.13	0	0.95	0
Brunswick	0.95	0	1.35	0	1.23	0	1.1	0
Coolaroo	1.22	0	1.41	0	1.2	0	0.97	0
Doveton	0.64	0	0.71	0	0.7	0	0.65	0
Parkville	0.56	0	0.55	0	0.32	0	0.37	0
Narre Warren	0.75	0	0.75	0	7.24	98.8	8.02	99.1
Roxburgh Park	6.09	100	6.06	100	5.97	100	5.93	100
Camberwell	1.79	0.7	2.47	2.5	1.06	0	0.77	0