NRL
National Radiation Laboratory

Electric and magnetic field levels around Christchurch

M D Gledhill

1992/1
NRL Report

MINISTRY OF HEALTH
MANATŪ HAUORA

Report NRL 1992/1
ISSN O111-753x

ELECTRIC AND MAGNETIC FIELD LEVELS AROUND CHRISTCHURCH

M D Gledhill

National Radiation Laboratory
PG Box 25-099
Christchurch
New Zealand

February 1992

TABLE OF CONTENTS

page

ABSTRACT

Measurements have been made of the magnetic flux density and electric field strengths beneath and around high voltage lines in the Christchurch area. Magnetic flux densities have been measured around low voltage lines and other electrical installations, and in houses.

The electric field strengths are less than 2 kV/m and similar to those measured elsewhere. Magnetic flux densities around high voltage lines show large seasonal variations, and can differ widely from one line to another. The magnetic flux densities around substations are low except in the vicinity of overhead lines leading into or out of the installation.

A broad range of magnetic flux densities is found beneath low voltage street wiring, sometimes exhibiting large daily variations. The levels fall off quickly with distance. Buried low voltage cables produce lower fields.

Magnetic flux densities in houses are similar to those measured overseas.

1. INTRODUCTION

This report presents the results of measurements of magnetic and electric fields made around various types of power line, electrical installation and residences in the Christchurch area during 1991. These data can be used to assess typical exposures to these fields in New Zealand. Some comparisons are made with overseas data.

2. METHODS

Measurements of the magnetic and electric fields were made using a Genitron EL-MAG-024 Field Monitor, using SM-024 and HK-024 probes for the magnetic and electric fields respectively.
Characteristics of this device and the probes are given in Appendix A.

2.1 Power lines

2.1.1 Magnetic fields around power lines

A profile of the magnetic flux density under high voltage lines was taken along a direction at right angles to the cables themselves. Measurements were made one metre above ground level and, where possible, on both sides of the line from a point mid-way between two pylons (ie, where the power line is closest to the ground). Measurements were taken at two metre intervals up to fifty metres from the line, and at larger intervals thereafter, until the magnetic flux density had decreased to about 50 nanotesla (nT). At this level, the flux densities are similar to, or less than, those commonly encountered in homes. In addition, at these distances there were relatively large transient fluctuations of 20 nT. The cause of these is not clear, but they could be the result of small changes in the relative loadings of the phases.

Under low voltage distribution (street) lines, measurements were made at the mid-point of each span, about one metre above ground level. A few readings were taken to judge the decrease in field strength with distance away from the line.

Procedures followed for underground lines varied and are discussed in the results section.

2.1.2 Electric fields around power lines

Electric fields were only measured beneath high voltage lines. The probe was supported on a plastic stand, with the probe about 1.5 metres above the ground and the meter box some two metres away. This ensures minimal distortion of the electric field lines. It is assumed (following guidelines given in IEEE 1987) that at this distance from the ground the electric field is oriented vertically.

2.2 Magnetic fields around substations

Magnetic fields were measured around parts of substations normally accessible to the public, for example, along the fenceline, and a few metres away from the fenceline.

2.3 Magnetic fields in houses

Measurements were taken in most living areas of the houses surveyed (lounge, dining area, kitchen, bedrooms) in low and ‘high’ power conditions. Low power conditions meant that very few appliances were being used (for example, one or two lights, refrigerator, water heating), while for high power conditions one or more high current appliances (usually an electric oven and hotplate, with perhaps an electric heater as well) were turned on. Measurements were taken in typical positions that would be occupied at some stage of the day, eg, seated in an armchair, at the dining table, standing in front of the range while cooking. In bedrooms, measurements were made a few cm above the bed, with and without an electric blanket/waterbed turned on (if used). Finally, a measurement was made about thirty cm from the fuse box/power inlet.

The standard form used in a residential survey is shown in figure 2.1. Some houses were surveyed during the day, and some in the evening.

3. RESULTS

3.1 HV transmission lines

Magnetic field measurements were made in winter and summer under a 220 kV line and three 66 kV lines, at times of peak loading. Electric fields were measured only during the summer. Since the electric field strength does not depend on the line loading, it was only measured once.

3.1.1 220 kV lines at Victoria Park

This is a double circuit line, with one circuit linking Twizel and the Bromley substation, and the other linking Islington with the Bromley substation. At the point where the fields were measured, it was possible to make measurements only on the side of the Twizel/Bromley circuit. The ground is level for about 50 metres and then rises slightly.

The magnetic flux densities and line load information are presented in figure 3.1a, and the electric field strengths in figure 3.1b. Distances are measured from midway between the two sets of conductors.

3.1.2 66 kV line Islington – Addington

These lines consist of two sets of double circuits (ie, two parallel sets of pylons, with a double circuit on each pylon). Measurements were made where these lines cross flat ground adjacent to Riccarton Racecourse. In summer, measurements were made only on one side (south) of the lines, but in winter measurements were also made on the north side.

The magnetic flux densities and loading information are presented in figure 3.2a, and electric field strengths in figure 3.3. Distances are measured from midway between the two sets of lines.

3.1.3 66 kV line Islington – Papanui

These lines also comprise two sets of double circuits. Measurements were made on the north and south sides of the lines where they cross Burnside Park.

Loadings and magnetic flux densities are presented in figure 3.2b, and electric field strengths in figure 3.3. Distances are measured from midway between the two sets of lines.

3.1.4 66 kV line Islington – Halswell

This is a double circuit line servicing mainly residential areas. Measurements were made on the east side of the line where it crosses Wilmot Park, at mid-day (low loading) and early evening. For much of the length of this line, the pylons are of non-standard design, in order to ummariz the height close to Wigram airfield.

Results are presented in figure 3.2c. Distances are measured from midway between the two sets of lines.

3.2 Low voltage distribution lines

3.2.1 11 kV overhead lines

Measurements were made under a number of 11 kV lines on semi-rural land to the south-west of Christchurch (Halswell/Oaklands, south Hornby). Beneath most of these the magnetic flux densities were very low (less than 50 nT). A limited profile was measured beneath one line that did have a significant field, and is presented in figure 3.4.

3.2.2 11 kV underground lines

Measurements were made along a line known to cut perpendicularly across 11 kV underground cables. The magnetic flux density varied between 0.05 and 0.08 µT, but not in any way that correlated with the known position of the line.

3.2.3 400 V street distribution overhead lines

Two types of measurement were made – firstly to measure the variation of flux density with distance from the line, and secondly to measure the magnetic flux density beneath each span of the line along the length of the street. Under some lines, measurements were made in the early afternoon and early evening to enable comparisons of the different loading conditions (in residential areas, loads are usually higher in the early evening). In some of the streets it appeared that there were underground low voltage lines, which could have influenced the measurement.

Variations of flux density with distance are presented in figure 3.4. As there is a considerable variation in the rates at which the field falls off with distance (due possibly to the influence of underground lines), computed values of field strength against distance have been plotted for a three-phase line on 7 metre high poles. The currents in each phase were chosen to give a field of one microtesla directly beneath the line.

Variations along the street of the flux density directly beneath 400 V lines are presented in figure 3.5. All the streets are residential except street 4, which is in a light industrial area. Both sets of measurements on this street were made at about midday.

3.2.4 400 V street distribution underground lines

Measurements taken above known low voltage underground lines showed some fairly rapid fluctuations of ± 50%, presumably as the loads on the three phases varied. There was a maximum value of about 0.4 microtesla.

3.2.5 Measurements on central Christchurch streets

Measurements were made along a number of streets in the central shopping area of Christchurch, almost all of which have no overhead power lines. Readings were taken at 50 m intervals. Results are presented in figure 3.6. Where both sides of the street were surveyed, results are reported separately.

3.3 Substations

3.3.1 Addington

This is a large substation, fed by overhead 66 kV lines from the Islington switchyard. It feeds much of central Christchurch via underground 66 kV lines to smaller substations.

Measurements were made along three sides of the switchyard, outside the fences, and are summarised in the table.

	Magnetic flux density (microtesla)		
	Range	Mean	Median
Side 1 (north)* 10 m away	0.48 – 2.3 0.15 – 0.9	1.2 0.58	0.96 0.7
Side 2 (west)	0.1 – 0.7	0.27	0.2
Side 1 (north)* 10 m away	0.1 – 0.4 0.07 – 0.15	0.28 0.10	0.3 0.09

*note: 66 kV lines pass above part of side 1.

3.3.2 Oxford/Tuam substation

This is housed inside a brick building, accessible on two sides, and fed by underground cables with the outlets also underground. Fields were measured on the pavement on the accessible sides. Distances are measured from the walls of the building.

	Magnetic flux density (microtesla)		
	Range	Mean	Median
Side 1 @ 4 m	0.24 – 2.0	0.53	0.35
Side 1 @ 7 m	0.10 – 0.27	0.21	0.24
Side 2 @ 0 m	0.15 – 0.36	0.24	0.23
Side 2 @ 3 m	0.12 – 0.4	0.20	0.20

3.3.3 Local transformer at 108 Victoria Street

This is a small transformer which supplies a single building. It is housed in a rectangular enclosure 3.5 m x 2.6 m. Measurements were taken along the two long sides (1 and 2) and one short side (3).

Although there are locally intense fields along side 3, at two metres from the transformer the levels were similar to those along side 1.

	Magnetic flux density (microtesla)		
	Range	Mean	Median
Side l @ 0 m	2.0 – 8.5	6.2	6.5
Side l @ l m	1.0 – 1.5	1.2	1.2
Side 1 @ 2 m	0.45 – 0.65	0.56	0.5
Side 2 @ 0 m	1.0 – 3.0	2.0	1.8
Side 2 @ 1 m	0.65 – 1.2	0.93	0.9
Side 3 @ 0 m	3.5 – 40	16	17
Side 3 @ l m	1.5 – 3.0	2.8	3.0
Side 3 @ 2 m	0.65 – 0.9	0.82	0.9

3.4 Houses

Measurements were made in thirteen houses. The results are ummarized in figure 3.7, which gives the range of measurement values in each category, and the mean and median. The figure above each range bar gives the number of samples in each measurement category. These vary due to incomplete sets of measurements made in some houses, and the different numbers of living areas and bedrooms in each house.

In living areas and bedrooms, there were few differences between the fields in low and high power conditions. In some houses, a sharp increase in flux density at one measurement location occurred under high power conditions if that location was close to where the electrical cables from street poles entered the house. In other houses, there was a more general increase in flux density in several measurement sites. This tended to occur in older houses, and is probably related to the house internal wiring.

Measurements in bedrooms are listed in four categories: “bedrm – no blanket” for low power conditions with no electric blanket on, “bedrm – blanket low/high” for low power condition with the blanket setting on low/high, and “bedrm high” for high power, electric blanket off.

As was expected, the flux density close to the electric range increased significantly when the oven and a ring were turned on. However, the fact that the mean and median “kitchen – high” values were little changed suggest that these locally intense fields decrease very quickly with increasing distance.

None of the houses was near a high voltage line, and although some had low voltage overhead lines in the street outside, these were generally at least ten metres away.

4. COMPARISON WITH OTHER MEASUREMENTS

4.1 Overseas results

Few overseas data have been published which can be directly compared with the information presented in this report. Sections 4.1.1 and 4.1.2 compare what data are available.

4.1.1 Fields beneath power lines

High voltage lines

Because of the number of variables involved, comparison of the results noted here with measurements from overseas is difficult. The field strengths depend on the line voltage, height, geometry and current loading. Several countries establish a right of way beneath high voltage lines, in which no development or full-time activities are permitted, so the fields to which people are actually exposed are less than the maximum developed directly beneath the line.

Bearing this in mind, table 4.1 presents the calculated electric field strengths and magnetic flux densities that would be found beneath transmission lines operating at particular voltages and load conditions (data from Lee et al, 1986).

Table 4.1 Calculated magnetic flux densities and electric field strengths for certain types of line

Line voltage (kV)	Current (Amps per phase)	Total power (MW)	Electric field strength (kV/m)	Magnetic flux density (microtesla)
230	954	800*	2-3	13
500	2624	5000*	7-8	33
1100	4800	10000#	9	30

* Double circuit
# Single circuit

Only the 230 kV line is directly comparable with the measurements presented in this report.

4.1.2 Residential magnetic fields

Measurements of residential magnetic fields have been made in conjunction with many epidemiological studies investigating possible links between power lines and cancer. A summary of the results is shown in figure 4.1 (taken from Bracken 1988). It can be seen that most of the US studies have geometric means between 0.05 and 0.07 microtesla (0.5 - 0.7 milligauss). The UK and Swedish results are slightly lower than this.

The New Zealand results are similar to these overseas figures. The geometric means of the low and high power measurements in living areas, kitchens (excluding the range) and bedrooms are 0.054 and 0.070 microtesla respectively. The geometric mean of the low and high power measurements considered together is 0.065 microtesla.

4.2 Comparison with results from elsewhere in New Zealand

The Auckland Electric Power Board has made some measurements around power lines in the Auckland area. Their results are summarised in table 4.2.

Table 4.2 Measurements by the Auckland Electric Power Board

Line Voltage (kV)	Magnetic flux density (microtesla)	Electric field strength (kV/m)	Comments
11	Negligible	negligible	
33	1.1	1.6	Decreases to 0.4 µT, 0.9 kV/m at 10 m.
66	0.4	0.25	
110	0.7 - 2.5	0.4 - 1.5	
220	2.5 - 3.5	0.5 - 1.0	Various line configurations

The results from these measurements are similar to those presented in this report.

5. CONCLUSIONS

The results presented in this report show that there is a broad range of magnetic flux densities and electric field strengths beneath, and in the neighbourhood of, high voltage power transmission lines. An assessment of the likely magnetic flux density beneath any particular line is difficult to predict without some knowledge of the loading conditions. There can also be large seasonal variations.

A broad range of magnetic flux densities is also found under low voltage distribution wires, but there can be large differences from span to span and over the day. The field strength drops off rapidly with distance. Buried low voltage cables produce field levels somewhat lower than those from overhead lines, and which also decrease rapidly with distance from the line. Ideally, a buried three phase cable should produce very low field levels if the currents in each phase are balanced, but slight imbalances in the loading are bound to occur in low voltage lines as electrical equipment is turned on and off.

The magnetic fields around large substations are very localised and outside these installations the field levels are mostly influenced only by the lines feeding the substation.

ACKNOWLEDGEMENTS

Thanks are due to the Southpower staff who were of assistance during this survey. In particular Ian Wells answered many questions regarding the local distribution network, and supplied a number of wiring maps.

REFERENCES

Bracken T D 1988. Power frequency electric and magnetic fields in the environment. In EPRI Utility Seminar (1988 Oct 12 - 14 Colorado Springs). Power frequency electric and magnetic field exposure assessment.

IEEE 1987. IEEE standard procedures for measurement of power frequency electric and magnetic fields from AC power lines. ANSI/IEEE Std 644-1987. IEEE, New York.

Lee J M et al 1986. Electrical and biological effects of transmission lines: a review. US Department of Energy, Bonneville Power Administration, Portland, Oregon.

APPENDIX A

Specification of Genitron EL-MAG-024 Mobile Field Intensity Meter

Frequency response:	10 Hz- 10 kHz
Magnetic Field range:	0.001 μT - 100 μT (SM-024 probe)
Electric field range:	20 V/m - 100 kV/m
Specified accuracy:	5% of full scale

The magnetic field sensor is of the induction type, in which an alternating magnetic field induces an emf in the sensing coil. The orientation of the coil has to be adjusted to obtain the maximum response. A frequency-dependent amplifier in the meter corrects for the frequency response of the probe.

The electric field sensor is a capacitive device (sometimes referred to as “free-body”), in which the alternating electric field causes an alternating current to flow between the two plates. The size of the current is proportional to the electric field strength.

National Radiation Laboratory
Home Magnetic Field Survey

Address:
Date:
Time Start:
Time Finish:

Location	High* Power	Low Power		
Living Area:				
1				
2				
3				
Kitchen:				
1				
Near range				
		Elec blanket/waterbed		
Bedroom:		high	low	off
1				
2				
3				
4				
5				
Others:				
Power inlet				
Street				
1				
2				
3				

Street Wiring Confign:

* Appliances:

Figure 2.1 Survey form for home surveys

Electric and magnetic fields around 220 kV line, Victoria Park

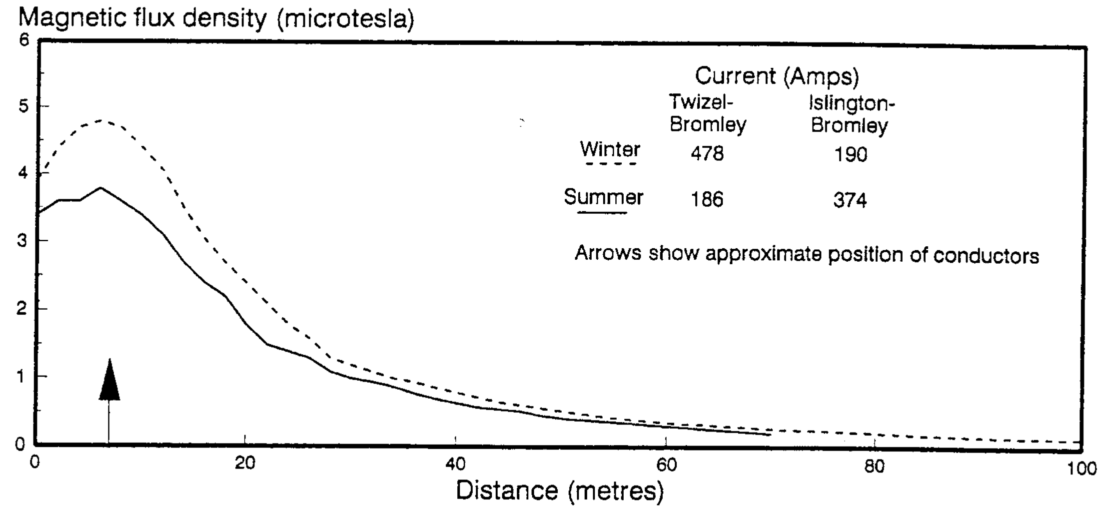


Figure 3.1a Magnetic fields

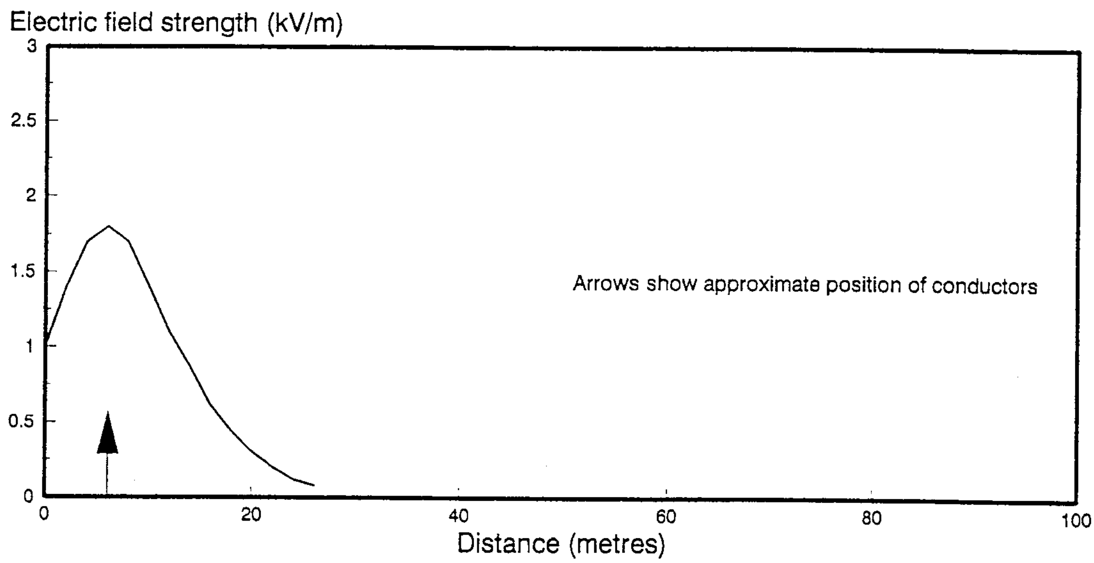


Figure 3.1b Electric fields

Magnetic fields around 66 kV lines

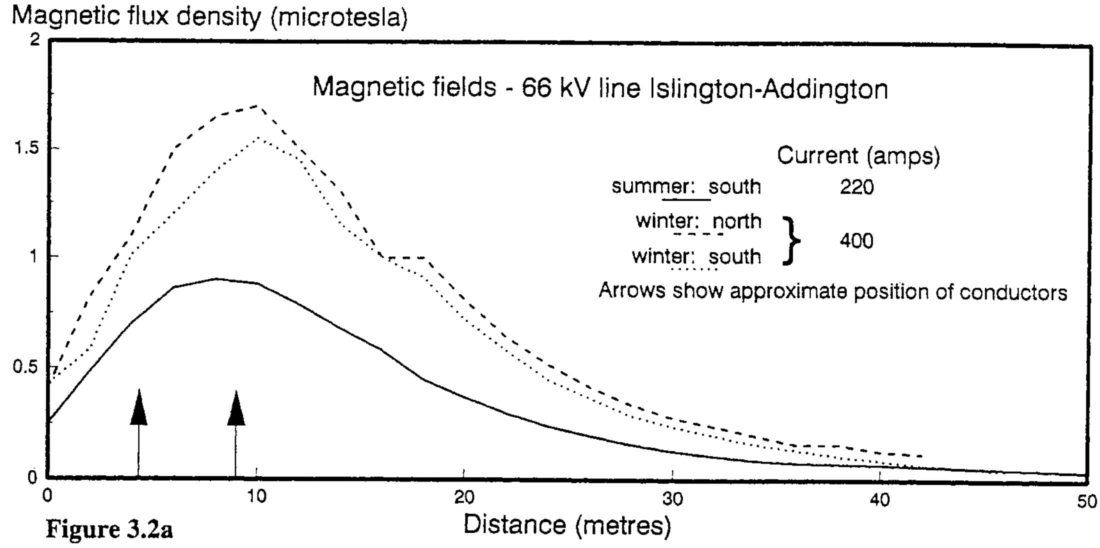


Figure 3.2a

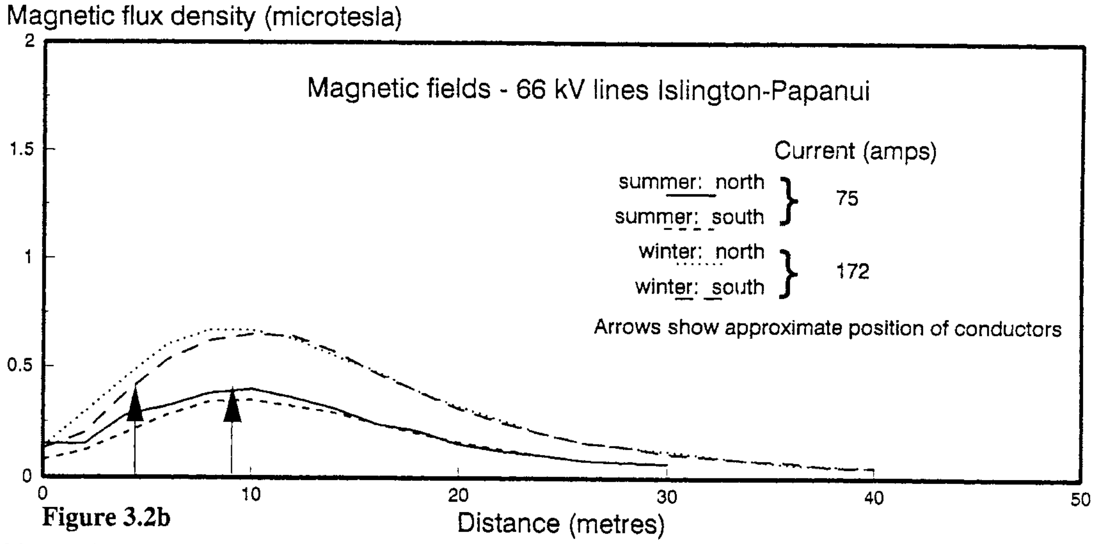


Figure 3.2b

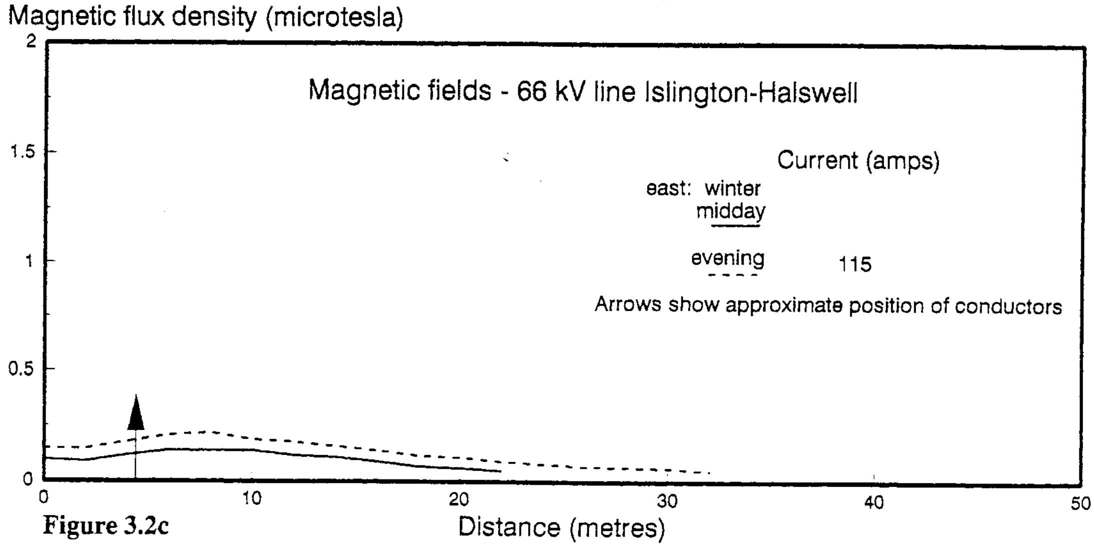


Figure 3.2c

Electric fields around 66 kV lines

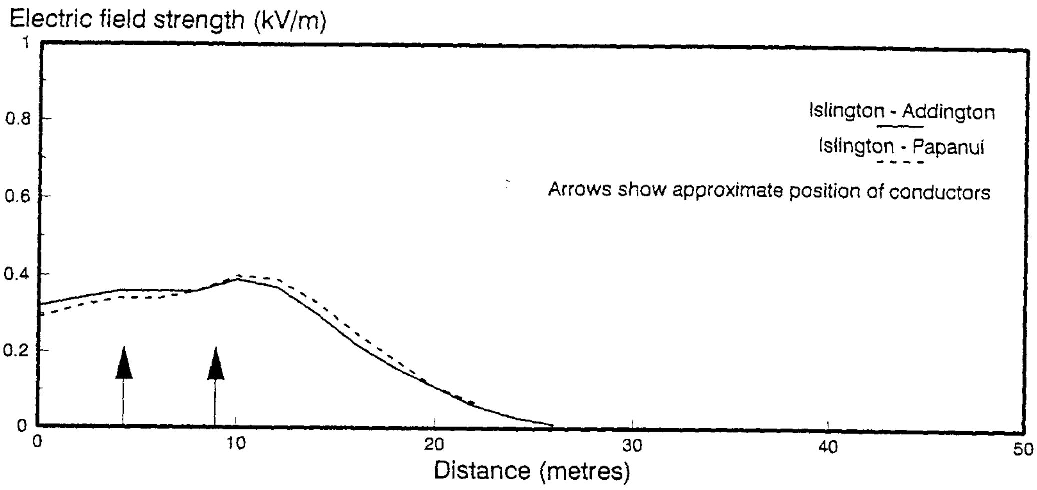


Figure 3.3

Magnetic fields around low voltage lines

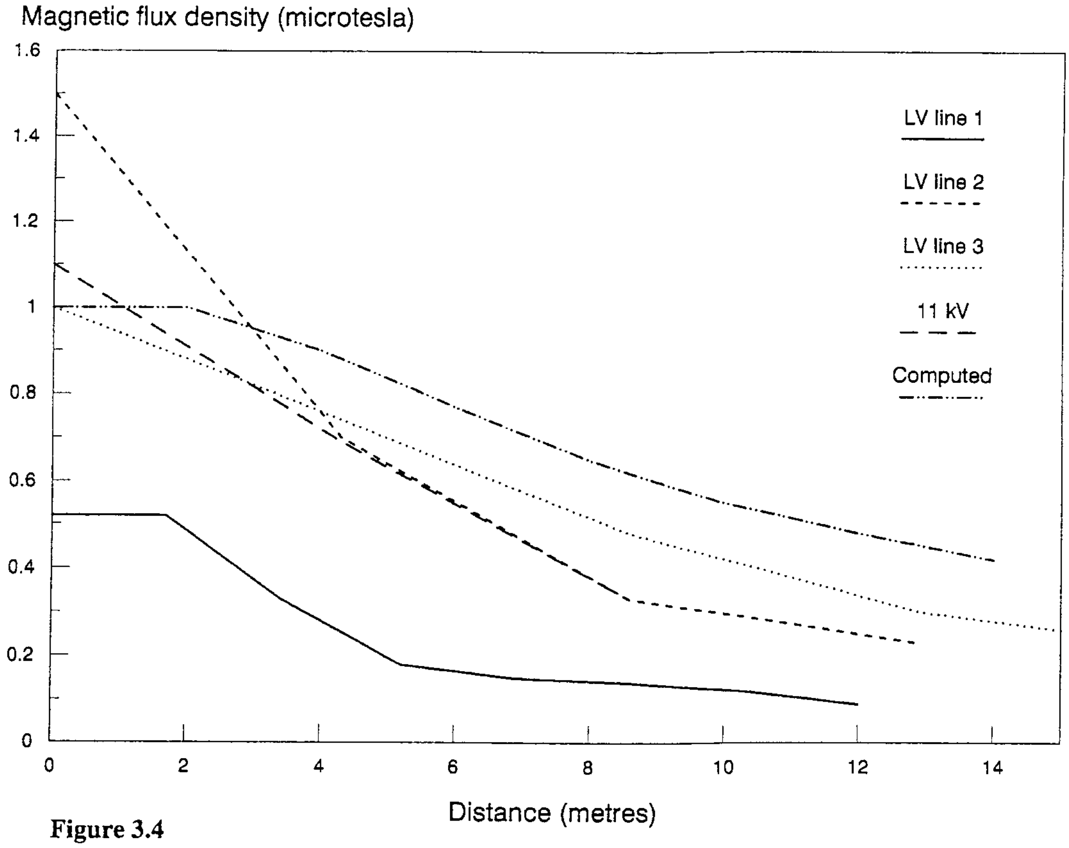


Figure 3.4

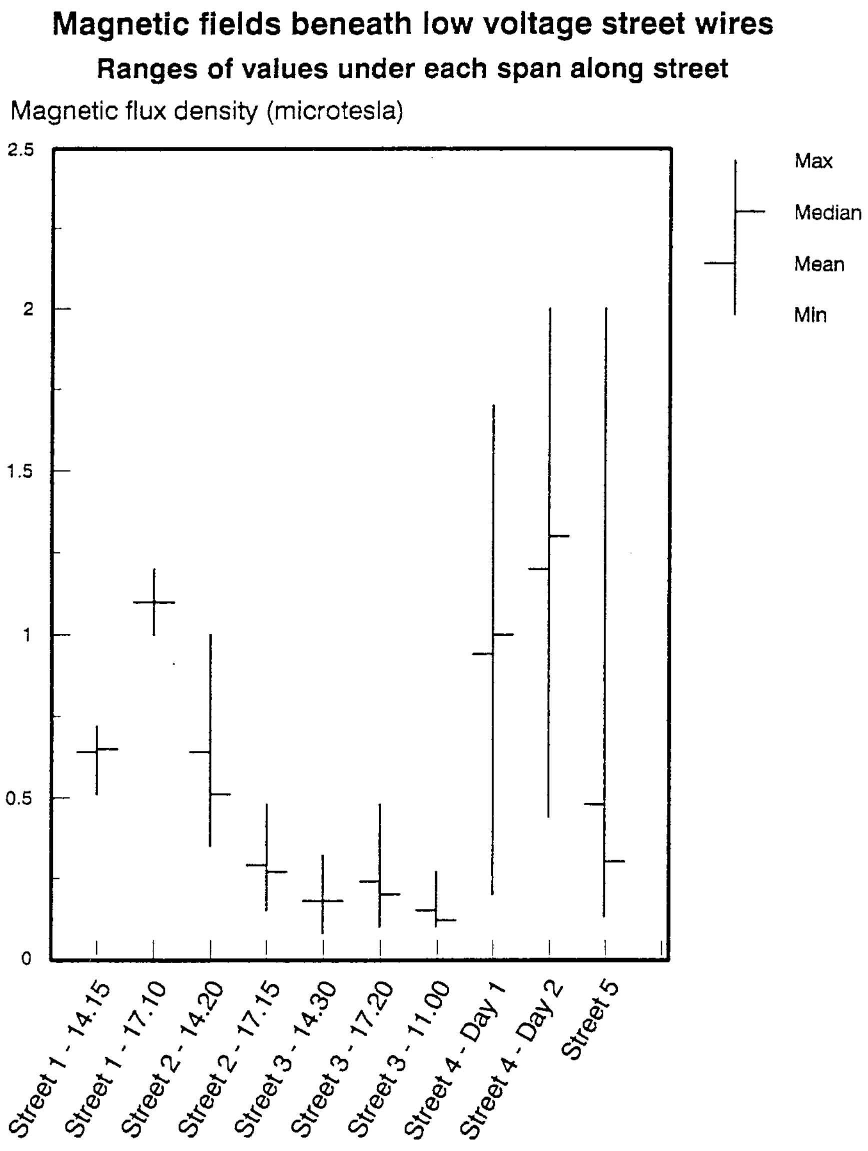
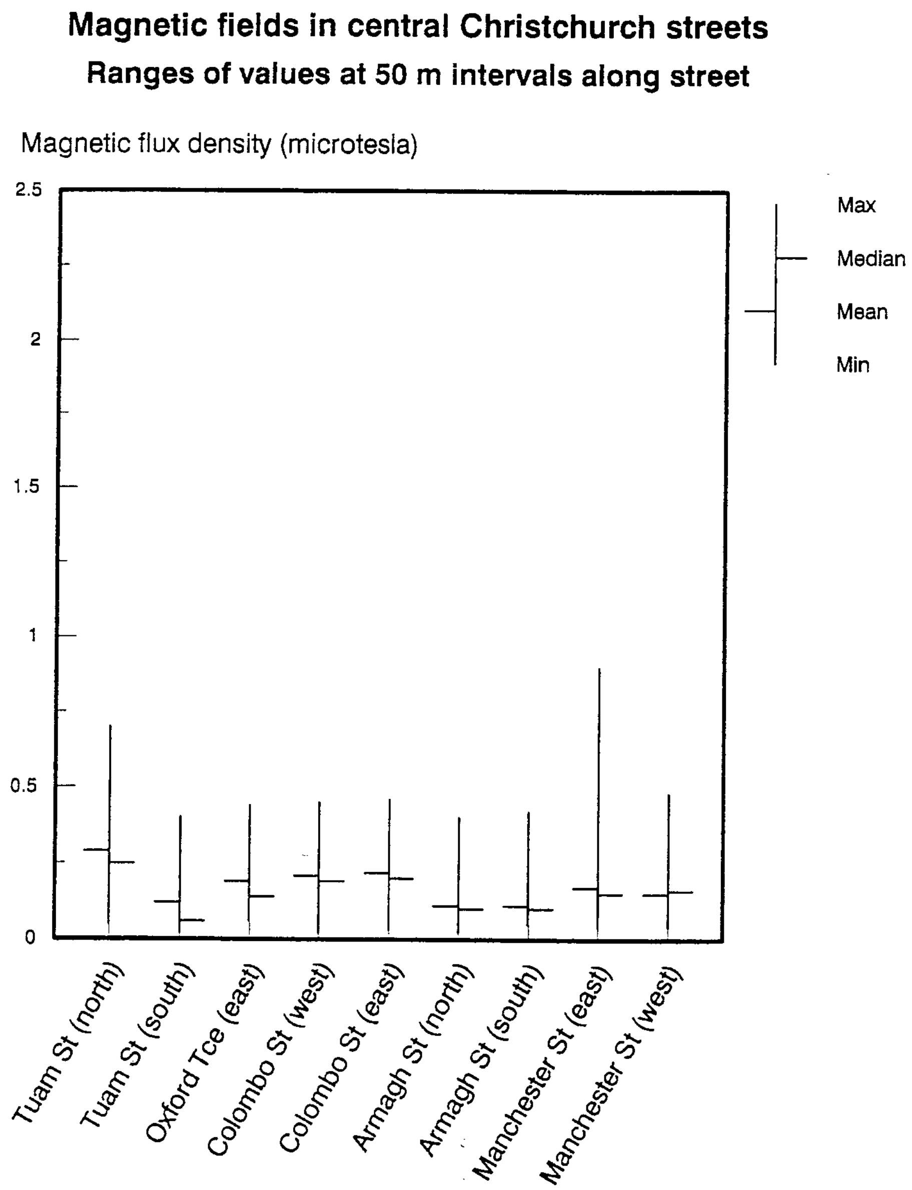

Magnetic fields beneath low voltage street wires
Ranges of values under each span along street
Magnetic flux density (microtesla)
2.5
2
1.5
1
0.5
0
Max
Median
Mean
Min
Street 1 - 14.15
Street 1 - 17.10
Street 2 - 14.20
Street 2 - 17.15
Street 3 - 14.30
Street 3 - 17.20
Street 3 - 11.00
Street 4 - Day 1
Street 4 - Day 2
Street 5

Figure 3.5



Magnetic fields in central Christchurch streets
Ranges of values at 50 m intervals along street
Magnetic flux density (microtesla)
2.5
2
1.5
1
0.5
0
Max
Median
Mean
Min
Tuam St (north)
Tuam St (south)
Oxford Tce (east)
Colombo St (west)
Colombo St (east)
Armagh St (north)
Armagh St (south)
Manchester St (east)
Manchester St (west)

Figure 3.6

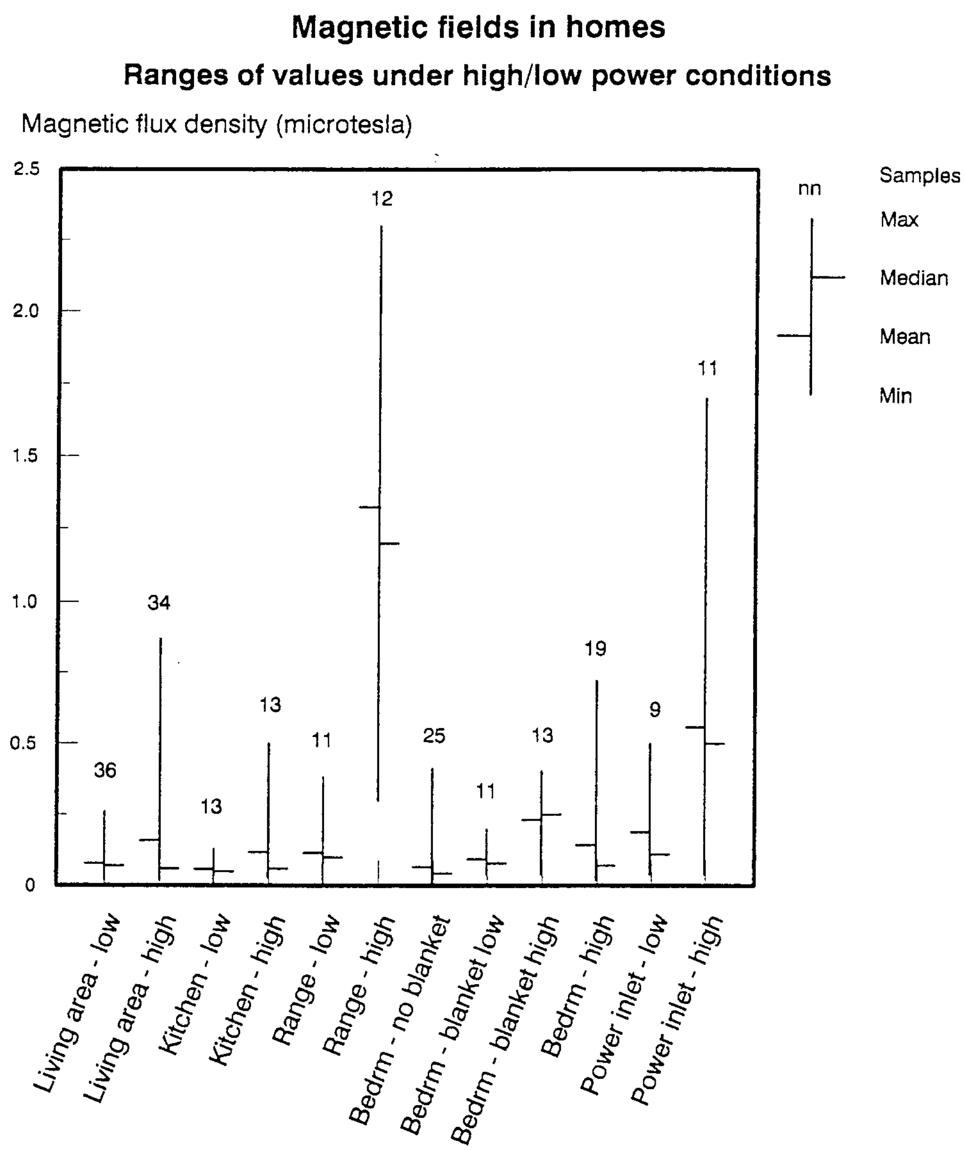

Magnetic fields in homes
Ranges of values under high/low power conditions
Magnetic flux density (microtesla)
2.5
2.0
1.5
1.0
0.5
0
36
34
13
13
11
12
25
11
13
19
9
11
nn
Samples
Max
Median
Mean
Min
Living area - low
Living area - high
Kitchen - low
Kitchen - high
Range - low
Range - high
Bedrm - no blanket
Bedrm - blanket low
Bedrm - blanket high
Bedrm - high
Power inlet - low
Power inlet - high

Figure 3.7

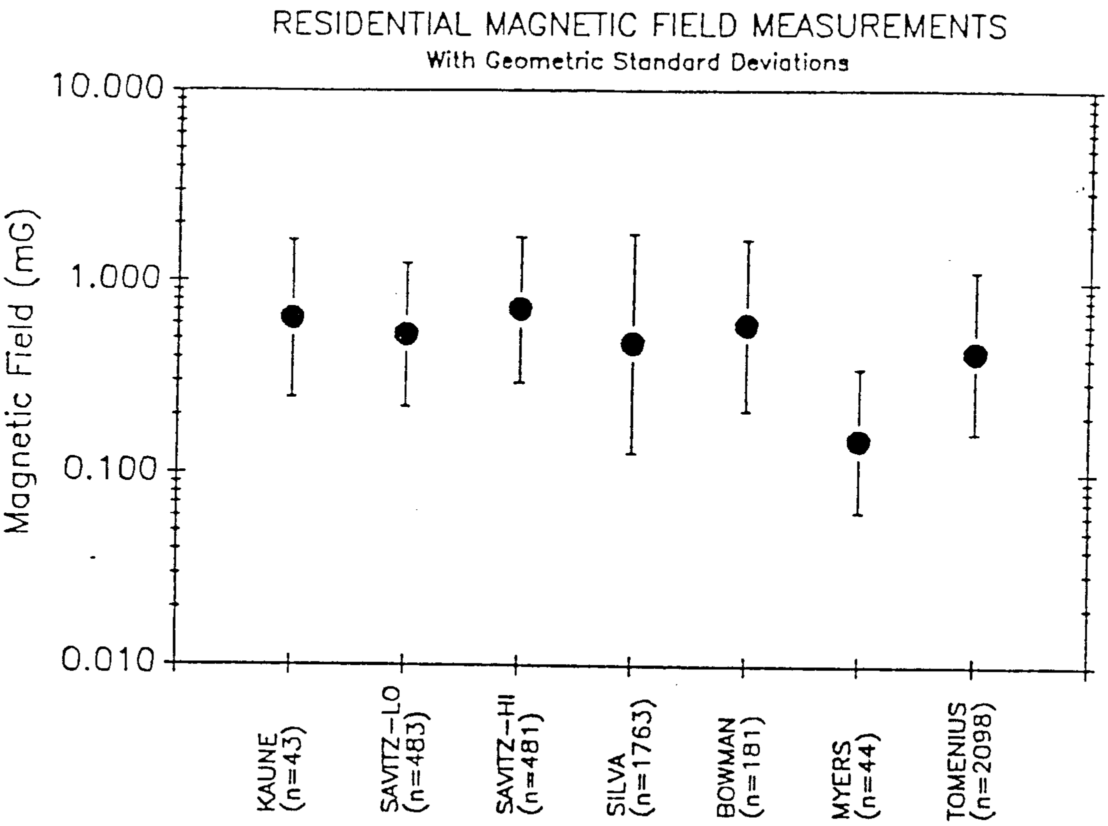


Figure 4.1 Residential magnetic field measurements from overseas surveys (from Bracken, 1988)