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Measurement of Extremely Low Frequency Electric and Magnetic Fields Associated with Electricity Supply and Distribution Infrastructure

David Urban, Lydiawati Tjong and Ken Karipidis

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Executive Summary

The objective of this study was to provide better understanding of the levels of extremely low frequency (ELF) electric and magnetic fields (EMF) in residences which are in close proximity to different types of electricity infrastructure commonly found in Melbourne.

Exposure to ELF EMF at high levels can affect the functioning of the nervous system and limits of 5,000 V/m and 100 µT, for the electric and magnetic field, respectively, have been recommended by the National Health and Medical Research Council (NHMRC) to prevent such effects. There are a number of epidemiological studies which have reported an association between prolonged residential exposure to magnetic fields below the NHMRC limits but greater than what is normally encountered and an increased risk in childhood leukaemia. However, the evidence is not adequate to suggest that prolonged exposure to magnetic field levels below the NHMRC limits is a hazard to human health.

A total of 52 separate sites of different types of electricity infrastructure were chosen for measurement in Melbourne. These included 20 substations of various types, 12 cable risers, 5 transformers, 2 terminal stations, and 13 transmission line routes.

Spot measurements of ELF EMF were taken at incremental distances away from the electrical infrastructure and at the nearest boundary of residential properties and other public places. Public places included bus stops, playgrounds, schools and childcare centres.

The key findings of this study are:

- All measurements of ELF EMF around electricity supply infrastructure were well below the NHMRC exposure limits (generally below 1% of the limits).
- The levels of ELF EMF generally decreased rapidly with increasing distance. However, the rate of decrease with respect to distance was highly variable for all types of infrastructure apart from transmission lines. Residential properties (at the boundary) and other public places in close proximity generally had higher than normal magnetic fields however these areas are not considered to represent “prolonged residential exposure”.
- The electric fields measured at the boundary of residential properties near transmission lines were higher compared to homes near other types of infrastructure.

1. Introduction

Electricity sub-stations, transformers, transmission lines and other electrical sources such as common electrical appliances and wiring, all emit extremely low frequency (ELF) electric and magnetic fields (EMF). Due to the widespread use of electricity, we are surrounded by these electrical sources in our daily lives. Therefore we are all exposed to some level of ELF EMF constantly.

Exposure to ELF EMF at high levels can affect the functioning of the nervous system. While such exposures are very unusual, there are exposure limits issued by the National Health and Medical Research Council which are aimed at preventing established harmful effects (NHMRC, 1989). The NHMRC limits for exposure to the general public are 5,000 V/m and 100 µT, for the electric and magnetic field, respectively.

Based on current research, there is little evidence that exposure to ELF electric fields below the NHMRC limits is a health hazard. The majority of the research has also not shown ELF magnetic fields below the NHMRC limits to be hazardous to human health. However a number of epidemiological studies have reported an association between average residential exposure to magnetic fields greater than what is normally encountered (0.4 µT) and an increased risk in childhood leukaemia (IARC, 2002). However, this association is not supported by laboratory or animal studies and no credible theoretical mechanism has been proposed. Homes with background magnetic field levels above 0.4 µT are usually due to close proximity to electrical supply infrastructure (such as sub-stations, transformers, transmission lines etc). In 2002, the International Agency for Research on Cancer (IARC) classified ELF magnetic fields as "possibly carcinogenic to humans" based on the combined results of epidemiological studies.

It is important to note that an average level of 0.4 µT is not an exposure limit or safe level. This exposure level was statistically selected to distinguish "exposed" and "unexposed" participants in epidemiological studies. The evidence is not adequate to suggest that prolonged exposure to magnetic field levels below the NHMRC limits is a hazard to human health.

ARPANSA conducted a series of measurements of ELF EMF in the vicinity of common electricity supply infrastructure to gain understanding of the levels that may be encountered by the general public.

1.1 Objective

The objective of this report is to provide a better understanding of the levels of ELF EMF in residences which are in close proximity to various types of electrical supply infrastructure located in Melbourne.

1.2 Scope

The scope of the measurement study was to:

- Develop a field based ELF EMF measurement protocol
- Measure ELF EMF associated with electricity supply and distribution infrastructure
- Analyse the measurement data to identify trends and typical ELF EMF levels when in close proximity to electrical supply infrastructure located in Melbourne

2. Method

2.1 Selection of sites

The infrastructure that was chosen for measurement was not statistically representative of the entire infrastructure in Melbourne. It was decided that the sample set should contain as many different sub-types for each infrastructure to be measured. For example, for measurements of substations, as many different configurations as possible including substations contained within a building where the outer walls formed the boundary to public access, fenced installations and kiosk type substations, were taken into account. Cable risers were selected depending on wire size (and therefore difference in current and voltage carried) and height from the ground of attached overhead wires.

Several methods were employed in selecting appropriate infrastructure for measurements. As a preliminary strategy to locating suitable measurement sites ARPANSA staff located at the Melbourne campus were requested to provide information about known locations of any electrical infrastructure types. This led to only a few appropriate sites being chosen for measurements, however, as a result of driving to these locations, other infrastructure candidates were revealed by visual reconnaissance.

The most successful method for choosing suitable measurement locations for transmission lines was to use the SP Ausnet publication ”A Guide to Living with Transmission Line Easements” (2012). This publication contained a schematic map of the SP Ausnet transmission line network. Combining this with the 2010 Melway street directory for Melbourne (Melway Publishing Pty Ltd, Melbourne, Australia), transmission line routes could be located between terminal stations. Once the route was known, Google Maps was used to obtain a satellite view of the areas in order to find a suitable location along the transmission line easements to perform measurements. Each set of transmission line measurements was conducted at a different route on the system and an attempt was made to choose the routes taking into account the coverage of as many different configurations of conductor sets and voltages and/or currents that might be carried.

Further, locations for measurements of all infrastructure types were also decided by examining their accessibility and proximity to residential areas and places of public interest. Once each piece of infrastructure and site was selected, the area was documented with photos and general site information.

Altogether, 52 sites were chosen for measurement, including 20 substations of various types, 12 cable risers, 5 transformers, 2 terminal stations, and 13 transmission line routes.

2.2 ELF EMF measurement protocol

The measurements were carried out from the start of May 2010 to the end of July 2010 for infrastructure including substations, terminal stations, transformers and cable risers. Transmission line measurements were conducted in November 2010. All measurements were conducted on weekdays between 9 AM and 6 PM, by trained ARPANSA staff members.

The ELF electric field was measured with a Narda EHP50C analyser probe (Narda, Germany), interfacing with a laptop computer. The ELF magnetic field was measured with an Emdex II hand-held magnetic field meter (Enertech, United States). The instruments were calibrated using the method described in Appendix C. The distances between the nearest house/places of public interest to the infrastructure were measured using a laser range finder.

With the exception of the transmission lines, the starting point of ELF EMF measurements was approximately 0.2 metre (m) away from the wall or other physical boundary of the infrastructure. This was the nearest point at which the probe could be placed with the fully extended tripod legs on which it sat. The starting point of measurement would be the side of the infrastructure where the highest reading was encountered (searched by moving around the perimeter of the infrastructure using the hand-held magnetic field meter). Subsequently, measurements were performed at 1 m increments, up to 10 m away from the infrastructure. Figures 1 and 2 show the schematic diagrams of substations and transformers/cable risers measurements, respectively. This measurement procedure was conducted on each of the four sides of individual infrastructure unless there was no access to a particular side.

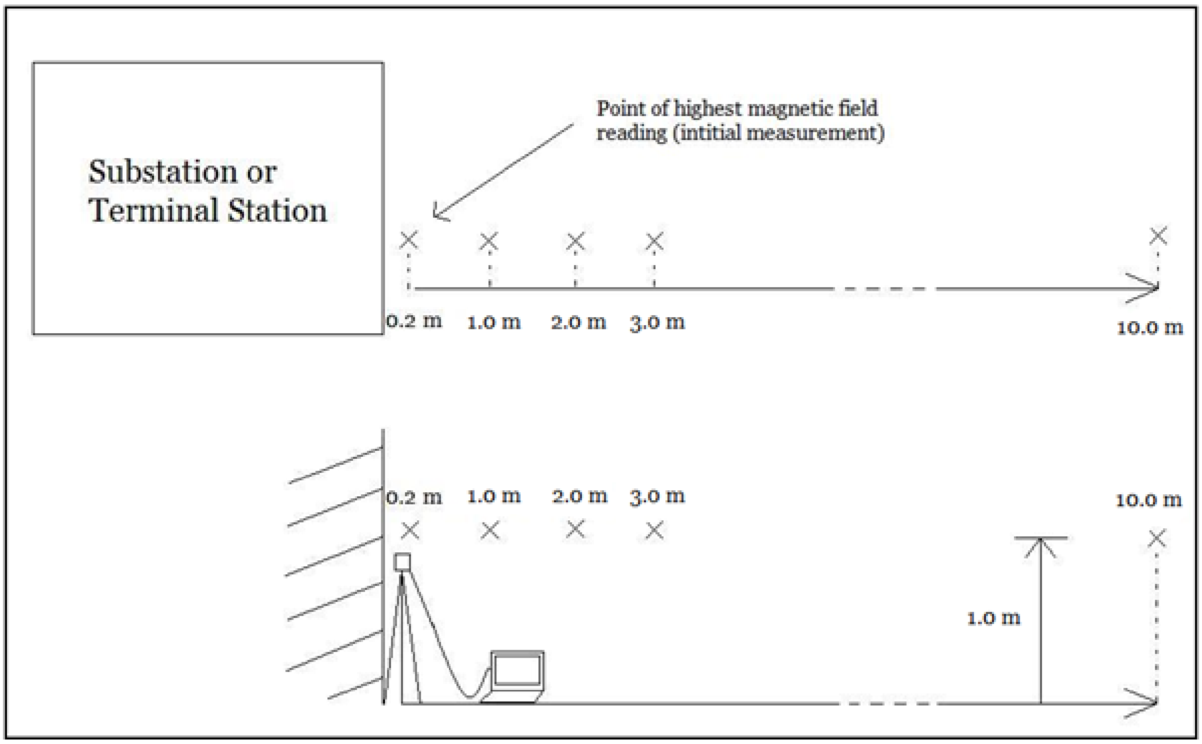

Figure 1. Substation Measurement Diagram

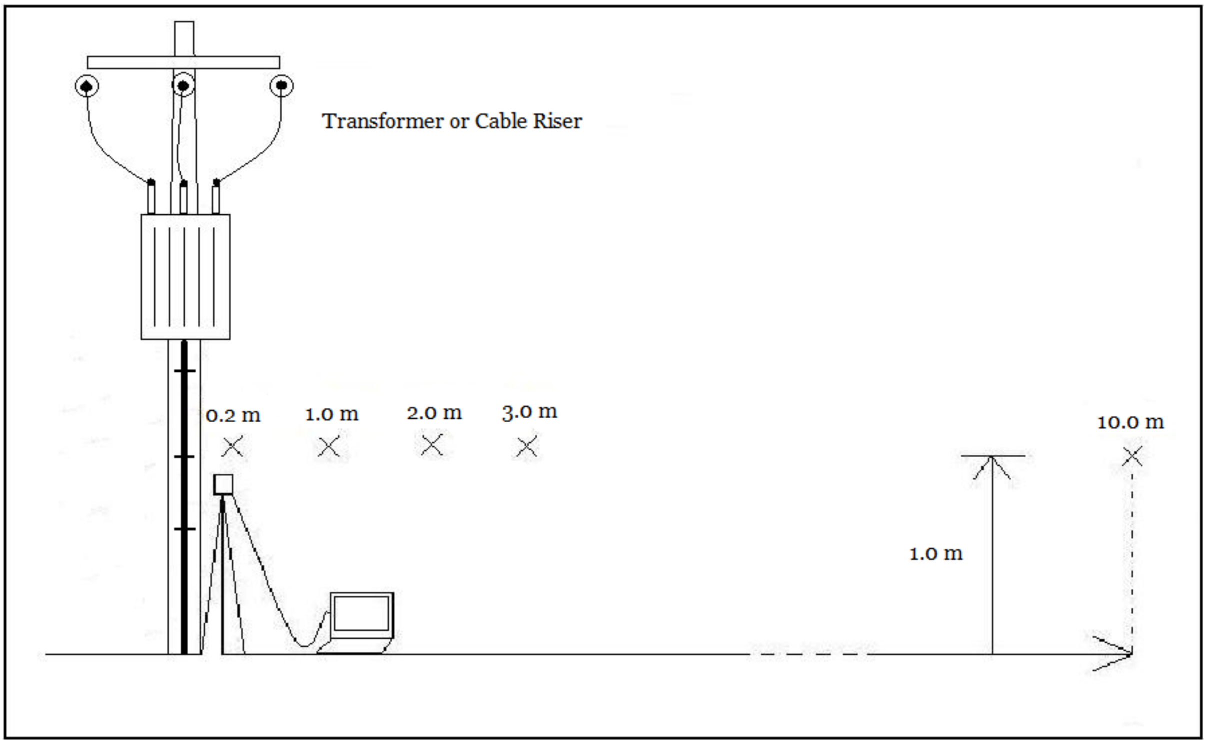

Figure 2. Transformer or Cable Riser Measurement Diagram

In the case of transmission lines, the ELF EMF measurements were conducted along a straight line perpendicular to the direction of the conductors. Whenever possible, the spot measurements in the middle of two transmission line towers were taken. It was assumed that this central measurement point represented the highest level of ELF EMF, since the conductors sag and they are the closest to the ground at that point. Measurements underneath the centre and both outer conductors, up to distances of 30 m, in 5 m increments were taken. In some cases, the measurements stopped at less than 30 m if houses were present. Due to the different configurations of transmission lines, the measurement's starting point varied (refer to Appendix D). Figure 3 shows the schematic diagram of transmission lines' measurements.

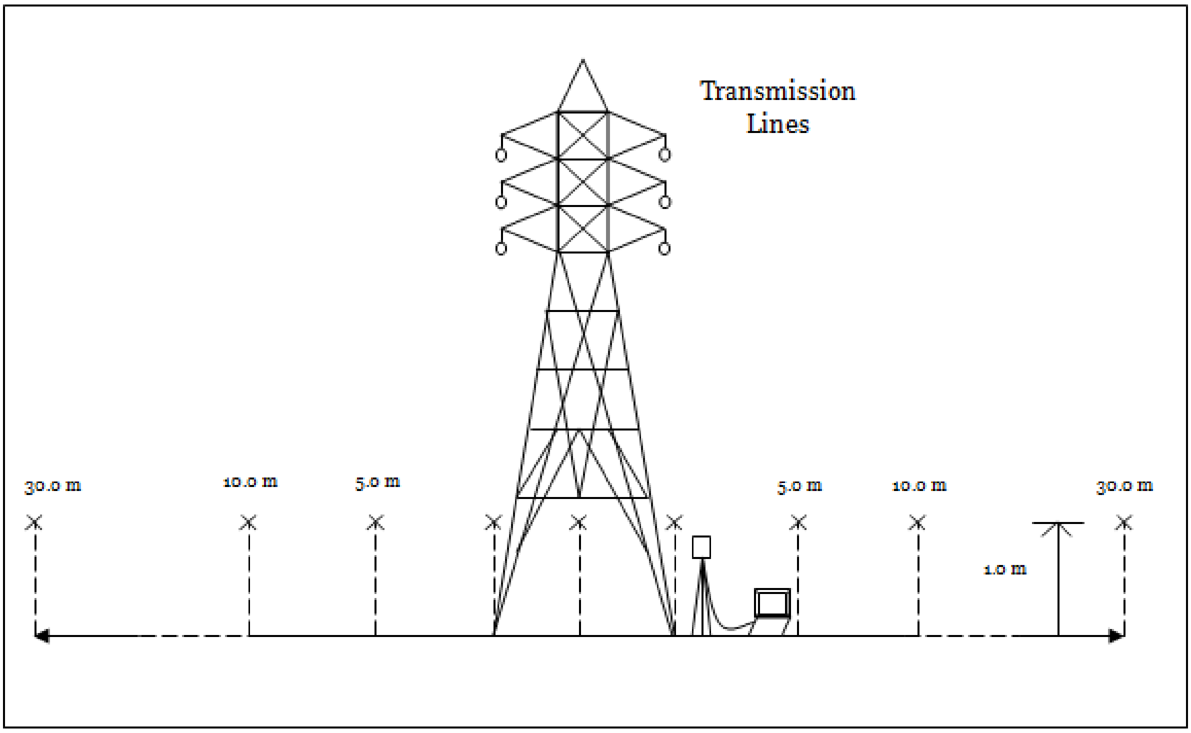

Figure 3. Transmission Lines Measurement Diagram

In all cases, we also conducted spot measurements at the boundaries of nearby residential properties within 50 m and other public places of interest (bus stops, playgrounds, schools and childcare centres) within 100 m. We performed all spot measurements at a height of 1 m.

All of the infrastructures measured were photographed and their location details are documented in Appendix B.

2.3 Statistical analysis

The data from all measurements was analysed using Microsoft Excel to generate descriptive statistics i.e. mean, median, maximum and minimum values.

3. Results

Tables 1 and 2 show summary statistics for the electric and magnetic fields, respectively, measured at nearby residences to terminal stations/substations, cable risers and transformers. Measurements generally showed a log-normal distribution so they are best characterised using the median. The electric and magnetic fields around terminal stations/substations, cable risers and transformers generally reduced rapidly with increasing distance. However due to the presence of other electrical current sources, there was no clear pattern relating EMF exposure and distance for each type of infrastructure.

Table 1. Electric fields at residences nearby electrical infrastructure

Statistic	Infrastructure								
	Terminal Stations and Substations			Transformers			Cable Risers		
	Nearest Residences			Nearest Residences			Nearest Residences		
	Electric Field (V/m)	% of NHMRC Limit	Distances (m)	Electric Field (V/m)	% of NHMRC Limit	Distances (m)	Electric Field (V/m)	% of NHMRC Limit	Distances (m)
Median	1.10	0.02	14.90	3.45	0.07	12.05	7.59	0.15	5.65
Mean	31.97	0.64	13.19	15.76	0.32	10.27	21.41	0.43	8.72
Range	892.37	17.85	42.10	91.96	1.84	24.3	215.74	4.31	24.10
Minimum	0.03	0.00	0.00	0.34	0.01	1.5	0.04	0.00	1.00
Maximum	892.40	17.85	42.10	92.3	1.85	25.8	215.78	4.32	25.10
n	**63**		**66**	**13**		**13**	**14**		**14**

Table 2. Magnetic fields at residences nearby electrical infrastructure

Statistic	Infrastructure								
	Terminal Stations and Substations			Transformers			Cable Risers		
	Nearest Residences			Nearest Residences			Nearest Residences		
	Magnetic Field (µT)	% of NHMRC Limit	Distances (m)	Magnetic Field (µT)	% of NHMRC Limit	Distances (m)	Magnetic Field (µT)	% of NHMRC Limit	Distances (m)
Median	0.30	0.30	14.90	0.49	0.49	12.05	0.58	0.58	5.65
Mean	0.54	0.54	13.19	0.52	0.52	10.27	0.62	0.62	8.72
Range	3.33	3.33	42.10	1.31	1.31	24.3	1.95	1.95	24.10
Minimum	0.01	0.01	0.00	0.05	0.05	1.5	0.04	0.04	1.00
Maximum	3.34	3.34	42.10	1.36	1.36	25.8	1.99	1.99	25.10
n	**66**		**66**	**13**		**13**	**14**		**14**

All the median electric and magnetic field measurements around terminal stations/substations, cable risers and transformers were below 1% of the NHMRC limits. Houses were generally closer to cable risers (median distance of about 6 m) so median measurements were higher compared to houses nearby terminal stations/substations and transformers.

Table 3 and 4 show summary statistics for electric and magnetic fields measured at incremental distances from transmission lines. The electric and magnetic fields around transmission lines reduced rapidly with increasing distance, as expected. Figures 4 and 5 show the median electric and magnetic fields at different distances from transmission lines, respectively. The median electric and magnetic fields measured at the boundary of the nearest residences (about 20 m away) were much lower than the NHMRC limits (3.9% of the limit for the electric field and 0.7% for the magnetic field).

Table 3. Electric fields around transmission lines

Transmission Lines											
Statistic	Distance Away from Infrastructure (m)								Nearest Residences Electric Field (V/m)	% of NHMRC Limit	Nearest Residences Distances (m)
	0	5	10	15	20	25	30	50			
	Electric Field (V/m)										
Median	2451.38	2106.55	1053.69	632.25	416.6	253.73	176.45	120.46	**195.45**	3.91	19.25
Mean	2332.15	1955.3	722.16	279.35	92.31	75.45	46.75	92.91	**136.35**	2.73	16.00
Range	4824.6	5570.1	4372.48	3549.1	2254.63	1625.34	1244.2	350.6	**973.64**	19.47	45.00
Minimum	79.9	50.8	6.72	6.4	14.17	8.96	6.9	4.46	**1.16**	0.02	5.00
Maximum	4904.5	5620.9	4379.2	3555.5	2268.8	1634.3	1251.1	355.06	**974.80**	19.5	50.00
n	**24**	**24**	**23**	**17**	**13**	**11**	**11**	**7**	**20**		**20***

*Electric field measurements were not taken at one site

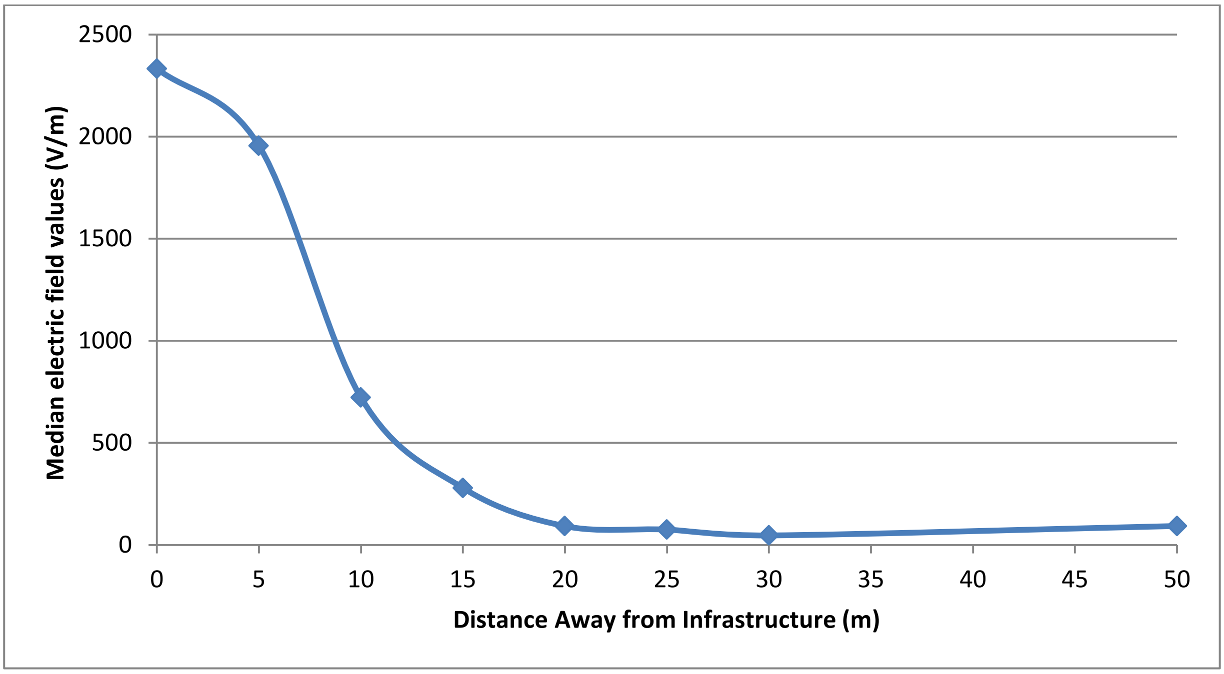

Figure 4. Median electric fields at different distances from transmission lines

Table 4. Magnetic fields around transmission lines

Transmission Lines											
Statistic	Distance Away from Infrastructure (m)								Nearest Residences Magnetic Field (µT)	% of NHMRC Limit	Nearest Residences Distances (m)
	0	5	10	15	20	25	30	50			
	Magnetic Field (µT)										
Median	2.61	2.01	1.5	1.15	1.05	0.9	0.72	0.40	**0.71**	0.71	19.25
Mean	1.99	1.52	1.21	0.82	0.72	0.61	0.54	0.23	**0.53**	0.53	16.00
Range	7.28	6.16	4.88	3.68	2.87	2.05	1.67	0.97	**1.79**	1.79	45.00
Minimum	0.48	0.38	0.28	0.18	0.19	0.39	0.31	0.11	**0.19**	0.19	5.00
Maximum	7.76	6.54	5.16	3.86	3.06	2.44	1.98	1.08	**1.98**	1.98	50.00
n	**26**	**26**	**24**	**19**	**14**	**11**	**11**	**9**	**21**		**21**

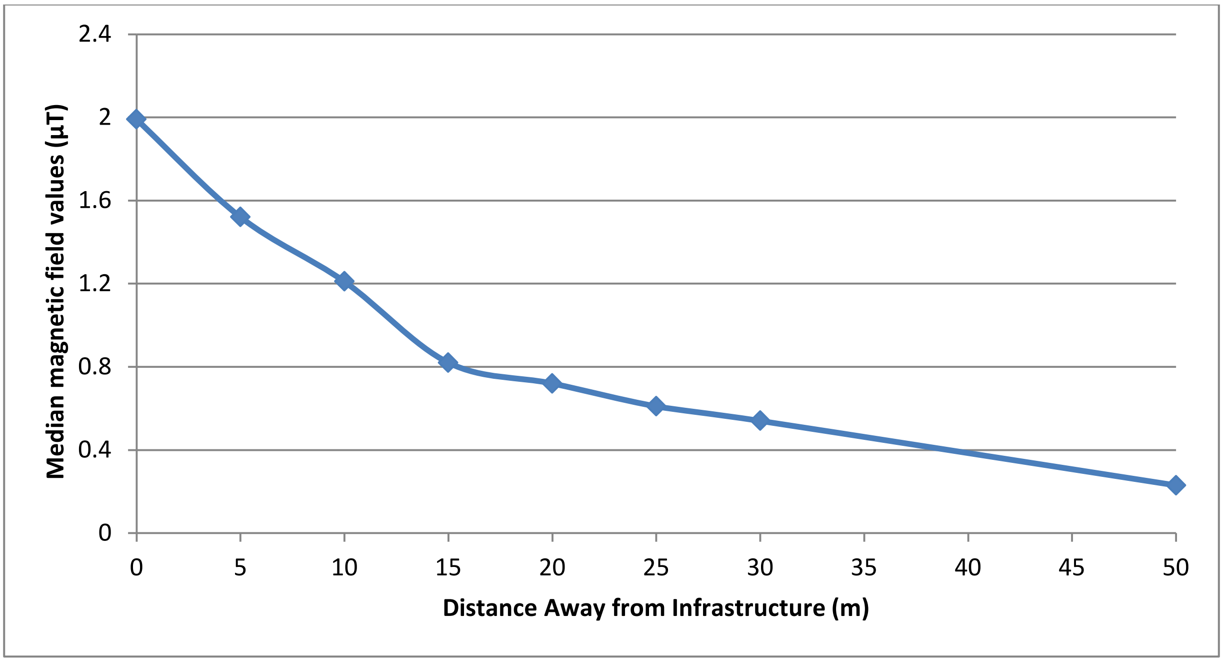

Figure 5. Median magnetic fields at different distances from transmission lines

Summary statistics for the electric and magnetic field measurements at public places (including bus stops, playgrounds, schools and childcare centres) nearby electrical infrastructure (terminal stations/substations, cable risers, transformers and transmission lines) are shown in Table 5. The median electric and magnetic fields were below 1% of the NHMRC limits.

Table 5. Electric and magnetic fields at public places near electricity supply infrastructure

Statistic	Distances (m)	Magnetic Field		Electric Field	
		Values (µT)	% of NHMRC Limit	Values (µT)	% of NHMRC Limit
Median	19.60	0.59	0.59	4.20	0.08
Mean	29.34	0.64	0.64	94.58	1.89
Range	106.00	2.62	2.62	1675.75	33.52
Minimum	0.00	0.04	0.04	0.05	0.00
Maximum	106.00	2.66	2.66	1675.80	33.52
n	**26**	**26**		**25**	

4. Discussion

4.1 General observations

Measurements of ELF EMF around electricity supply infrastructure were well below the NHMRC exposure limits (generally below 1% of the limits). Although electric and magnetic fields generally decreased rapidly with distance, the rate of decrease with respect to distance was highly variable for all types of infrastructure apart from transmission lines. This could be due to a number of reasons:

- variation of electrical current flowing in the infrastructure during different periods in measurement
- contributions from other infrastructure and electrical devices in the vicinity
- presence of other objects in the vicinity

4.2 Limitations

The measurements conducted within this study were not always indicative of the source of the EMF exposure. For example, in the case of the pole mounted transformers and cable risers measured, they were always located around overhead distribution lines of varying voltages and currents. It was not clear how much of the contribution to the field levels was from the wires overhead or the infrastructure in question. Also, infrastructure such as terminal stations and substations were almost always surrounded by cable risers and distribution lines. Transmission lines were always present around terminal stations. Higher readings were consistent around the additional infrastructure associated with these facilities.

Additionally, the measurements conducted were spot measurements and so did not take into account how the fields fluctuated over time. Fluctuations could also be caused by load on the infrastructure and may vary over a day. Also, no detailed distance criteria was set for measurements at the boundaries of surrounding residential properties, so the measurements were conducted at distances that were extremely variable, ranging from immediately adjacent or up to 50 m away for substations and terminal stations and up to 100 m away for transmission lines. The overall levels reported for the nearest residential properties do not therefore reflect consistent distances away from the infrastructure.

The ability to conduct some measurements was limited by physical obstructions such as walls, buildings, adjoining residential or commercial properties, or trees blocking the line of measurement. Where roads were present, no measurements were taken for safety reasons.

5. Conclusion

Measurements of ELF magnetic fields around electricity supply infrastructure were well below (generally less than 1%) the exposure limit of 100 µT (NHMRC 1989). Residential properties (at the boundary) and other public places in close proximity generally had magnetic fields higher than normal however these areas are not considered to represent “prolonged residential exposure”. Inside homes in Melbourne, a recent survey conducted by ARPANSA found that only about 2% are likely to have higher than normal magnetic fields (Karipidis, 2014).

The electric fields at nearby residences and other places of interest were also well below the 5000 V/m limit (NHMRC 1989). The higher electric fields measured at the boundary of residential properties near transmission lines compared to other types of infrastructure are due to the higher voltage.

6. References

[All web links were accessed successfully on 18 June 2014]

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Appendix A: Transmission Line Route Map

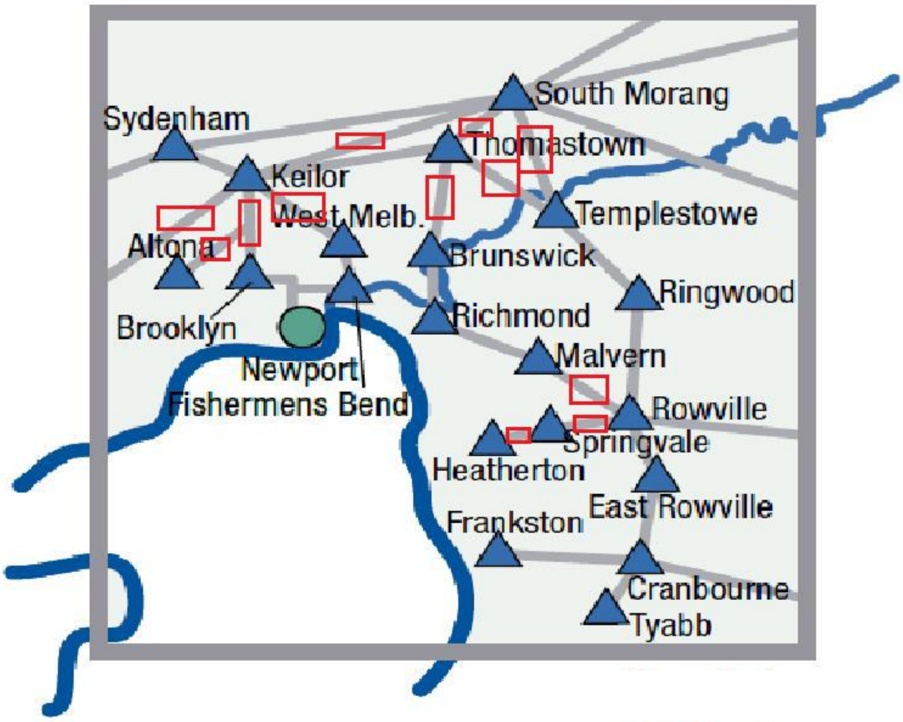


Figure A1. **Sourced from:** ***Electricity distribution network*** **2012, SP AusNet, Australia, viewed 10 October 2012, <**http://www.sp-ausnet.com.au/?id=22023012026C624F8D0B9B72DCA2575DE0036D105**>**

Appendix B: Site Pictures and Descriptions

Transformers

Pole mounted transformer located at approx. 183 Anderson Rd Fawkner. Transformer is located in front of a residential property with a bus stop and a health care centre (Chiropractor) nearby.

Pole mounted transformer located at approx. 23 Myddleton Dr Viewbank. Transformer is located in front of residential property.

Pole mounted transformer located at approx. 1 Bosquet St Maidstone. There is a residential property on the east side of the transformer.

Pole mounted transformer located at approx. 25 Gower St Kensington. There are residential properties on all sides of the transformer and a primary school nearby.

Power substation (fenced) located at 661-663 Moreland Rd Pascoe Vale. The station is adjacent to residential properties and there is an ABC Child Learning Centre nearby.

Power Substations

Pole mounted transformer located at approx. 83 Yallambie Rd Yallambie. There are residential properties on the north side of the transformer.

Power substation (building) located at approx. 33 Inglesby Rd Camberwell with residential properties adjoining both sides and a school sportsground on the opposite side of the road.

Kiosk type substation located near a playground on the corner of Wenden Rd and Roycroft Ave Mill Park.

Kiosk type substation located at approx. 1 Wenden Rd Mill Park. The substation is adjacent to residential properties and near a playground.

Kiosk type substation located at approx. 21 Jacaranda Dr Mill Park. There is a playground and recreation area nearby and adjacent residential properties.

Power substation (fenced) located at 42 Hotham St St Kilda East. The station has multiple adjacent residential properties including houses and units and a bus stop in front on Hotham St.

Power substation (building) located on the corner of Holden St and Pilkington St Fitzroy North. There is a residential property adjacent to the substation.

Power substation (fenced) located on the corner of Todman St and Frensham Rd Watsonia. The station is located near multiple residential properties. There are also two sets of double-circuit transmission lines nearby for convenient measurement.

Power substation (fenced) located at the end of Bolton St and on Brisbane St. The station is next to commercial properties on Brisbane St.

Kiosk type substation located at approx. 3 Schafter Dr Doncaster East. There are residential properties on both sides of the kiosk.

Power substation (fenced) located at approx. 86 Northumberland Rd Pascoe Vale. The station is next to residential properties on all sides of the boundary fence line.

Power substation (fenced) located near approx. 14 Sefton Pl Camberwell and East Camberwell train station. There are residential properties nearby to the west and walking tracks around the station.

Power substation (fenced) located on the corner of Riversdale Rd and Redfern Rd Camberwell. There is a skate park on the west side of the station and residential properties to the south.

Kiosk type substation located at Cookson Rd in Camberwell. The substation is located on the corner of park land and there is a residential property across the road from it.

Power substation (fenced) located at approx. 13 Smith St Kensington. The station is next to residential properties along the fence line.

Power substation (building) located at 547 Macaulay Rd Kensington. There are a residential properties adjoining the substation and residential properties within 30 m across the road.

Power substation (building) located at approx. 55 Margaret St Box Hill. There are residential properties adjoining the substation

Power substation (building) located at approx. 125 Noone St Clifton Hill. There are residential properties adjoining the substation.

Power substation (fenced) located at approx. 230 Williams St Toorak. There are nearby residential properties on all sides.

Power substation (fenced) located at approx. 28 Hopetoun St Kensington. There are nearby residential properties on all sides.

Transmission Lines

Three sets of double-circuit transmission lines located near Clivedon Crt Doncaster. There are residential properties near the conductors on the south side and a walking track directly underneath.

Two sets of double-circuit transmission lines located at approx. 46 Morwell Ave Watsonia. There are residential properties on either side of the easement which contains a playground directly underneath the conductors about 50 metres away from the steel support towers to the northwest.

Two sets of double-circuit transmission lines located at approx. 26 Tennolli Cres Mill Park. There are residential properties on either side of the easement.

Two sets of double-circuit transmission lines located at approx. 57 Watsons Rd Glen Waverley. There are backyards of residential properties directly underneath the conductors.

One set of double-circuit transmission lines located at approx. 11 Mahoneys Rd Thomastown. There are residential properties directly underneath the conductors about 50 metres away from the steel support towers to the northeast.

One set of double-circuit transmission lines located at along the central nature strip of Washington Dr Oakleigh East. There are also power distribution lines on both sides of the road where residential properties are located.

One set of double-circuit transmission lines located on the corner of Van Ness Ave and Oakland St Maribyrnong. The conductors pass over within about 10 metres of residential property boundaries. There are also power distribution lines on the road where one property is located.

One set of single-circuit transmission lines located at approx. 34 Epping Rd Epping. There are residential properties on either side of the easement including a new housing estate to the north.

One set of single-circuit and one set of double-circuit transmission lines located at approx. 46 Winslow Cres Deer Park. The single-circuit transmission lines come within about 10 metres of the residential properties located to the South East.

One set of double-circuit transmission lines located at approx. 29 Hall St West Sunshine. The conductors pass over a walking track and near residential properties. There is also a bus stop underneath the conductors.

Two sets of single-circuit transmission lines located at approx. 1404 Main Rd Eltham. There are residential properties on either side of the easement.

Two sets of double-circuit transmission lines located at Lynch Rd Brooklyn. There are residential properties on the north side of the conductors. Both sets of double circuit conductors are supported by one set of towers.

One set of double-circuit transmission lines located along the end of Kalimna Ave Mulgrave. There are residential properties to the south of the conductors.

Terminal Stations

Terminal station located at the corner of Mahoneys Rd and High St Thomastown. There are residential properties to the south along Mahoneys Rd and bus stops on High St.

Terminal station located at Barkley Ave and Mary St Richmond. There are residential properties to the west along Mary Rd.

Cable Risers

Cable riser located at approx. 124 Adderley St West Melbourne. There are no residential properties around the cable riser.

Cable riser located at approx. Stubbs St 161-179 Kensington. There are no residential properties around the cable riser. There is one commercial property nearby.

Cable riser located at the corner of Upper Heidelberg Rd and Abbotsford Rd Ivanhoe. There is a restaurant underneath the west side of the cable riser.

Cable riser located at approx. 383 Lower plenty Rd Viewbank. There is a bus stop nearby and residential properties to the north.

Cable riser located at the corner of Cookson St and Broadway Camberwell. There are residential properties on the north side of the cable riser.

Two cable risers located at the Thompsons Rd Service Ln in Lower Templestowe. There are residential properties on the west side of the cable riser and a bus stop directly underneath one of them.

Cable Riser located at approx 330 Arden St Kensington. There are no residential properties or public amenities nearby. There is one commercial property nearby.

Two large cable risers located at approx. 16 Arden St Kensington. There are no residential properties nearby. There is a walking and bike track underneath the cable risers.

Site Information: Cable Riser located at approx. 231 Yallambie Rd Yallambie. There are residential properties on the south side of the cable riser and a primary school on the north side.

Site Information: Cable Riser located at approx. 578 Lower Plenty Rd Viewbank. There are residential properties on the west and east sides of the cable riser.

Site Information: Cable Riser located at approx. 11 Derby St Kensington. There are residential properties on the north and south sides of the cable riser.

Appendix C: Equipment Calibration and Verification

Before any field measurements on infrastructure were conducted, the EMDEX II meters and NARDA EHP50C probe to be used were calibrated in the ARPANSA EMR Laboratory. Two EMDEX II magnetic field meters (in-house designations B1 and B3) and the NARDA EHP50C probe were exposed to known magnetic field strengths produced by a Helmholtz coils at frequencies of 50 Hz, 100 Hz, 200 Hz and 400 Hz to check the responses of the probes. The range of frequencies was tested in order to ensure that both the meters and the probe would respond accurately to harmonics of the 50 Hz primary frequency for electric power that may be encountered in the field. Each probe was tested across the three dimensional measurement vectors (x, y, and z axes) that would be combined to give a resultant field.

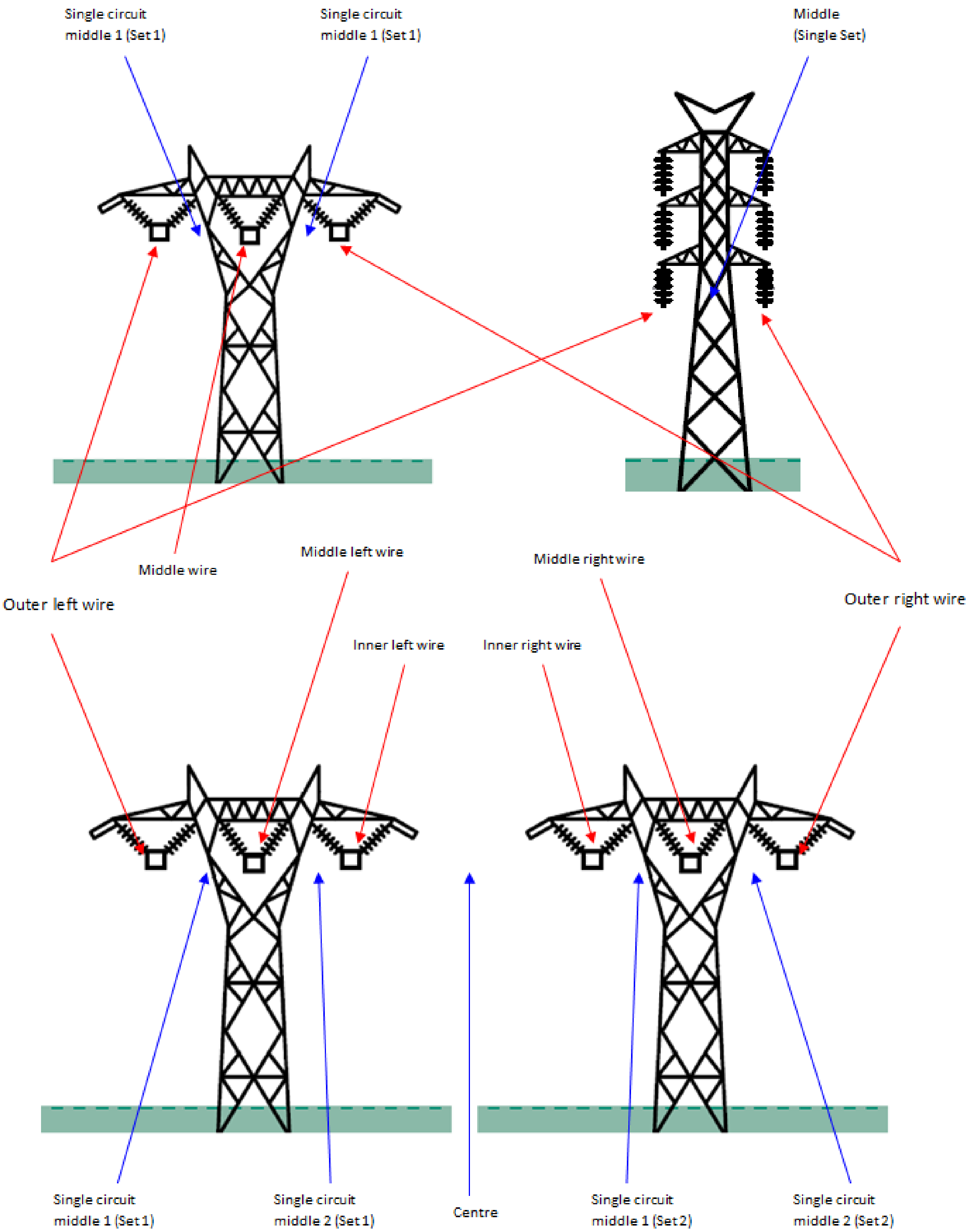
Calibration of the electric field response from the NARDA EHP50C was not conducted in-house, however, the probe and software were sent to The National Physical Laboratory (NPL) in the UK for calibration in August 2010. (NPL Certificate of Calibration for NARDA EHP50C magnetic and electric field analyser, Reference: 2010070170-1/2)

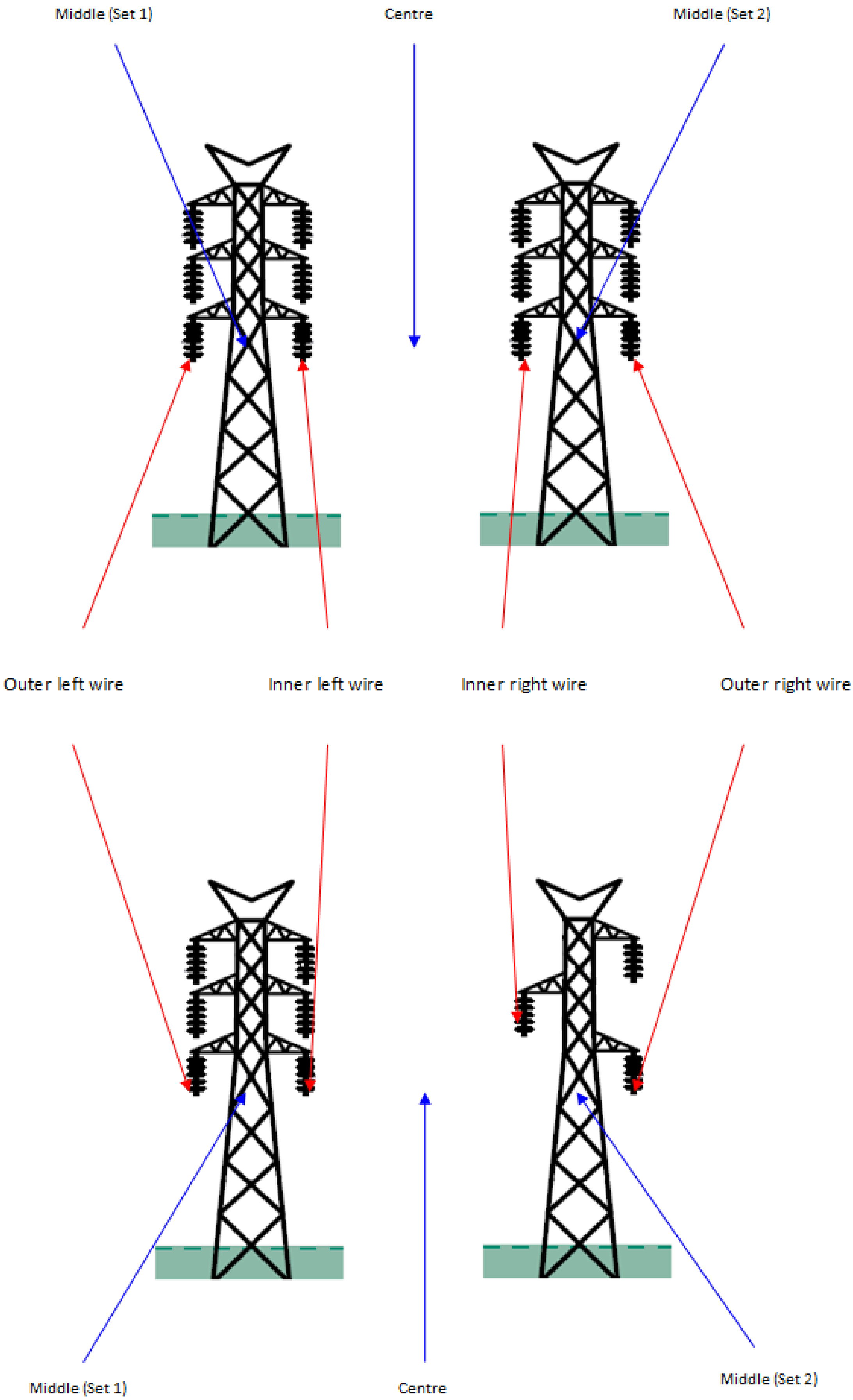
In order to make sure that the readings on both instruments were consistent in the field, it was decided to conduct some measurements in and around the ARPANSA Yallambie Campus. Also, a few measurements were conducted under a set of nearby transmission lines that run over Yallambie Road in Yallambie. During these exercises it was noted that the frequency response of the NARDA EHP50 probe below 40 Hz had to be removed from the frequency response range in order to eliminate background noise that would interfere with accurate readings of both the electric and magnetic field. The response of the NARDA probe to the EMFs was therefore limited to the contributions from generation at frequencies between 40 and 1000 Hz. This was appropriate as this range is relatively close to the flat line frequency response of the EMDEX II meters of between 40 Hz and 800 Hz.

Results of Laboratory Calibrations and Instrument Comparisons

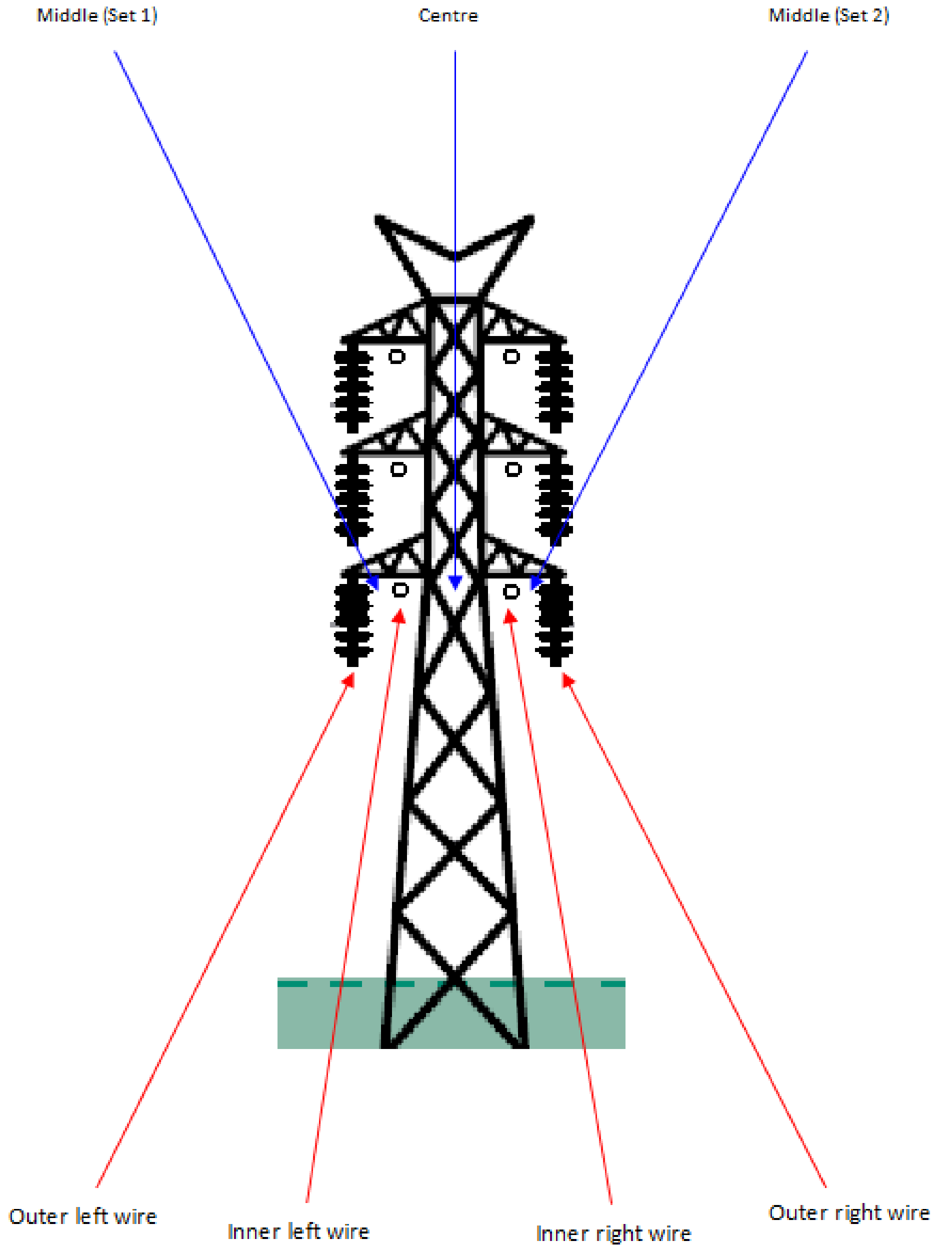
The results of the comparison between the ENERTECH EMDEX II magnetic field meters and the NARDA EHP50C magnetic and electric field analyser showed that the instruments measured magnetic fields accurately and consistently when they were exposed to known magnetic field strengths across the range of frequencies tested in laboratory conditions. The calibration factors for each instrument were extremely close to 1.0 (1.05 for EMDEX II meter B1, 1.03 for EMDEX II meter B3, 1.01 for NARDA EHP50C). The calibration factor for the NARDA EHP50C electric field component was determined to be 1.02 by the NPL certified calibration. When tested around power infrastructure in the ARPANSA building and at the transmission lines traversing Yallambie Road, the readings from both instrument types were within reasonable agreement of each other.

Appendix D: Transmission Line Measurement Legend





Middle (Set 1)
Centre
Middle (Set 2)
Outer left wire
Inner left wire
Inner right wire
Outer right wire
Middle (Set 1)
Centre
Middle (Set 2)


Middle (Set 1)
Centre
Middle (Set 2)
Outer left wire
Inner left wire
Inner right wire
Outer right wire