AMI Meter Electromagnetic Field Survey

Final Report

Prepared For Department of Primary Industries

Document Number: M110736

Date: 20 October 2011

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Final Rev 1.0	K. Ng, H. Girnara, C. Zombolas, Professor A. Wood	17/10/2011	Chris Zombolas	18/10/2011	Chris Zombolas	20/10/2011

Document Record

Rev. No.	Date	Recipient	Pages
Final Rev 1.0	20 October 2011	Tim Benjamin, DPI	All

Electromagnetic Field (EMF)[1] measurement site surveys were conducted on a range of Advance Meter Infrastructure (AMI) meters (also known as Smart Meters) installed in various types of houses. The EMF measurements were performed on AMI Meters installed by the major Victorian Electricity Distribution Businesses (DB) namely – United Energy Distribution, Jemena Electricity Networks, Citipower, Powercor and SP AusNet. As Jemena and United Energy have established a joint AMI program under the management of Jemena Asset Management, and Citipower and Powercor also have a joint AMI project; the DB AMI metering programs tested were: Jemena/United Energy, Citipower/Powercor and SP AusNet. The aim of the survey was to determine if EMF from the smart meters meets the Exposure Limits for General Public as specified by the relevant ARPANSA Radiation Protection Standards.

A review of these EM emissions in relation to Australian and international standards is given in Attachment A, together with a discussion of the magnitude of safety margins based on modeling and measurement studies. The attachment also reviews evidence of possible long-term health effects associated with exposure to EMF below the limits set by the standards.

The ARPANSA RPS3 standard specifies limits of human exposure to radiofrequency fields (RF) in the range 3 kHz to 300 GHz to prevent adverse health effects. The standard is applicable whenever any member of the general public may be exposed to RF fields and whenever employees may be exposed in the course of their work. The limits are given for exposure averaged over a 6 minute interval.

The ARPANSA Draft Radiation Protection Standard: Limits for Electric and Magnetic Fields, 0 Hz to 3 kHz applies to EMF from the mains electric powerlines and from apparatus using mains power. This frequency range is often referred to as Extremely Low Frequency (ELF).

Most measurements were conducted on single AMI installations, but also included a Group Meter installation (with 9 to 12 meters) from each of the three DBs.

On site measurements included:

- Narrowband[2] Radio Frequency (RF) Measurements, with and without HAN radio activated, conducted outside and inside the house;
- Extremely Low Frequency (ELF) 50 Hz Magnetic Field measurements resulting from power line currents , conducted outside and inside the house, with and without a 4kW electrical test load.

EMF Exposure at RF

At Group Meter sites, up to 6 AMI meters were interrogated simultaneously to measure the maximum combined EMF from multiple transmissions.

It was not practical to measure the 6 minute average field due to the transient (short burst) nature of the transmit cycles and the extremely variable duty cycle. The measurements were facilitated by forcing the meters to transmit continuously, an operating mode which would never occur while in service. The Duty Cycle is the length of time that the transmitter is actually transmitting and is expressed as a percentage. A Duty Cycle of 100% represents continuous transmissions. The actual Duty Cycle varied between the AMI Meters using the Mesh Radio technology (Jemena/United Energy and Citipower/Powercor) and those using the WiMax technology (SP AusNet). This was due to different meter reading schemes, modulation, and how the meter maintains the link with back office. The maximum or "worst case" duty cycle of 2.5% was used for AMI Meters using the Mesh Radio technology and 1.39% for AMI Meters using the WiMax technology. The use of the "worst case " duty cycle ensured that the results were broadly applicable to all meter installations and that it would be highly unlikely that any single meter or installation would cause higher EMF than what was measured during this survey.

The cumulative exposure over 6 minutes depends on the Duty Cycle of the meter transmissions. The narrowband RF peak power averaged over 6 minutes was derived by analysis using the worst case operational Duty Cycle. See paragraphs 4 and 13 of Attachment A of the Study Report by Professor Andrew Wood and Section 5.1 of this report for further details.

The test results showed that the maximum RF EMF Power Density levels were well below the ARPANSA General Public Limit, even when the meter was forced to transmit continuously (100% Duty Cycle).

Measurements made at Group Meters sites showed that, even with a number of meters being requested for meter data upload, the EMF peak field measured did not increase above the level of a single meter transmission. This showed that no two meters were transmitting simultaneously. Thus, it is expected that the maximum RF EMF power density from a Group Meter installation would not be higher than that of a single meter installation.

Table 1 below summarizes the results of the measurements of the RF EMF Power Density levels at 30cm calculated for each site based on the derived maximum Duty Cycle for the meter technology used. These results are presented in graphical form below in Figure 1 and 2. Figure 1 shows the RF EMF levels against 100% of the ARPANSA limit. Figure 2 has an expanded scale showing the RF EMF levels against % of the ARPANSA limit.

Table 1 – RF EMF Power Density Levels at 'Maximum' Operating Duty Cycle at 30 cm from meter in % of ARPANSA General Public Limit

Site No.	Distribution Business	Site Location	Outside Dwelling (% of Limit)		Inside Dwelling (% of Limit)
			Meter Box Door Open	Meter Box Door Closed	
1	Jemena	Attwood, 3049	0.012*	NM	NM
2***	Jemena	Craigieburn, 3064	0.6863	0.0083	0.0073

Site No.	Distribution Business	Site Location	Outside Dwelling (% of Limit)		Inside Dwelling (% of Limit)
			Meter Box Door Open	Meter Box Door Closed	
3	Powercor	Eaglehawk, 3556 (Bendigo)	0.112	0.0066	0.0015*
4	Powercor	Sedgwick, 3551 (Bendigo)	0.5671	0.00037	0.0017*
5	Jemena	Glenroy, 3046	0.1294	0.105	0.0056*
6	Jemena	Essendon, 3040	0.4067	0.001	0.0013
7	SP AusNet	Lower Plenty, 3093	0.0268	NM	0.0004
8**	Powercor	Balwyn, 3103	0.6271	NM	0.0113
9**	SP AusNet	Boronia, 3155	N/M	0.012	N/M
10	SP AusNet	Mooroolbark, 3138	0.0069	NM	0.000001
11	SP AusNet	Croydon, 3136	NM	0.0196	0.00009
12	SP AusNet	Bayswater North, 3153	0.0001	0.00006	NM
13**	United Energy	Elwood, 3184	0.8215	NM	NM
14***	United Energy	Hampton, 3188	0.7273	0.0017	0.00013
15	United Energy	Springvale South, 3172	NM	0.039	0.00018
16	Powercor	Clifton Hill, 3068	0.1156	NM	0.0056*

* Measured at 50cm from meter

** Group Meter Site.

*** Higher levels probably due to reflections from the metal door of the meter housing

'NM'- Not Measured

'Maximum' Operational Duty Cycle – 2.5% for Jemena/United Energy/CityPower/Powercor meters 1.39% for SP AusNet meters

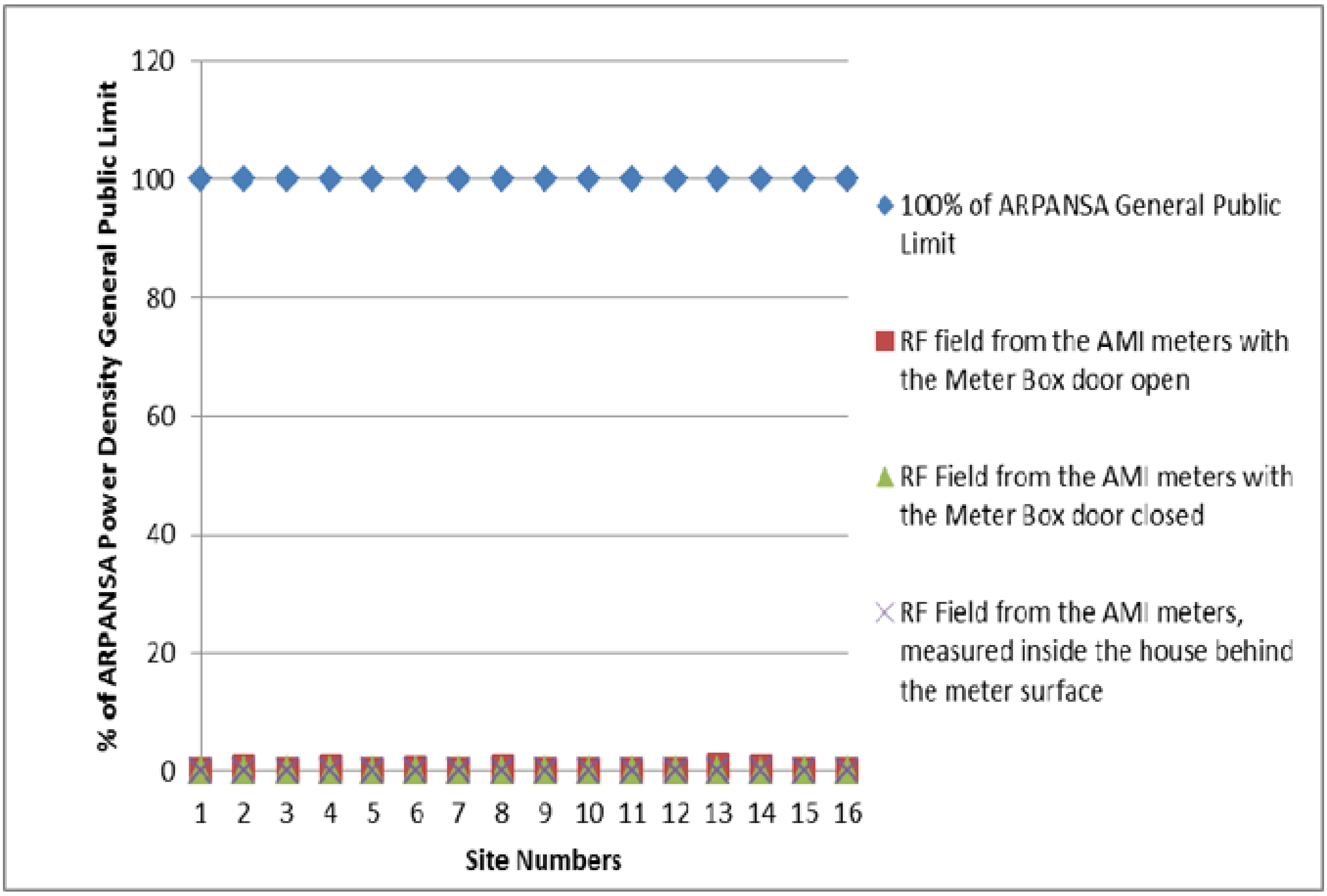

Figure 1 – Comparison of RF EMF Power Density levels from AMI meters to the ARPANSA General Public Limit. *(Refer to Table 1 in the report for the data points for Figure 1.)*

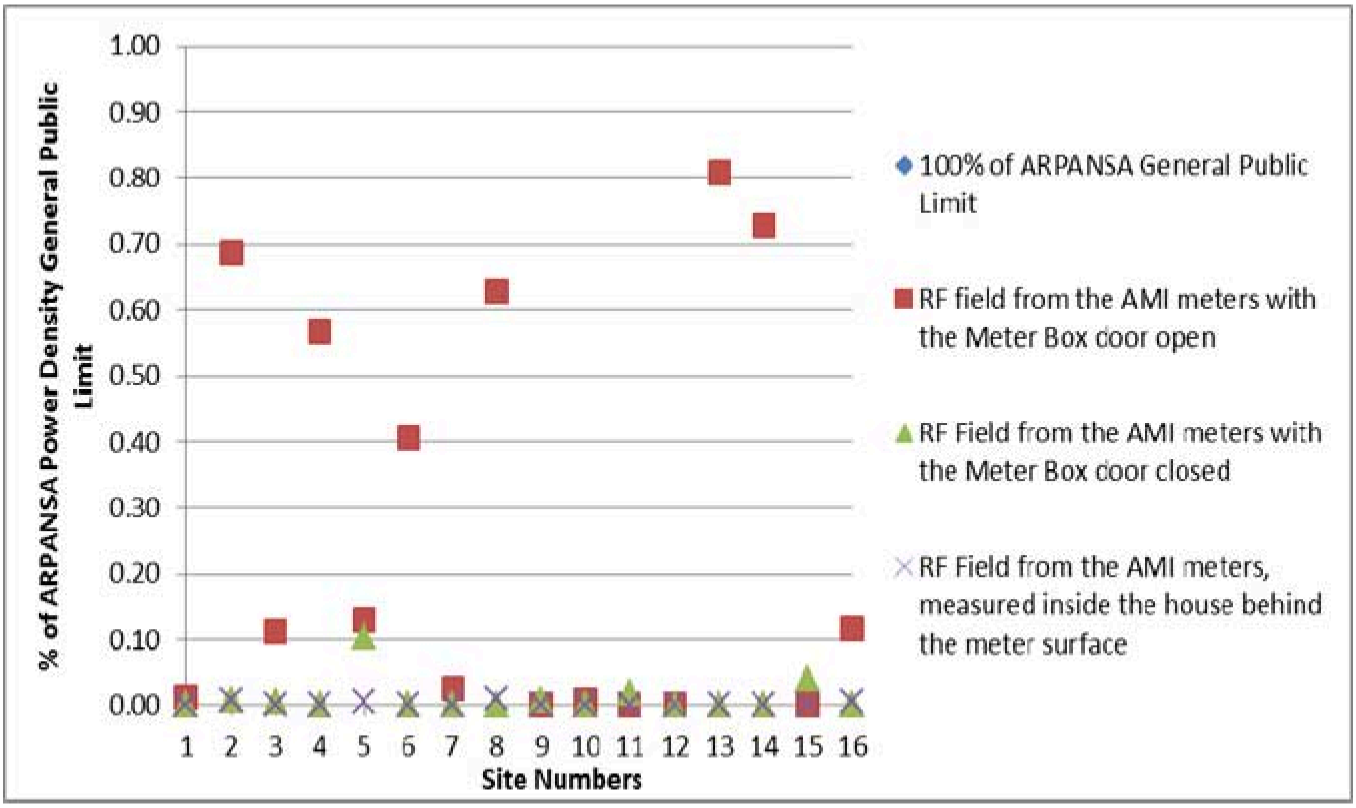

Figure 2 – Zoomed graph of Figure 1. *(Refer to Table 1 in the report for the data points for this graph.)*

The results show that the RF EMF Power Density levels measured at 30 cm from the AMI meters at 16 sites were less than 1% of the ARPANSA General Public Limit. Despite the variety of meter and antenna combinations, the test results indicate that the RF EMF levels do not vary by significant amounts. Some of the higher levels measured were due to reflections from the metal door of the meter box, however, when allowing for the transmit Duty Cycle, the average RF EMF level over 6 minutes is still very low compared to the ARPANSA limit. The levels inside the house were much lower still.

The EMF levels from the WiMax meter were generally lower than the Mesh Radio meter as it uses a lower transmitter power.

RF EMF tests were conducted on various other household appliances which involve exposure to RF fields, namely – Wireless Modem, Microwave Oven, Baby Monitor, Mobile Phone and Cordless Phone. The results are compared on Figure 3. The results show that the RF EMF levels from the Meters, even when measured just 30 cm away, are lower than the levels from other common household items. The actual EMF levels from a meter inside the house are very low compared to the levels from such devices as wireless modems, mobile phones and microwave cookers. The mobile phone is usually the highest EMF that people experience because they are used in close proximity to the body. The actual transmit power from the mobile phone was not known since the actual power transmitted varies depending on distance from a base station. The level measured here at 30 cm would be typical exposure to the head of the user when using a mobile phone with a hands free kit. The typical exposure from a mobile phone used at the ear or in the pocket is 1 to 2 Watt/m^2 (50 to 100% of the limit) for localised exposure.

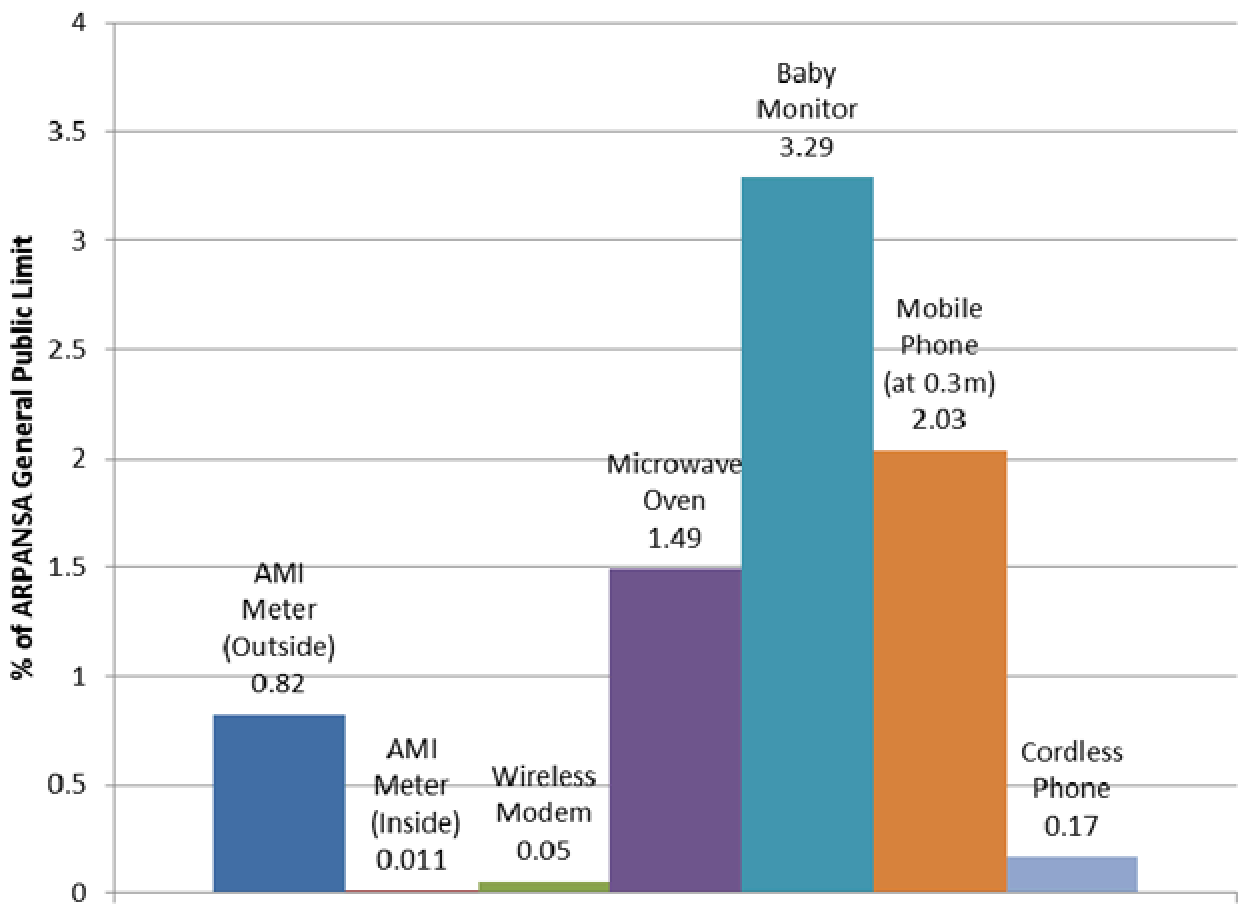

Figure 3 – Comparison of RF EMF Power Density levels : AMI Smart Meters and other Household Appliances.

EMF Exposure at ELF

ELF (50Hz) Magnetic Field measurements were conducted on household appliances including: old rotating disc electricity meter, electric blanket, vacuum cleaner, microwave oven and CRT (Cathode Ray Tube) TV. The results are compared to the Magnetic Field levels measured around AMI meters in Figure 4. The 50 Hz fields are lower than from some other common appliances such as vacuum cleaners and microwave ovens. The levels from other appliances such as hairdryers, power tools, induction cookers, fans and air conditioners would also be much higher. The results show that the fields from the Smart meter are slightly lower than the fields from the older electricity meter. It can be safely stated that the Smart meters themselves do not cause any increase in the power line related EMF levels and that replacement of the older meters with the AMI meters is a good way to reduce 50 Hz EMF exposure. (Refer to Section B of Attachment A of this report).

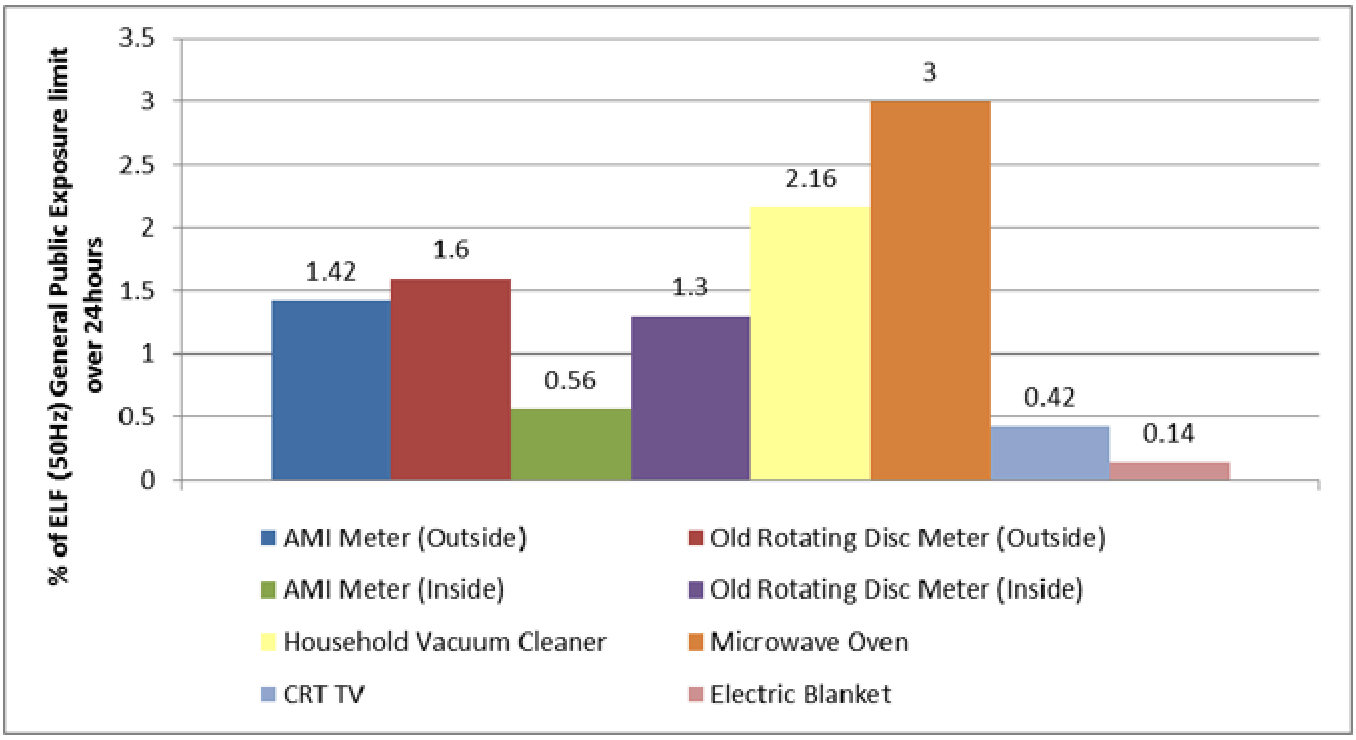

Figure 4 – Comparison of ELF Magnetic Field (50 Hz) Exposure levels at 30cm : AMI Smart Meter and other Household Appliances.

This Study Report details the results of Electromagnetic Filed (EMF) measurements on a number of Advance Meter Infrastructure (AMI) meters. Measurements were conducted on meters installed in dwellings of various type of construction.

The EMF measurements included Narrowband (NB) RF Field Measurements and ELF (50 Hz) Magnetic Field measurements.

The scopes and limitations of the tests conducted were:

- Not all types of house construction and meter configurations were tested due to unavailability of test sites.
- All meters tested were Single Phase AMI Meters, except for one 3-Phase Meter.
- Only one house with metal cladding and metal roof was tested.
- Only Peak RF power measurements were made on site. The power averaged over 6 minutes, as specified by ARPANSA RPS3, could not be measured due to the wide variability of the Duty Cycle. The average power was derived by analysis.
- Only measurements at 30cm and 50cm from the Meter are presented as 1m measurements could not be made at some houses because of the close proximity to the fence or neighbour’s wall.
- The only regional centre tested was in the Bendigo area (Eaglehawk and Sedgwick).
- HAN radio function was disabled for the WiMax Meters. HAN radio emissions were not tested on SP AusNet meters.

The terms Electromagnetic Fields (EMF), Electromagnetic Energy (EME) and Electromagnetic Radiation (EMR) have the same meaning for the purposes of this report.

1.1 Referenced Documents

A M110736-1	EME Test Plan For Advanced Metering Infrastructure (AMI) Meters Rev. 1.0, EMC Technologies Test Plan, 4/08/2011
B ARPANSA RPS3	Maximum Exposure Levels to Radiofrequency Fields - 3 kHz to 300 GHz, Radiation Protection Series Publication No. 3 (RPS3), issued by Australian Radiation Protection and Nuclear Safety Authority (ARPANSA)
C ARPANSA Draft ELF Exposure Standard	Draft Radiation Protection Standard Exposure Limits for Electric and Magnetic Fields — 0 Hz to 3 kHz, 7 December 2006

1.2 Acronyms

AMI	Advance Meter Infrastructure
ARPANSA	Australian Radiation Protection and Nuclear Safety Agency
BB	Broadband
DB	Distribution Business (Electricity)
DPI	Department of Primary Industries
ELF	Extremely Low Frequency
EMCT	EMC Technologies Pty. Ltd.
EME	Electromagnetic Energy
EMF	Electromagnetic Fields
EMR	Electromagnetic Radiation
FHSS	Frequency Hopping Spread Spectrum
HAN	Home Area Network
mG	MilliGauss
MIMO	Multiple Input Multiple Output (antenna)
NB	Narrowband
NIC	Network Interface Card
PD	Power Density
RF	Radio Frequency
RSS	Root Sum Square
µT	microTesla (1µT = 10mG)

1.3 Terminology

Narrowband – Refers to the fixed operating frequency band of the AMI Meters Transmit Frequencies.

Broadband – refers to a wide bandwidth which may include a number of transmissions from multiple sources such as mobile phones, TV broadcasts, two way radios etc.

Radio Frequency – Electromagnetic energy with frequencies in the range of 3kHz to 300GHz.

ELF – Stands for Extremely Low Frequency electromagnetic fields at frequencies of 50 and 60 Hz predominantly from electric energy generation, transmission, distribution and use.

Duty Cycle – When referred to in this report indicates the time that the AMI meters spend in transmit mode as a fraction of the total time of 6 minutes under consideration as specified by ARPANSA.

Power Density – The rate of flow of RF energy through a unit area normal to the direction of electromagnetic wave propagation; expressed in watt per square meter (W/m^2)

Back Office – Is the Distribution Businesses office which can communicate with all the meters in the area. Meters are controlled and read from the Back office.

Mesh Radio Network – A network architecture where high transmit powers are not required due to every node being capable of repeating the signal in the network.

WiMax – Is a communication protocol defined in IEEE 802.16.

Magnetic Field – When referred to in this report is the field produced by ELF (50Hz) mains frequency in the close vicinity of the Meters/Objects tested.

EMC Technologies (EMCT) was contracted by the Victorian Department of Primary Industries (DPI) to conduct Electromagnetic Field (EMF) measurements on a number of AMI Meters installed by five major Victorian Electricity Distribution Businesses (DBs). The DBs are: Jemena/United Energy, CitiPower/Powercor and SP AusNet. The aim was to provide independent measurements of the EMF emanating from the meters and to compare the levels against the Australian national standards for General Public exposure. The exposure levels were also compared with results from similar overseas measurements.

Testing was conducted on a range of dwellings of different construction, different meter box construction and meters with internal and external antennas. The total number of sites tested was 16 dwellings, including a Group Meter site (with 9 to 12 AMI Meters) for each of the DBs. The testing included Narrowband RF field measurements and ELF (50Hz) Magnetic field measurements. The list of the 16 dwellings is given in Table 2.

Table 2 – List of 16 sites tested

Site No	Site Locations	DB	Meter Type	Construction	Meter Box	Antenna
1	Attwood, 3049	Jemena	iCredit 500	Brick Veneer	Metal	External
2	Craigieburn, 3064	Jemena	iCredit 500	Brick Veneer	Metal	Internal
3	Eaglehawk, 3556 (Bendigo)	Powercor	L&G E350	Brick/Timber	Timber	Internal
4	Sedgwick, 3551 (Bendigo) – 3Phase Meter	Powercor	L&G E350	Metal Shed	Metal	Internal
5	Glenroy, 3046	Jemena	iCredit 500	Brick Veneer	Metal	Internal
6	Essendon, 3040 (tested before and after AMI Meter installation)	Jemena	iCredit 500	Brick Veneer	Metal	Internal
7	Lower Plenty, 3093	SP AusNet	L&G E350	Brick Veneer	Metal	Internal
8	Balwyn, 3103 (Group of 13 meters)	Powercor	iCredit 500	Cement Block	None	Internal
9	Boronia, 3155 (Group of 9 meters)	SP AusNet	L&G E350	Metal cabinet	Metal	External
10	Mooroolbark, 3138	SP AusNet	L&G E350	Brick Veneer	Metal	External
11	Croydon, 3136	SP AusNet	L&G E350	Brick Veneer	Timber	External
12	Bayswater North, 3153	SP AusNet	L&G E350	Brick Veneer	Metal	Internal
13	Elwood, 3184 (Group of 11 meters)	United Energy	iCredit 500	Brick Veneer	Timber	Internal
14	Hampton, 3188	United Energy	iCredit 500	Weatherboard	Metal	Internal

Site No	Site Locations	DB	Meter Type	Construction	Meter Box	Antenna
15	Springvale South, 3172	United Energy	iCredit 500	Weatherboard	Metal	External
16	Clifton Hill, 3068	Powercor	L&G E350	Weatherboard	None	Internal

2.1 AMI Meter Overview

2.1.1 Meter Network Technologies

The AMI Meters deployed in Victoria use two types of technologies:

- Jemena/United Energy: Mesh Radio Network
- Citipower/Powercor: Mesh Radio Network
- SP AusNet: WiMax Network

There were only two types of meters used by the DBs. These were:

- PRI/Secure iCredit 500 and
- Landis & Gyr (L&G) E350

The particular technology used is determined by the Communication Module (also known as Network Interface Card (NIC)), fitted inside the meter and by the antenna used. Figure 5 and 6 show the iCredit 500 and the L & G E350 Meter respectively.

Figure 5 – PRI/Secure iCredit 500 Meter

Figure 6 – L & G E350 Meter

2.1.2 Mesh Radio Network (Information provided by the DB)

The Mesh Radio Network uses a Silver Springs Communication Module that operates in the 915MHz to 928MHz band with an output RF power of one Watt (1W). The radio employs Frequency Hopping Spread Spectrum (FHSS) techniques to avoid mutual interference with other nearby meters operating in the same frequency band. The characteristics and capabilities of the Mesh Radio Network can be readily found on the Internet and will not be discussed in detail here. The key advantage of the Mesh Radio is that an AMI Meter does not need to be able to communicate directly with an Access Point (similar in function to a Mobile Phone Base Station) so that a meter with poor coverage can relay through a network of neighbouring AMI Meters to communicate with the central office (also known as back office). Therefore the network is dynamic and adaptive, but it also means that, other than the periodic transmission during the routine meter read time, the meter may transmit randomly at other times, either to maintain link with Back Office or to act as relay for neighbouring meters.

In normal operation, the meter data is read 6 times a day (every 4 hours). The Jemena/United Energy meter read schedule is different from Citipower/Powercor, thus reducing the spectrum traffic. Jemena/United Energy and Citipower/Powercor meters do not interfere with each other through the use of FHSS and by their unique network ID, similar to the Wi-Fi network operation.

Jemena/United Energy and Citipower/Powercor have deployed both iCredit 500 and L&G E3500 meters. Most meters use the inbuilt antennas inside the meter housing while two Jemena/United

Energy meters had an external CSM900 Omni Directional antenna mounted outside and beneath the meter box. The position of the external mounted antenna is approximately 1m above ground and at waist level of an average height person.

The Meters are mounted inside a meter box that may be timber or metal. DB engineers have indicated that meter with internal antenna mounted inside a metal meter box may lose 10 to 15dB power with the metal door closed, but the signal is still adequate for normal communication.

2.1.3 WiMax Network (Information provided by the DB)

The SP AusNet WiMax Network Meter uses a GE WiMax SmartGrid Card operating in the 2.3GHz band with an output RF power of 0.4W.

In normal operation, the WiMax meter transmits 4 times (sessions) a day. At other times during the day, the meter stays in Idle mode except for the transmission of very short bursts of time synchronisation signal which is transmitted every hour. At the pre-programmed time slot, the meter starts to establish a session with the Access Point/Base Station, uploads meter data and then closes the session. Advice from SP AusNet was that the session typically takes approximately 10 second. If no further request is made by the Back Office for more than 15 seconds, the meter returns to Idle mode. During the 15 sec timeout, the meter transmits a few very short bursts (in millseconds) but will stop transmission after returning to Idle mode.

Each WiMax Meter is assigned a time slot for its 4 times a day communication with the Back Office. The time slot is based on a random number, thus the probability of more than 1 meter transmitting at the same time is very small and even in a Group Meter installation, simultaneous multiple meter transmissions is highly unlikely, as they would interfere with each other. The WiMax network behaves very similar to the Ethernet network with its Collision Avoidance capabilities.

Most SP AusNet meters use external IN1682 MiMo Antenna glued to the outside of the Meter Box. Some meters use IN1768 Dual WiMax antennas glued to either side of the AMI Meter housing on the inside of the meter box.

2.1.4 HAN Radio

Both systems also incorporate a Home Area Network (HAN) radio for wireless networking of smart appliances inside the house. The HAN radio is also known as Zigbee Radio and operates in the 2.4 GHz Band with an RF output power of 0.2W. The HAN radio is only turned on when requested by the customer.

2.2 Configurations of Properties Surveyed

The following table lists the various combinations of house constructions, meter box constructions and antenna installation that were surveyed.

Table 3 – Type of Properties Surveyed

Building	Meter Box	Antenna
Brick Veneer	Metal	Internal
Brick Veneer	Metal	External
Brick Veneer	Timber	Internal
Brick Veneer	Timber	External
Weatherboard	Metal	Internal
Weatherboard	Metal	External
Weatherboard	Timber	Internal
Weatherboard	Timber	External
Metal Cladding	Metal	Internal

2.3 Meter Box Locations

It was observed that most houses tested had the meter box mounted against a bed room wall or a lounge room wall on the side of the house. It was not possible to conduct RF measurements at 1m distance from the Meter at some houses because of the narrow space between the meter box and the side fence.

2.4 Test Equipment

The test equipment used in the site survey is listed in Table 19 in Appendix A.

2.5 Measurement Uncertainty

The following measurement uncertainty has been conservatively determined in accordance with ISO17025 and NATA requirements.

2.5.1 Narrowband E-field Measurement Uncertainty:

Spectrum Analyser	±1.2dB (worst case)
Antennas	±1.8dB
Cables	±0.2dB
Environmental	±2.0dB (worst case)
Total (Root of the Sum of the Squares)	±3.0dB

2.5.2 Magnetic Field Measurement Uncertainty:

EMDEX II meter	±3%

2.6.1 RF Exposure Limits

Table 7 of ARPANSA RPS3 specifies the maximum 6 minute average E-Field or Power Density RF exposure limits for the General Public. These are frequency dependent.

Jemena and Powercor Mesh Radio Meters at 915 MHz -	41.7V/m rms or 4.575 Watt/m^2
SP-AUSNET Wi-Max Meters at 2.3 GHz -	61.4V/m rms or 10 watt/m^2
HAN Radio at 2.4 GHz -	61.4V/m rms or 10 Watt/m^2
Composite Mesh Radio and HAN Radio (use the lower limit) -	41.7V/m rms or 4.575 Watt/m^2

2.6.2 ELF Magnetic Field Exposure Limits

Referring to ARPANSA Draft ELF Standard Table 3, the ELF General Public Exposure Limit for 50Hz Magnetic fields is 1000 milliGauss (mG) or 100μT.

EMF measurements at each site included Narrowband (NB) RF Field Measurements and ELF Magnetic Field (at the power frequency of 50Hz) measurements. The test procedures were outlined in the test plan M110736-1,

3.1 Narrowband RF Measurements

Narrowband measurements were conducted using the Rohde & Schwarz FSH3 Spectrum Analyser controlled by a laptop computer. The WINTEST control software sets the analyser's measurement parameters and then displays and stores the spectrum plots.

A standard Dipole antenna mounted on a wooden tripod was used to measure the RF fields from the AMI meter. One covered the Mesh Radio 915MHz to 928MHz frequency band while a second standard Dipole covered the WiMax 2.3GHz band and the HAN radio 2.4GHz band.

Measurements were also made at 30cm, 50cm and at 1 metre if the space in front of the meter permitted.. The same set of measurements was made outside and inside the house. If the meter box was metal, then measurements were made with the meter door opened and then closed.

Measurements inside the house were made with the antenna pointing directly at the wall behind the AMI Meter. The metallic meter door was closed when measuring inside the house.

It was decided to set the AMI Meter under test to respond to continuous 'ping' so that a lot more RF bursts from the meter could be captured. While this is not a normal operation for the AMI meter, it allowed for easier measurement of the peak RF power level of the burst. It also allowed the discrimination of the meter transmissions over the emissions from other sources.

The Spectrum Analyser made a number of sweeps with the detector set to Peak Hold in order to capture as many peaks as possible. The sweep was then stopped and WINTEST would then identify the highest peak level from the spectrum plot.

Once the RF peak power was obtained, the level was then multiplied by the Duty Cycle to produce the average level over a 6 minute period. ARPANSA RPS3 limits are based on a 6 minute average exposure. This is further discussed in the data analysis process in Section 5.

At the Group Meter site, RF field measurements were first made on the individual AMI Meter being pinged. The DB engineer was then asked to ping multiple meters. The aim was to determine if the measured peak RF field level would increase due to simultaneous transmission from a number meters. In this case, the measurement antenna was placed in the middle of the group of meters.

HAN radio transmissions were made separately by requesting the DB engineer to stop pinging the main meter transmitter and then to activate the HAN function. Once activated, a portable wireless HAN display unit was use to ping the AMI Meter.

3.2 ELF Magnetic Field Measurement

Measurements were made using an EMDEX II Magnetic Field Meter. Measurements were made on the surface of the AMI Meter, at 30cm and at 50cm away. This was repeated inside the house immediately behind the AMI Meter. The ELF measurement results for the16 sites are listed in Table 27.

Ambient measurements were made initially, then a 4kW test load (two 2 kW fan heaters) was plugged into the GPO inside the house and the Magnetic field was measured again. One of the houses tested still had an original rotating-disc meter. This provided an opportunity to measure the Magnetic field associated with the old meter for comparison with the Magnetic field associated with the new AMI meter. These results have been listed in Table 28.

4.1 Test Locations

Table 20 in APPENDIX A lists all the properties tested. Note that Citipower/Powercor have meter installations outside the Melbourne Metropolitan areas. The only Regional Centre tested was a Citipower/Powercor installation in the Bendigo area. The property in Essendon was surveyed prior to the AMI Meter installation to compare the ELF Magnetic field from an old rotating-disc meter with the field from a new AMI Meter.

4.2 AMI Meter E-Field Measurements – Single Meter Installation

4.2.1 Narrowband EMF Measurements

The RF Spectrum of the meter transmission was measured at 30cm and 50cm from the meter.Table 21 lists the peak RF field obtained from the single meter sites. The fields are derived by calculating the Root of the Sum of the Squares (RSS) of the Vertical and Horizontal components of the measured E-field. The data indicates that the measured levels at 30cm varied by approximately 5 times between sites. (Ignoring the levels from Site No.12 which will be discussed in detail in Section 5.2.1).

The meter was forced to continuously transmit (100% Duty Cycle) and the E-field levels were measured. The RF peak power density levels shown in Table 4 were determined from the measured E-field levels. Normal operation of the meters does not include 100% duty cycle. The minimum level was 0.49% from a SP AusNet WiMax site which had an external antenna mounted outside the metal meter box. The maximum level was 29.57% from a Jemena Mesh Radio site with an internal antenna with the metal meter box door opened. While this appears to be a high level, it is still well under the ARPANSA limit and it should be noted that continuous transmit (100% duty cycle) would never occur in actual service. Notwithstanding the forced continuous transmission, the levels inside the house were very low at 0.005% of the ARPANSA limit. Note that the low levels measured at Site 12 were due to the AMI Meter antennas. These variations will be discussed in detail in Section 5.2.1.

Table 4 – RF Power Density levels determined for single meter sites with the meter forced to transmit continuously (100% Duty Cycle)

Site No	% of ARPANSA Power Density General Public limit					
	Meter Box Door Open		Meter Box Door Closed		Inside House (Behind meter)	
	30cm	50cm	30cm	50cm	30cm	50cm
1	NM	0.471	NM	NM	NM	NM
2	27.453	8.405	0.334	0.18	0.291	0.156
3	4.48	NM	0.266	NM	NM	0.062
4	22.684	NM	0.015	NM	NM	0.068
5	5.178	NM	4.219	NM	NM	0.225
6	16.267	1.568	0.042	0.033	0.055	0.058
7	1.93	0.70	NM	NM	0.027	0.005
10	0.495	0.18	NM	NM	0.0001	0.00004
11	NM	NM	1.398	0.537	0.006	0.003

Site No	% of ARPANSA Power Density General Public limit					
	Meter Box Door Open		Meter Box Door Closed		Inside House (Behind meter)	
	30cm	50cm	30cm	50cm	30cm	50cm
12	0.004	0.001	0.004	0.003	NM	NM
14	29.091	11.202	0.07	0.053	0.005	0.005
15	NM	NM	1.568	1.444	0.007	0.003
16	4.623	9.874	NM	NM	0.122	0.225

* Group Meter site

'NM'- Not Measured

4.2.2 HAN Radio Emission

Only a few HAN radio transmissions were measured since HAN Radio meters have not been fully deployed. Table 5 indicates some measurements with the HAN radio transmitting. Table 6 indicates the combined field level at those sires with Meter transmission and HAN radio transmission. This is derived from the RSS (square root of the sum of the squares) of the meter's E-Field and the HAN radio E-Field.

Table 5 – HAN RF EMF Power Density levels determined for single meter sites.

Site No	% of ARPANSA Power Density General Public limit					
	Meter Box Door Open		Meter Box Door Closed		Inside House (Behind meter)	
	30cm	50cm	30cm	50cm	30cm	50cm
3	NM	0.33	NM	0.019	NM	0.0025
4	NM	1.11	NM	NM	NM	NM
5	NM	0.02	NM	0.00004	NM	0.0013
14	0.55	NM	NM	NM	0.0006	NM
16	0.35	0.05	NM	NM	0.0017	0.0009

'NM'-Not Measured

Table 6 – Combined (HAN Radio and Meter) RF EMF Power Density levels determined for single meter sites (100% Duty Cycle)

Site No	% of ARPANSA Power Density General Public limit					
	Meter Box Door Open		Meter Box Door Closed		Inside House (Behind meter)	
	30cm	50cm	30cm	50cm	30cm	50cm
3	4.48	0.73	0.27	0.04	NM	0.062
4	22.68	2.43	0.02	NM	NM	0.067
5	5.18	0.05	NM	NM	NM	0.225

Site No	% of ARPANSA Power Density General Public limit					
	Meter Box Door Open		Meter Box Door Closed		Inside House (Behind meter)	
	30cm	50cm	30cm	50cm	30cm	50cm
14	29.12	11.2	0.07	0.05	0.01	0.004
16	4.69	9.87	NM	NM	0.12	0.225

'NM'- Not Measured

The results of Table 5 shows that the Power Density levels measured for the HAN radio were considerably lower than the levels from the Meters operating at their normal frequency. Table 6 shows that even with the meters forced to transmit continuously with 100% duty cycle and even if the HAN radio is active, the combined EMF power density was only increased by at most 1.37% (Site 16). The results also show that the highest possible resulting EMF levels from both Meter and HAN Radio transmissions, even at 100% Duty Cycle, would still be well below the ARPANSA limit. This scenario would never occur in actual service and has been presented here for illustrative purposes only.

4.3 AMI Meter ELF Magnetic Field Measurements – Single Meter Installation

The measured levels are listed in Table 7. Again, the field levels, albeit low, varied widely between sites. Some of the variations could be attributed to the fact that there were already appliances drawing electricity from the switchboard before the 4kW test load was inserted. The relatively high Magnetic Field for Site 12 is to be expected given the large amount of electrical wiring present near the meters.

The results show that the Magnetic fields measured directly at the meters were still well below the ARPANSA limit. The Magnetic field level at 50 Hz reduces exponentially as the distance from the source increases. With a 4kW load, the highest level measured inside the house at 30cm was 33mG (3.3% of the limit). The highest level at 50cm was 12.6mG (1.26% of the limit). It is important to note that the levels inside the house would not be different if the older rotating disc meter was used, because the electrical wiring at the switchboard generate higher fields than the meters themselves.

The levels shown in Table 7 are typical of most homes and offices that have electricity connected and that use domestic appliances.

Table 7 – ELF (50Hz) Magnetic Field measurement results for Single meter sites.

Site No	Ambient Magnetic Field Measured (No Load) (mG)						50Hz Magnetic Field Measured (4kW Load) (mG)					
	Outside			Inside			Outside			Inside		
	On meter	30 cm	50 cm	On meter	30 cm	50 cm	On meter	30 cm	50 cm	On meter	30 cm	50 cm
1	26	1.4	NM	4.4	1	NM	145	10.3	NM	11.1	4.5	NM
2	8	0.8	0.6	1.1	0.5	0.4	155	6	2	33	2.6	1
3	22	5	0.7	3	1	0.4	198.4	13	1.1	19.8	3	1
4	22.8	1	0.5	34.7	1	0.4	34.7	1.2	0.5	84.3	9.9	1.3
5	17.8	1.3	1.2	1	1	1	257	2.28	1.3	39.7	4.8	1
6	8.2	1.6	1.5	2	1	1.3	132	14.2	4.1	34	5.6	1.6

Site No	Ambient Magnetic Field Measured (No Load) (mG)						50Hz Magnetic Field Measured (4kW Load) (mG)					
	Outside			Inside			Outside			Inside		
	On meter	30 cm	50 cm	On meter	30 cm	50 cm	On meter	30 cm	50 cm	On meter	30 cm	50 cm
7	100	5	1	3	10	8	255	8	2	28	10	8
10	9	0.8	0.3	15.4	0.8	0.3	45	5	2.1	82	6.6	2.2
11	10	0.6	0.2	88	1.8	0.4	120	4.3	1.2	483	9.3	2.6
12	NM	NM	NM	1.2	0.2	0.2	100	4.1	3.7	49.6	1.8	0.6
14	48	2.1	1.2	9	1.6	0.7	88	7.8	2.9	33	4.7	2.7
15	40	5.3	2.3	14	4.1	1.2	136	24	9	42	12	5.6
16	52	10	3.3	35	10.2	2.5	142	18	10	146	33	12.6

'NM'- Not Measured

4.4 AMI Meter RF E-Field Measurements – Group Meter Installation

The measured RF E-Field from multiple meters and from a single meter in the group is listed in Table

24. The peak RF field levels resulting from multiple meter transmissions do not differ significantly from a single meter transmission. This is discussed further in Paragraph 5.2.2. Table 8, Table 9 and below, indicate the Power Density (PD) levels in percentage (%) of ARPANSA General Public Limit for the 3 Group meter sites tested with Meters set to transmit continuously.

Table 8 – Citipower/Powercor Group meter site Power density (PD) levels determined for continuous meter transmission.

Group Meter site number 8 (Citipower/Powercor)					
Meter Number			DZ103548	DZ103500	DZ103549
% of ARPANSA Pd General Public Limit (Meter transmitting)	Infront of the Meter Box	30 cm	8.21	12.67	25.50
		50 cm	5.75	7.45	15.15
	Meter Box Door Closed	30 cm		Not Applicable	
		50 cm			
	Rear of the Meter Box	30 cm	0.14	0.46	0.19
		50 cm	0.13	0.26	0.18
% of ARPANSA Pd General Public Limit (HAN Radio transmitting)	Infront of the Meter Box	30 cm	0.67	NM	NM
		50 cm	0.13	NM	NM
	Meter Box Door Closed	30 cm		Not Applicable	

Group Meter site number 8 (Citipower/Powercor)					
Meter Number			DZ103548	DZ103500	DZ103549
		50 cm			
	Rear of the Meter Box	30 cm	0.0019	NM	NM
		50 cm	0.0032	NM	NM
% of ARPANSA Pd General Public Limit (Combined field)	Infront of the Meter Box	30 cm	9.75	NM	NM
		50 cm	6.04	NM	NM
	Meter Box Door Closed	30 cm		Not Applicable	
		50 cm			
	Rear of the Meter Box	30 cm	0.15	NM	NM
		50 cm	0.14	NM	NM

Table 9 – SP AusNet Group meter site Power density (PD) levels determined for continuous meter transmission.

Group Meter site number 9 (SP AusNet) (External Antennas)						
Meter Number			4141549	4141309	4141616	4141616 & 4141617
% of ARPANSA Pd General Public Limit (Meter transmitting)	Infront of the Meter Box	30 cm	Not measured as the Meter Box Cabinet was locked			
		50 cm				
	Meter Box Door Closed	30 cm	0.28	0.41	0.48	0.12
		50 cm	0.05	0.13	0.08	0.17
	Rear of the Meter Box	30 cm	Rear of the Meter Box Cabinet was inaccessible			
		50 cm				
% of ARPANSA Pd General Public Limit (HAN Radio transmitting)			HAN Could not be enabled, therefore no measurements conducted for HAN radio			
% of ARPANSA Pd General Public Limit (Combined field)			Not Applicable			

Table 10 – Jemena/United Energy Group meter site Power Density (PD) levels determined for continuous meter transmission.

Group Meter site number 13 (Jemena/United Energy) (Internal Antennas)						
Meter Number			0518791	0518803	0518816	6 meters *
% of ARPANSA Pd General Public Limit (Meter transmitting)	In front of the Meter Box	30 cm	17.14	32.86	26.97	21.01
		50 cm	10.36	9.87	1.49	2.77
	Meter Box Door Closed	30 cm	Not measured (internal antennas, Wooden meter box)			
		50 cm				
	Rear of the Meter Box	30 cm	Not Measured. Access could not be arranged.			
		50 cm				
% of ARPANSA PD General Public Limit (HAN Radio transmitting)			HAN Could not be enabled, therefore no measurements conducted for HAN radio			
% of ARPANSA PD General Public Limit (Combined field)			Not Applicable			

*6 meters (0518803, 0518805, 0518791, 0518771, 0518789, 0518816) transmitting simultaneously.

4.5 AMI Meter ELF Magnetic Field Measurements – Group Meter Installation

4.5.1 Jemena/United Energy Group Meter Measurements

It was not possible to conduct measurements inside the apartment behind the Meter Box because access to the apartment was not possible. The external measurements were therefore made without the 4 kW load. Referring to the photo of the timber meter box in Figure 46, there are two rotating-disc meters inside the meter box, thus a comparison was made of the ELF Magnetic field levels between the old and new meters. The measurements showed that the Magnetic field on the old meter was higher than the field from the AMI Meter. Since the electrical loads on the meters were not known, the comparison may be biased, however, the Magnetic field levels of the two old meters were consistently higher than any of the AMI Meters. See results in Table 11.

Figure 44 shows, the Powercor Group Meter site located in the basement Meter Room beneath a three storey apartment building. The Meter Room is only 1.5m wide and is normally locked to restrict access. The meters are mounted on a cement block divider wall which has a corridor behind it. RF spectrum measurements made in front and behind the wall are shown in Figure 26 and Figure 28 respectively.

Magnetic field measurements were made in an empty apartment with the 4kW Test Load plugged in. The Magnetic field was subsequently measured at the specific AMI Meter associated with that apartment.

Table 11 - ELF (50Hz) Magnetic Field measurement results for Mesh Radio Group meter sites.

	Site No	Ambient Magnetic Field Measured (No Load) (mG)						50Hz Magnetic Field Measured (4kW Load) (mG)					
		Outside			Inside			Outside			Inside		
		On meter	30 cm	50 cm	On meter	30 cm	50 cm	On meter	30 cm	50 cm	On meter	30 cm	50 cm
	8	300	90	65	250	92	35	100	65	26	45	32	17.6
	9	12.3	1.1	0.4	NM	NM	NM	NM	NM	NM	NM	NM	NM
13	Old Rotating Disc Meter	281	9.8	5.3	NM	NM	NM	NM	NM	NM	NM	NM	NM

	Site No	Ambient Magnetic Field Measured (No Load) (mG)						50Hz Magnetic Field Measured (4kW Load) (mG)					
		Outside			Inside			Outside			Inside		
	Smart meter	52	9.2	3.2	NM	NM	NM	NM	NM	NM	NM	NM	NM

4.5.2 SP AusNet

The SP AusNet Group Meter site was located at the front garden of a block of units. The AMI Meters were mounted inside a large metal cabinet (see photo in Figure 45), with the antennas glued to the external side of the door of the cabinet. The door of the metal cabinet was locked hence Magnetic field measurements were not performed. Only RF field measurements were made. The rear of the cabinet was obstructed by vegetation therefore only measurements at 30cm were possible.

4.6 RF and ELF EMF Measurements of Common Household Emitters

The EMF from a number of common household appliances and consumer electronic equipment was measured to provide a comparison with the EMF levels of the AMI Meters. RF and/or ELF Magnetic field was measured depending on the item. Table 12 and Table 13 relate to the measured RF EMF and ELF Magnetic field respectively.

Note that mobile phone is usually the highest EMF that people experience because they are used in close proximity to the body. In this case, the field was measured at 30cm away. The level is expected to be significantly higher when placed closed to the ear or if the phone is in the pocket/beltclip. However, EMF measurement close to the phone transmit antenna (Near Field) cannot be accurately measured except by SAR method which is outside of the scope of this test program. Based on results from some mobiles phones tested at the EMCT SAR laboratory, EMF levels at ear level may be as high as 50% of ARPANSA General Public Limit and up to 100% when the phone is in the pocket or beltclip.

Table 12 – Comparison of Power Density measured at 30cm from RF devices in % of ARPANSA General Public Limit.

Test Sample	% of ARPANSA Power Density General Public Limit
AMI Meter*1	0.82
Wireless Modem	0.05
Microwave Oven	1.49
Baby Monitor	3.29
Mobile Phone	2.03
Cordless Handset	0.17

Table 13 - Comparison of ELF (50Hz) Magnetic Field measured at 30cm from household devices in % of NHMRC General Public Limit.

Test Sample	% of NHMRC General Public Limit
AMI Meter (highest emitter)	1.42
Electric Blanket	0.14
Electric Blanket (on surface)	.3.17
Household Vacuum Cleaner	2.16
Microwave Oven	3.0

Test Sample	% of NHMRC General Public Limit
CRT TV	0.42

Table 14 Comparison of ELF (50Hz) Magnetic Field measured at Surface of household devices in % of NHMRC General Public Limit.

Test Sample	% of NHMRC General Public Limit
AMI Meter* (with 4kW)	13.2
Old Rotation Disc Meter* (with 4kW)	27
Electric Blanket	3.17
Household Vacuum Cleaner	28.8
Microwave Oven	14.2
CRT TV	4.2

* Measured at Site 6 before and after the installation of the AMI Meter

5.1 Determination of Duty Cycle

5.1.1 Jemena/United Energy and Citipower/Powercor Mesh Radio Network

The AMI Meters of Jemena/United Energy and Citipower/Powercor both use the same Silver Springs Communication Modules so the transmission characteristics should be similar. It can be assumed that the Duty Cycle of RF the transmission should also be similar.

The RF burst transmission was monitored at a number of sites surveyed. Figure 41 shows a time trace of a Powercor meter over a 500sec period. Although the trace shows a large number of burst transmission, the analysis showed that the total burst transmission is only 166 with a total transmission time of 0.687sec. Therefore, the Duty Cycle over 500sec is only 0.14%.

Figure 42 and Figure 43 show time traces of two Jemena meters over 500sec interval, the traces show only 6 bursts in one meter and 3 bursts in the other meter. These traces demonstrate the randomness of the Mesh Radio network traffic.

Jemena and Powercor were requested to provide data (byte) counts (total number of bytes sent by the meter between an elapsed time period) from some of the AMI Meters tested. The data counts were made in segments of 11 minutes (Jemena) and 6 minutes (Powercor) over more than 1 hour. Table 15 summarises the maximum Duty Cycles derived from the supplied data. The full lists are provided in Table 31 for Jemena meters and Table 32 for Powercor meter. The investigation found that the Duty Cycle of the majority of the meters was less than 0.1%, with a few meters over 0.1% and only 1 meter above 1% (1.191%). However, these were results from only 7 meters and should not be used as the maximum duty cycle that could be encountered across the whole population of meters installed.

Table 15 - AMI Meter Duty Cycle derived from Byte Count

Distribution Business	Meter number	Maximum Derived Duty Cycle (%)
	0020979	0.067
	0077292	0.036
Jemena	0076724	0.046
	0057323	1.191
	0642675	0.033

Distribution Business	Meter number	Maximum Derived Duty Cycle (%)
	0655877	0.172
Powercor	A4206942	0.071

After consultation with the DB technical experts, byte count measurement data from over 2000 meters was provided. The data was based on field observations of a highly loaded Access Point. A distribution chart of the number of meters (population) communicating with this Access Point versus the Duty Cycle is shown in Figure 7 below. From the Distribution Chart, it can be seen that the majority of the meters were transmitting at between 0.3% – 0.4% and that 99.9% of the meters were transmitting below a Duty Cycle of 2.5%.

Since the results of the byte counts from only 11 Mesh Radio Network AMI meters did not show any Duty Cycle of more than 1.2% and the lack of other supporting data, it was not possible to determine a definitive Duty Cycle for the Mesh radio network. It was decided to use a Duty Cycle of 2.5% based on the observed maximum in Figure 7. This will give the most conservative assessment of the RF EMF that are generated by the Mesh Radio Network meters.

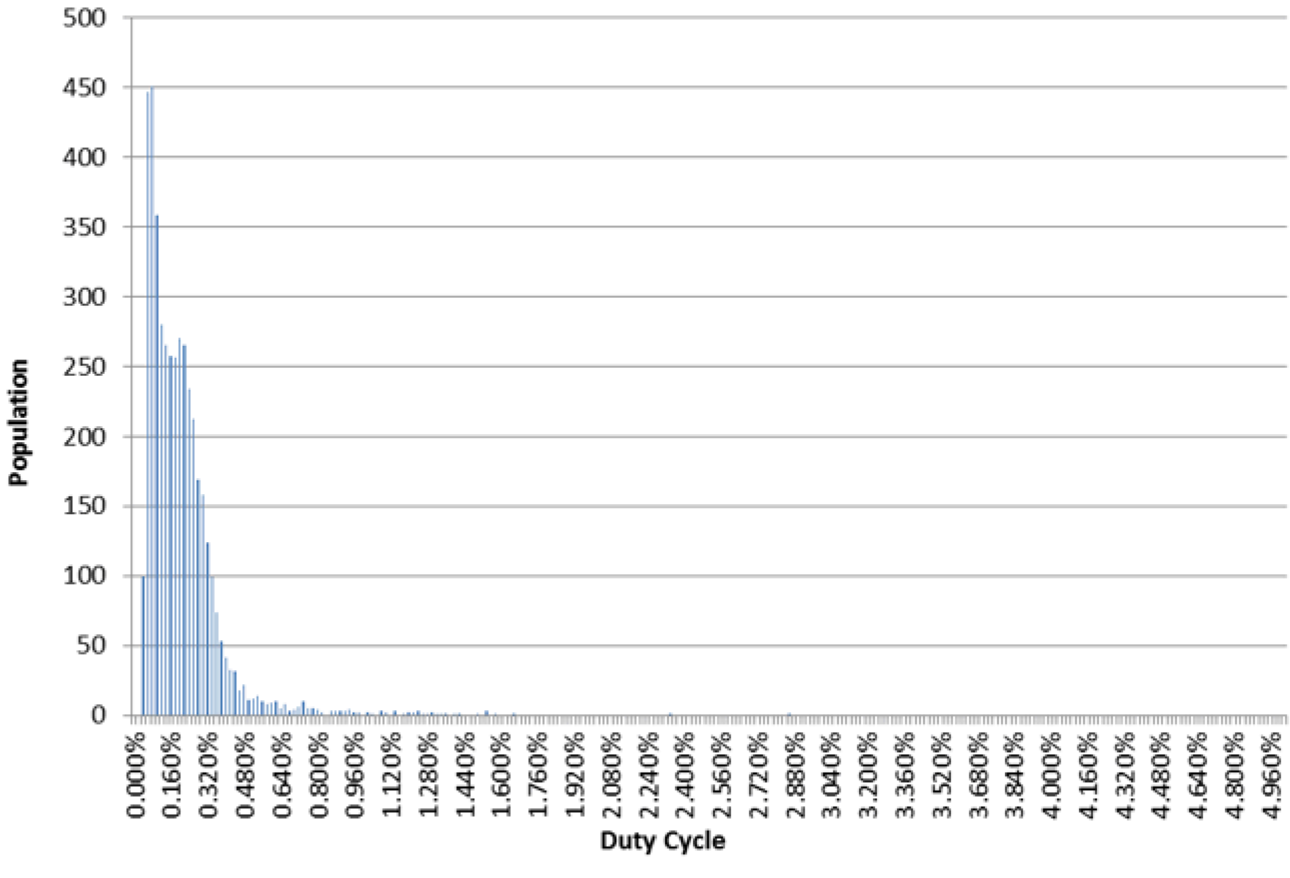

Figure 7 – Distribution of Meter Duty Cycle at an Access Point Based on Byte Counts

Table 16 below summarises the results of Power Density levels determined from the single meter sites based on a worst case 2.5% Duty Cycle and corrected to represent the ARPANSA 6 minute average exposure.

Table 16 – Power Density levels for Jemena/United Energy and Citipower/Powercor Single Meter Sites based on 2.5% Duty Cycle

Site Number	% of ARPANSA Power Density General Public Limit based on Maximum Transmission Duty Cycle of 2.5%					
	Meter Box Door Open		Meter Box Door Closed		Inside House (Behind meter)	
	30cm	50cm	30cm	50cm	30cm	50cm

Site Number	% of ARPANSA Power Density General Public Limit based on Maximum Transmission Duty Cycle of 2.5%					
	Meter Box Door Open		Meter Box Door Closed		Inside House (Behind meter)	
	30cm	50cm	30cm	50cm	30cm	50cm
1	NM	0.012	NM	NM	NM	NM
2	0.6863	0.21	0.0083	0.0045	0.0073	0.0039
3	0.112	NM	0.0066	NM	NM	0.0015
4	0.5671	NM	0.00037	NM	NM	0.0017
5	0.1294	NM	0.105	NM	NM	0.0056
6	0.4067	0.039	0.001	0.0008	0.0013	0.0014
14	0.7273	0.28	0.0017	0.0013	0.0001	0.0001
15	NM	NM	0.039	0.0361	0.0002	0.00008
16	0.1156	0.247	NM	NM	0.003	0.0056

5.1.2 SP AusNet Wi-Max Network

The WiMax System deployed by SP AusNet only transmits 4 times (sessions) a day. At other times, the meter stays in Idle mode with an occasional very short RF transmission for 6 hours (for housekeeping purposes). At the preprogramed time slot, the meter starts to establish a session with the Access Point/Base Station, uploads meter data and then closes the session. SP AusNet advised that the session typically takes approximately 10 seconds. If no further request is made by the back office for more than 15 sec, the meter returns to Idle mode. During the 15 sec timeout, the meter transmits few very short bursts (in milliseconds) but will stop transmission after returning to Idle mode.

Figure 40 is a time trace of the Meter transmission during a meter read session. The trace shows that the session took about 7 to 8sec; shorter than the 10sec period suggested by SP AusNet. The trace also shows a series of very shorts bursts after the session, which is likely to be the handshake transmission to the back office during the 15 sec time out.

It can be seen from the session time trace that the meter does not transmit continuously all through the session as it also needs to receive data from the base station. Based on the RF burst pattern observed and assuming the total meter transmit time is half the total session time 10/2 = 5 seconds, the Duty Cycle over 6 minutes will be 5/360 = 1.39%

Therefore, the Duty Cycle of 1.39% will be used to convert the peak RF level measured to the level averaged over 6 minutes as specified by the ARPANSA RPS3 Standard. Table 17 lists the field levels at each SP AusNet single meter site that has been corrected with the Duty Cycle to the average level over the 6 minute. The levels are also presented as a percentage of the ARPANSA General Public Limit.

Table 17 – Power density levels for SP AusNet based on 1.39% Duty Cycle

Site Number	% of ARPANSA Power Density General Public Limit based on 1.39% Transmission Duty Cycle					
	Meter Box Door Open		Meter Box Door Closed		Inside House (Behind meter)	
	30cm	50cm	30cm	50cm	30cm	50cm
7	0.0268	0.0098	NM	NM	0.0004	0.00007
10	0.0069	0.0025	NM	NM	0.000001	0.000001
11	NM	NM	0.0196	0.0074	0.00009	0.00003
12	0.0001	0.00002	0.00006	0.00003	NM	NM

5.2 Analysis and Discussion of Other Measurement Results

5.2.1 RF EMF from AMI Meters

The higher field level found at Site 14 and Site 2 are most likely due to reflections from the metal door of the meter box. At some test sites, the metal door was half opened (90°) or fully opened (180°) at other sites. If the door was only half opened, then the measured level would have been higher from the reflection. It can be seen from Table 22 that even with the door open the highest 6 minute averaged field was 8.49% of the ARPANSA limit. This reduced to 0.20% of the limit at 1 m from the meter box inside the house. The highest level inside the house was 0.84% of the limit.

The low levels at Site 12 shown in Table 21 are due to the use of the Dual Antenna on the SP AusNet meter. As the two antennas are mounted on either side of the meter housing (see photo in Figure 51), the antennas radiate at different directions from the front, resulting in lower levels at the measurement position.

5.2.2 RF EMF from Group AMI Meters

The measurements at Group Meter sites included “pinging” more than one meter to try and obtain multiple transmissions. The measured field levels presented in Table 24 show that the peak RF level did not increase when more than one meter was activated. Figure 34 is a spectrum plot of a Jemena Group Meter site with 6 meters pinged simultaneously. It can be seen that the spectrum appeared to be full, due to the Spectrum Hopping transmitters from multiple meters. There were no higher peaks or lower troughs (nulls) present among the signals. Peaks and troughs would result from simultaneously transmitted signals adding and subtracting from each other, therefore, it can be concluded that there were no simultaneous transmissions from more than one meter at a time, even in a Group Meter site. Figure 38 shows an SP AusNet Group Meter site with two meters pinged simultaneously, again, no higher peaks were observed.

5.2.3 ELF Magnetic Fields from AMI Meters

The measurements indicate that the Magnetic field from the old rotating-disc is generally higher than the Magnetic field from the AMI Meter. However, the Magnetic field from the wiring inside the switch board is much higher than the field from the AMI meters. This presented difficulty in measuring Magnetic field on the wall inside the house as it was difficult to locate the exact position of the AMI meter. The test results from single AMI meter sites in Table 7 showed some high ELF Magnetic fields measured on the wall inside the house, eg. Site 11, was most likely due to the electrical wiring inside the wall cavity and not from the AMI Meter.

5.3 Comparison with Other Common Household RF EMF Emitters

The RF EMF levels measured for each of the common household items listed in Table 30 can be assumed to be the 6 minute average level since the duty cycles are essentially 100%. The results show that the RF EMF levels from the AMI Meters, even when measured just 30 cm away, are lower than the levels from other common household items. The actual RF EMF levels from an AMI meter inside the house is very low compared to the levels from such devices as wireless modems, mobile phones and microwave cookers. The mobile phone is usually the highest EMF that people experience because they are used in close proximity to the body. The actual transmit power from the mobile phone was not known since the actual power transmitted varies depending on distance from a base station. The level measured here at 30 cm would be a typical exposure level to the head of the user when using a mobile phone with a hands free kit. The typical exposure from a mobile phone used at the ear or in the pocket/beltclip is 1 to 2 Watt/m^2 (50% to 100% of the limit) for localised exposure.

Many suburban environments, especially those closer to commercial radio and TV broadcasting transmitters have continuous ambient RF EMF levels in the range 0.01% to 0.05% of the ARPANSA General Public limit. These areas include the Eastern suburbs of Melbourne near the Mount Dandenong broadcast transmitters and the Chatswood/Artarmon/Gore Hill areas of Sydney which are home to Sydney's broadcast transmitters. The environmental RF EMF levels associated with the broadcast transmitters are much higher than the RF EMF levels from the AMI Meter boxes when measured inside the home.

6.1 Summary of Test Results

Table 18 below is a summary of the measured test results.

Table 18 – RF EMF Levels at 30cm from Meter in % of ARPANSA Power Density General Public Limit at Maximum Duty Cycle

Site No.	Outside		Inside Dwelling
	Meter Box Door Open	Meter Box Door Closed	
1*	0.012	NM	NM
2	0.6863	0.0083	0.0073
3	0.112	0.0066	0.0015*
4	0.5671	0.00037	0.0017*
5	0.1294	0.105	0.0056*
6	0.4067	0.001	0.0013
7	0.0268	NM	0.0004
8**	0.6271	NM	0.0113
9**	N/M	0.012	N/M
10	0.0069	NM	0.000001
11	NM	0.0196	0.00009
12	0.0001	0.00006	NM
13**	0.8215	NM	NM
14	0.7273	0.0017	0.00013
15	NM	0.039	0.00018

Site No.	Outside		Inside Dwelling
	Meter Box Door Open	Meter Box Door Closed	
16	0.1156	NM	0.0056

* Measured only at 50cm from meter ** Group Meter Site 'NM' – Not Measured

The levels are based on the derived maximum Duty Cycles. The level averaged over 6 minutes is still very low and well below the ARAPANSA General Public limits. Similarly, the measured Magnetic field is also well below the ARPANSA ELF General Public limit.

6.2 Discussions

There are some very useful results drawn from the acquired data. These are:

- The RF EMF emissions from the AMI Meters were well below the ARPANSA limits, even with the transmitters forced to transmit continuously. AMI meter emission levels inside the dwelling were found to be significantly lower than outside the dwelling in front of the AMI Meter.
- RF EMF level could vary due to reflection from nearby metallic doors or objects; however the levels would still be very low.
- Multiple meters at a collocated site do not transmit simultaneously at the same frequency channel, thus the risk of increased EMF level due to multiple signals is very low;
- The maximum observed Duty Cycle (based on data provided by DB) was used for the Mesh Radio Network system thereby giving the most conservative assessment of the RF EMF emissions.
- The AMI Meter emissions were low compared to other common household devices such as mobile phones, microwave oven and baby monitors.
- Many suburban environments have 24 hour ambient RF EMF levels that are much higher than the AMI meter emissions inside the dwelling.
- It can be safely stated that the Smart meters themselves do not cause any increase in the power line related EMF levels. The replacement of the older meters with the AMI meters is a good way to reduce 50 Hz EMF exposure.

Table 19 - Measurement Instrumentation Details

EQUIPMENT TYPE	MAKE/MODEL SERIAL NUMBER	LAST CAL. DD/MM/YY	DUE DATE DD/MM/YY	CALIBRATED BY
E-field sensors	Field Strength Meter Asset Number: P-060 Manufacturer: Narda Model Number: EMR-300 Serial Number:	18/02/2011	18/02/2013	EMC Technologies Pty Ltd
	Electric Field Probe (3 MHz to 18 GHz) Asset Number: P-060 Manufacturer: Narda Model Number: Type 8.3 Serial Number: BB0012	18/02/2011	18/02/2013	EMC Technologies Pty Ltd
H-field sensors	Field Strength Meter Asset Number: P-121 Manufacturer: Narda Model Number: ELT-400 (F0004) Serial Number: BN2304/03	16/09/2010	16/09/2011	National Physical Laboratory (NPL) U.K
	Magnetic Field Probe (1Hz to 400KHz) Asset Number: P-121-2 Manufacturer: Narda Model Number: ELT-400 (F0004) Serial Number: BN2300/90.10	16/09/2010	16/09/2011	National Physical Laboratory (NPL) U.K
	EMDEX II Magnetic Field Exposure System Asset Number: M-115 Manufacturer: ENERTECH Model Number: EMDEX II	29/07/2011	29/07/2012	Enertech

EQUIPMENT TYPE	MAKE/MODEL SERIAL NUMBER	LAST CAL. DD/MM/YY	DUE DATE DD/MM/YY	CALIBRATED BY
Antennas	Precision Dipole FR 870MHz to 960MHz Asset Number: A - 248	26/05/2011	26/05/2012	EMC Technologies Pty Ltd
	Precision Dipole FR 2450MHz Asset Number: A - 251	26/05/2011	26/05/2012	EMC Technologies Pty Ltd
Spectrum Analyser	FSH3 portable Spectrum Analyser Manufacturer: Rohde & Schwarz Model Number: FSH3 (100KHz to 3GHz)	07/10/2010	07/10/2011	NATA
Oscilloscope	Yokogawa DL9140 Digital oscilloscope Asset Number: O-009	25/07/2011	25/07/2012	NATA calibration by Trio Smart Cal
Cable	Huber & Suhner N-Type Sucoflex 104 Low Loss RF Cable Asset Number: C-374 Manufacturer: Huber & Suhner Model Number: ELT-400 (F0004)	06/10/2010	06/10/2011	EMC Technologies Pty Ltd

Table 20 –Test Site Description

Site No	Test Date	Site Locations	DB	Meter Type	Construction	Meter Box	Antenna
1	3/08/2011	Attwood, 3049	Jemena	iCredit 500	Brick Veneer	Metal	External
2	4/08/2011	Craigieburn, 3064	Jemena	iCredit 500	Brick Veneer	Metal	Internal
3	5/08/2011	Eaglehawk, 3556 (Bendigo)	Powercor	L&G E350	Brick/Timber	Timber	Internal
4	5/08/2012	Sedgwick, 3551 (Bendigo) – 3-Phase Meter	Powercor	L&G E350	Metal Shed	Metal	Internal
5	8/08/2011	Glenroy, 3046	Jemena	iCredit 500	Brick Veneer	Metal	Internal
6	8/08/2011 & 19/08/2011	Essendon, 3040 (tested before and after AMI Meter installation)	Jemena	iCredit 500	Brick Veneer	Metal	Internal
7	15/08/2011	Lower Plenty, 3093	SP-AUSNET	L&G E350	Brick Veneer	Metal	Internal
8	16/08/2011	Balwyn, 3103 (Group of 13 meters)	Powercor	iCredit 500	Cement Block	None	Internal
9	16/08/2011	Boronia, 3155 (Group of 9 meters)	SP-AUSNET	L&G E350	Metal cabinet	Metal	External
10	17/08/2011	Mooroolbark, 3138	SP-AUSNET	L&G E350	Brick Veneer	Metal	External
11	17/08/2011	Croydon, 3136	SP-AUSNET	L&G E350	Brick Veneer	Timber	External
12	17/08/2011 & 22/08/2011	Bayswater North, 3153	SP-AUSNET	L&G E350	Brick Veneer	Metal	Internal
13	18/08/2011	Elwood, 3184 (Group of 11 meters)	Jemena	iCredit 500	Brick Veneer	Timber	Internal
14	18/08/2011	Hampton, 3188	Jemena	iCredit 500	Weatherboard	Metal	Internal
15	18/08/2011	Springvale South, 3172	Jemena	iCredit 500	Weatherboard	Metal	External
16	19/08/2011	Clifton Hill, 3068	Powercor	L&G E350	Weatherboard	None	Internal

Table 21 - Narrowband E-Field Measurements – Single Meter Sites

TEST RESULTS AND CALCULATED RF EMF LEVELS

Table 22 – Jemena/Powercor Meter Average RF E-Field & Power Density levels at 2.5% Duty Cycle

Single Meter Site No.		1		2		3	
Measurement type		V/m	W/m^2	V/m	W/m^2	V/m	W/m^2
Meter Box Open	30cm	NM	NM	3.44	0.0314	1.39	0.00512
	50cm	0.45	0.00054	1.90	0.00961	NM	NM
	1m	NM	NM	NM		0.81	NM
Meter Box Closed	30cm	NM	NM	0.37	0.00038	0.33	0.0003
	50cm	NM	NM	0.27	0.0002	NM	
	1m	NM	NM	NM		0.20	0.00011
Inside House	30cm	NM	NM	0.35	0.00033	NM	
	50cm	NM	NM	0.25	0.00018	0.16	0.00007
	1m	NM	NM	0.11		NM	
Single Meter Site No.		4		5		6	
Measurement type		V/m	W/m^2	V/m	W/m^2	V/m	W/m^2
Meter Box Open	30cm	3.12	0.0259	1.49	0.00592	2.64	0.0186
	50cm	NM	NM	NM	NM	0.82	0.00179
	1m	1.07	NM	1.09	NM	1.34	NM
Meter Box Closed	30cm	0.08	0.00002	1.34	0.00485	0.13	0.00005
	50cm	NM	NM	NM	NM	0.12	0.00004
	1m	0.05	0.00001	0.55	0.00082	0.07	0.00001
Inside House	30cm	NM	NM	NM	NM	0.15	0.00006
	50cm	0.17	0.00008	0.31	0.00026	0.15	0.00006
	1m	NM	NM	NM	NM	0.07	0.00002
Single Meter Site No.		14		15		16	
Measurement type		V/m	W/m^2	V/m	W/m^2	V/m	W/m^2
Meter Box Open	30cm	3.54	0.03327	NM	NM	1.41	0.005288
	50cm	2.19	0.01281	NM	NM	2.06	0.011293
	1m	1.18	0.00369	NM	NM	0.96	NM
Meter Box Closed	30cm	0.17	0.00008	0.82	0.00179	NM	NM
	50cm	0.15	0.00006	0.78	0.00165	NM	NM
	1m	0.10	NM	NM	NM	NM	NM
Inside House	30cm	0.04	0.0000006	0.05	0.000008	0.22	0.000139
	50cm	0.04	0.000005	0.03	0.000004	0.31	0.000257
	1m	0.08	0.00002	0.03	0.000004	0.26	0.000189

12 $W/m^2$0.000006 0.000002 0.000001 0.000006 0.000004 0.000002 NM

Table 23 – SP-AUSNET Meters Average RF E-Field & Power Density levels at 1.39% Duty Cycle

Single Meter Site No.			7		10		11		
Measurement type			V/m	W/m^2	V/m	W/m^2	V/m	W/m^2	V/m
Narrowband E-field measurement with Meter Transmitting (V/m)	Meter Box Open	30cm	1.132	0.00268	0.573	0.00069	NM	NM	0.052
		50cm	0.683	0.00098	0.348	0.00025			0.031
		1m	0.365	NM	0.204	NM			0.016
	Meter Box Closed	30cm	NM	NM	NM	NM	0.963	0.001943	0.054
		50cm					0.597	0.00075	0.041
		1m					0.228	0.00019	0.021
	Inside House	30cm	0.134	0.00004	0.008	0.00000	0.065	0.000009	NM
		50cm	0.058	0.000007	0.005	0.00000	0.041	0.000004	
		1m	0.044	0.000004	0.003	0.00000	0.041	0.000004	

View Table 24 - Group Meter sites Measurement Results

Table 25 -Jemena/Powercor Group Meter Average RF E-Field & Power Density levels at 2.5% Duty Cycle

Single Meter Site No.		8 – Meter DZ103548		8 – Meter DZ103500		8 – Meter DZ103549	
Measurement type		V/m	W/m^2	V/m	W/m^2	V/m	W/m^2
Meter Box Open	30cm	1.87	0.00929	2.32	0.01425	3.29	0.02869
	50cm	1.56	0.00647	1.78	0.00838	2.53	0.01704
	1m	NM	NM	NM	NM	NM	NM
Meter Box Closed	30cm	NM	NM	NM	NM	NM	NM
	50cm	NM	NM	NM	NM	NM	NM
	1m	NM	NM	NM	NM	NM	NM
Inside House	30cm	0.25	NM	0.44	0.00028	0.28	0.00012
	50cm	0.23	NM	0.33	0.00016	0.28	0.00011
	1m	NM	NM	NM	NM	NM	
Single Meter Site No.		13 – Meter 0518791		13 – Meter 0518803		13 – Meter 0518816	
Measurement type		V/m	W/m^2	V/m	W/m^2	V/m	W/m^2
Meter Box Open	30cm	2.70	0.01927	3.38	0.03696	3.38	0.03034
	50cm	2.10	0.01166	2.22	0.0111	2.22	0.01313
	1m	1.30	0.00315	0.80	0.00315	0.80	0.00168
Meter Box Closed	30cm	NM	NM	NM	NM	NM	NM
	50cm	NM	NM	NM	NM	NM	NM
	1m	NM	NM	NM	NM	NM	NM
Inside House	30cm	NM	NM	NM	NM	NM	NM
	50cm	NM	NM	NM	NM	NM	NM
	1m	NM	NM	NM	NM	NM	NM
Single Meter Site No.		13 – 6 meters					
Measurement type		V/m	W/m^2				

Single Meter Site No.		8 – Meter DZ103548		8 – Meter DZ103500		8 – Meter DZ103549	
Measurement type		V/m	W/m^2	V/m	W/m^2	V/m	W/m^2
Meter Box Open	30cm	2.99	0.02364				
	50cm	2.02	0.01085				
	1m	1.08	0.00312				
Meter Box Closed	30cm	NM	NM				
	50cm	NM	NM				
	1m	NM	NM				
Inside House	30cm	NM	NM				
	50cm	NM	NM				
	1m	NM	NM				

Table 26 – SP-AUSNET Group Meter Radio RF EMF RF E-Field & Power Density levels at 1.39% Duty Cycle

Group Meter Site No.			9							
Measurement type			4141549		4141309		4141616		2 meters*	
			V/m	W/m^2	V/m	W/m^2	V/m	W/m^2	V/m	W/m^2
Narrowband E-field measurement with Meter Transmitting (V/m)	In front of the Meter Box	30cm	*Note 1	*Note 1	*Note 1	*Note 1	*Note 1	*Note 1	*Note 1	*Note 1
		50cm								
		1m								
	Meter Box Closed	30cm	0.43	0.00038	0.52	0.00057	0.57	0.00067	0.28	0.00017
		50cm	0.18	0.00007	0.29	0.00018	0.23	0.00011	0.33	0.00023
		1m	NM	NM	NM	NM	NM	NM	NM	NM
	Rear of the Meter Box	30cm	NA	NA	NA	NA	NA	NA	NA	NA
		50cm								
		1m								
		50cm								
		1m								

Table 27 - ELF (50Hz) Magnetic Field Measurements

Site Number		Ambient Magnetic Field measured (No Load) (mG)							50Hz magnetic Field measured (4kW Load) (mG)							
		Outside			Inside				Outside				Inside			
	On meter	30 cm	50 cm	1m	On wall	30 cm	50 cm	1m	On meter	30 cm	50 cm	1m	On wall	30 cm	50 cm	1m
1	26	1.4	NM	NM	4.4	1		NM	145	10.3	NM	NM	11.1	4.5	NM	NM
2	8	0.8	0.6	NM	1.1	0.5	0.4	NM	155	6	2	NM	33	2.6	1	NM
3	22	5	0.7	NM	3	1	0.4	NM	198.4	13	1.1	NM	19.8	3	1	NM
4	22.8	1	0.5	NM	34.7	1	0.4	NM	34.7	1.2	0.5	NM	84.3	9.9	1.3	NM

Site Number		Ambient Magnetic Field measured (No Load) (mG)							50Hz magnetic Field measured (4kW Load) (mG)							
		Outside			Inside				Outside				Inside			
	On meter	30 cm	50 cm	1m	On wall	30 cm	50 cm	1m	On meter	30 cm	50 cm	1m	On wall	30 cm	50 cm	1m
5	17.8	1.3	1.2	1.1	1	1	1	1	257	2.28	1.3	1.2	39.7	4.8	1	1
6	8.2	1.6	1.5	1.5	2	1	1.3	1.4	132	14.2	4.1	0.7	34	5.6	1.6	1.4
7	100	5	1	0.5	3	10	8	0.8	255	8	2	0.8	28	10	8	0.8
8*	300	90	65	20	250	92	35	NM	100	65	26	4.4	45	32	17.6	6
9*	12.3	1.1	0.4	0.3	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
10	9	0.8	0.3	0.2	15.4	0.8	0.3	0.1	45	5	2.1	0.4	82	6.6	2.2	0.3
11	10	0.6	0.2	0.1	88	1.8	0.4	0.1	120	4.3	1.2	0.3	483	9.3	2.6	0.3
12	NM	NM	NM	NM	1.2	0.2	0.2	NM	100	4.1	3.7	0.6	49.6	1.8	0.6	0.3
13*	52	9.2	3.2	3	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
14	48	2.1	1.2	0.7	9	1.6	0.7	0.5	88	7.8	2.9	1.1	33	4.7	2.7	1.6
15	40	5.3	2.3	1	14	4.1	1.2	1	136	24	9	2	42	12	5.6	2.5
16	52	10	3.3	1	35	10.2	2.5	0.5	142	18	10	4.1	146	33	12.6	3.1

Table 28 – Comparison of ELF (50Hz) Magnetic Field Measurements between Old rotating-disc meters and New Smart meters

		Ambient Magnetic Field measured (No Load) (mG)								50Hz magnetic Field measured (4kW Load) (mG)							
	Site Number	Outside				Inside				Outside				Inside			
		On meter	30 cm	50 cm	1m	On wall	30 cm	50 cm	1m	On meter	30 cm	50 cm	1m	On wall	30 cm	50 cm	1m
6	Old rotating-disc meter	122	0.8	0.3	0.2	19	4	0.9	0.7	270	16	0.9	0.8	300	13	2.6	1.4
	Replaced Smart meter	8.2	1.6	1.5	1.5	2	1	1.3	1.4	132	14.2	4.1	0.7	34	5.6	1.6	1.4
13*	Old rotating-disc meter	281	9.8	5.3	2.2	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
	Adjacent Smart meter	52	9.2	3.2	3	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM

*Group meter site with combination of Old Rotating disc meters and Smart meters installed by Jemena.

Table 29 - Common Household Emitters : 50 Hz Magnetic Field Measurements

Test Sample	Magnetic Field measured (mG)			
	At surface level	30 cm away	50 cm away	1m away
Electric Queen Blanket (110-115W)	29.6	1.4	NM	NM
Household Vacuum Cleaner	288	21.6	7.8	1.4
Microwave Oven	131.4	30	14	4.6
CRT TV	NM	4.2	1.2	0.6

Table 30 - Common Household Emitters: RF EMF Power Density Measurements

Test Sample	Power Density (watt/m²)		
	30 cm away	50 cm away	1m away
Wireless Modem	0.005	0.0005	0.0004
Microwave Oven	0.149	0.093	0.061
Baby Monitor	0.066	0.0006	0.0004
Mobile Phone *1.	0.091	0.057	0.023
Cordless Handset (5.8 GHz)	0.017	0.006	0.002

*1. The actual transmit power from the mobile phone was not known since it varies depending on distance from a base station. The level measured here at 30 cm would be typical when using a mobile phone with a hands free kit. The typical exposure from a mobile phone used at the ear or in the pocket is 1 to 2 Watt/m^2 (50 to 100% of the limit) for localised exposure.

Table 31 – Duty Cycle Calculation for Jemena smart meters

Meter Number	Time between Byte Read (Minutes)	Transmit Byte 1	Transmit Byte 2	Derived Duty Cycle (%)
0020979	11	2281956	2284151	0.027
	11	2284151	2289692	0.067
	11	2289692	2292676	0.036
	11	2292676	2296262	0.043
	11	2316592	2321719	0.062
0077292	11	1580922	1582819	0.023
	11	1582819	1584165	0.016
	11	1562343	1565299	0.036
	11	1576765	1579386	0.032
	11	1589245	1591405	0.026
0076724	11	4251665	4254667	0.036
	11	4254667	4256582	0.023
	11	4268419	4272221	0.046
	11	4259543	4261302	0.021
	11	4261302	4263819	0.031
0057323	11	35983946	36014017	0.364
	11	36014017	36068557	0.661
	11	36068557	36166848	1.191

Meter Number	Time between Byte Read (Minutes)	Transmit Byte 1	Transmit Byte 2	Derived Duty Cycle (%)
	11	36166848	36196905	0.364
	11	36196905	36225531	0.347
0642675	11	22747085	22747949	0.010
	11	22747949	22750673	0.033
	11	22750673	22751829	0.014
	11	22751829	22752496	0.008
	11	22752496	22753744	0.015
0655877	11	1426680	1438858	0.147
	11	1438858	1453083	0.172
	11	1453083	1458619	0.067
	11	1458619	1460139	0.018
	11	1460139	1461804	0.020

Note: Data was taken between 2:41pm and 6:34pm

Table 32– Duty Cycle Calculation for Powercor smart meter

Meter Number	Time between Byte Read (Minutes)	Transmit Byte 1	Transmit Byte 2	Derived Duty Cycle (%)
	6	5160760	5162278	0.0337
	6	5162278	5165509	0.0718
	6	5165509	5166478	0.0215
	6	5166478	5168114	0.0364
A4206942	6	5168114	5169870	0.0390
	6	5169870	5171339	0.0326
	6	5171339	5173584	0.0499
	6	5173584	5176672	0.0686
	6	5176672	5178617	0.0432
	6	5178617	5180870	0.0501

Note: Data was taken between 2:02PM and 3:02pm

SAMPLE TEST RESULT PLOTS

Figure 8 – Spectrum of Powercor Meter at 30cm Outside (No Meter Box)

The data contained in the above image is shown in the table below:

Number	Frequency (MHz)	Peak (dBuV/m)	ARPANSA General Public limit (dBuV/m)	difference (dB)	Legend
1	916.09	136.8	152.4	-15.6	30cm Horizontal
2	920.58	136.8	152.4	-15.6	30cm Horizontal
3	924.17	135.9	152.4	-16.5	30cm Horizontal
4	926.56	135.3	152.4	-17.1	30cm Horizontal
5	917.59	135	152.4	-17.4	30cm Vertical

6	915.45	134.9	152.4	-17.5	30cm Vertical
7	919.98	134.3	152.4	-18.1	30cm Vertical
8	923.27	133	152.4	-19.4	30cm Vertical
9	925.66	131.6	152.4	-20.8	30cm Vertical

TEST PHOTOGRAPHS

Figure 44 – Powercor Group Meter Site

Figure 45 – SP-AUSNET Group Meter Site with External Antennas

Figure 46 – Jemena Group Meter Site

Figure 47 – Powercor Meter with no Meter Box

Figure 48 – Jemena Meter with External Antenna

Figure 49 – SP-AUSNET Meter in Metal Box - Ext Antenna

Figure 50 - SP-AUSNET Meter in Timber Box -Ext Antenna

Figure 51 – SP-AUSNET Meter with Dual Antennas attached

Figure 52 – Measurement inside the House

Figure 53 – Outside Measurement in the Rain

Figure 54 – RF Emission Test of a Mobile Phone

Figure 55 – RF Emission Test of a Baby Monitor

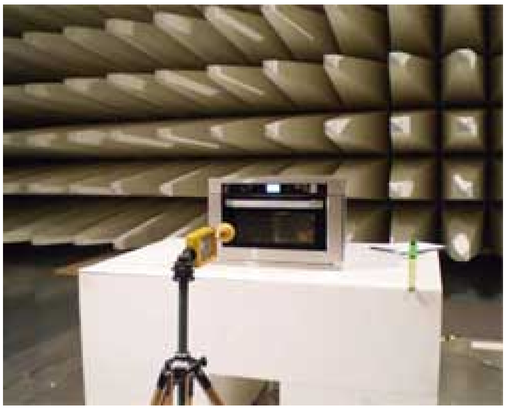

Figure 56 – RF Emission Test of a Microwave Oven

Figure 57 – Magnetic Field Test of a Vacuum Cleaner

STUDY REPORT

Comparison of the Preliminary Victorian Study

To Other Overseas Studies

Prepared by Professor Andrew Wood

Brain and Psychological Sciences Research Centre

Swinburne University of Technology

Section A: a review of the best available evidence on the safety of Advanced Metering Infrastructure (AMI) meter EMFs based on relevant Australian and international standards.

AMI emissions in relation to human health standards

1. Since AMI meters emit electromagnetic energy (EME) in the Radiofrequency (RF) section of the electromagnetic spectrum, they are required to comply with relevant RF human exposure standards. In Australia, the Australian Communications and Media Authority (ACMA) have mandated the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Radiation Protection Series 3 (RPS3) [1] document as providing a compliance standard for RF emissions. Worldwide, there are a number of bodies issuing RF standards. The two major standards bodies are: i) the International Commission for Non-ionising Radiation Protection (ICNIRP), which is linked to the World Health Organisation (WHO) and ii) the International Committee for Electromagnetic Safety (ICES), which is linked to the Institution for Electrical and Electronic Engineers (IEEE). In the United States, the Federal Communications Commission (FCC) takes a leading role in issuing compliance advice [2]. Both the ICNIRP and ICES standards are based on an evaluation of the research literature on RF bio-effects, including some comment on the epidemiological data available at the time of publication (see [3], [4]). RPS3 [1] includes annexes in which both the epidemiological and laboratory-based studies were reviewed by local experts.
2. Some countries have so-called ‘precautionary standards’ with extra safety margins included, often as a response to public concern. These are sometimes driven by the lowest level that can be reasonably achieved by telecommunications service providers rather than a ‘weight of evidence’ evaluation of the science and as such cannot be regarded as safety standards. The standards just referred to have large safety margins built in to account for scientific uncertainty and the most vulnerable members of the community. Typically this safety margin is of the order of 50. The standards are designed to prevent possibly dangerous rises in temperature in body tissue, particularly those tissues (such as the eye lens) which do not possess a convective blood supply. The possibility of non-thermal effects is discussed in these documents as part of the ‘weight of evidence’ evaluation. This will be discussed further in Section B.

Averaging time for gauging compliance with health standards.

3. Both standards have Basic Restrictions on the rate of energy absorption per unit tissue mass (Specific Absorption Rate or SAR, typically in W/kg) which are directly linked to temperature rise. However, since this is difficult to assess in a general exposure situation, limits are also placed on the power density (PD) of the ambient RF energy impinging on the body (typically in W/m^2). These limits are termed ‘Reference Levels’ in ICNIRP (and RPS3) and ‘Maximum Permitted Exposures’ (MPEs) in ICES. These have been conservatively determined from the Basic Restrictions by mathematical modelling. However, these models are less accurate for exposure situations close to the source (typically less than 1 wavelength, which is 33 cm at 900 MHz) – the so-called ‘near field’. Added to which, most measuring instruments measure only one of the electric (E) or magnetic (H) field associated with the EME. Away from the near field E and H are in constant proportion (E/H = constant), so it is only necessary to measure one of the two quantities when calculating PD, which is E multiplied by H. PD is thus proportional to E2 since E x H = E x E/constant).
4. Since the RF can be intermittent or of variable amplitude, the issue of averaging time is important. The purpose of the Australian RF standard is to prevent tissue temperature rise by more than approximately 1°C. On exposure to RF, temperature rise occurs more or less instantaneously, with a rising time constant of around 6 minutes determined by the diffusion properties of tissue. If the tissue temperature is allowed to increase by more than 6°C, this will start to affect protein structure irreversibly. This is why it is inappropriate to average over long time periods, such as 24 hours. As an illustration, a single 1 minute exposure to a PD of 1 kW/m^2 may be sufficient to cause thermal damage, even though when averaged over a 24 h period is equivalent to 0.7 W/m^2, even though this figure is well within limits at the frequencies relating to AMIs.
5. The Duty Cycle refers to the percentage of the period of interest that an intermittent signal (RF in this case) was actually present. In the example just given, the Duty Cycle for a 6 minute interval was 1/6 x 100 = 16.7%, but on the other hand based on a 24 hour interval it is (1/1440) x 100 = 0.07%. The issue of an appropriate Duty Cycle is critical when considering the degree of compliance of AMIs.
6. AMIs operate in a very similar manner to mobile phone handsets: most of the time neither transmitting nor receiving, but from time-to-time connecting to a base station and transmitting and receiving data during this connection. In addition, the AMI sends and receives short burst of ‘housekeeping’ data for the purpose of network optimisation. Each AMI actually has two transmitters/receivers: a Wireless Mesh Network (WMN) module to communicate power consumption data to the base-station and a Home Area Network (HAN) to communicate wirelessly with devices inside the house (to control heating/cooling systems, for example). These use two different frequencies and which particular frequencies are used depends on the model of the AMI. The SilverSpring AMI uses 900 MHz for the WMN (or Neighborhood Area Network, or NAN as the manufacturer calls it) and 2,400 MHz for the HAN. On the other hand, the WiMax Interval Meter (type GE WX-SGC) uses 2,300 MHz for the WMN and 900 MHz for the HAN.

Specific limit values and averaging times

7. The following Table gives the PD limits for the general public (in W/m^2) for the two major international standards and the US FCC standard for comparison. The Australian standard (ARPANSA) is based on the ICNIRP standard. The specified averaging times are also listed. The specific wavelengths are included to show the minimum distances that an E-field based measuring instrument can confidently be used. It should be noted that the frequency of 900 MHz given above is a nominal one, actual frequencies are above and below this value according to available frequency slots: note that the limit values vary somewhat across the range of values used. Within the band 2200 – 2600 MHz, however, the limit values do not change.

Frequency	Wavelength	ARPANSA/ICNIRP	ICES	FCC

MHz	cm	W/m^2	W/m^2	W/m^2
850	35	4.25	4.25	5.67
950	32	4.75	4.75	6.33
2300	13	10	10	10
Averaging time		6 min	30 min	30 min

Reports on AMI meter emissions in relation to standards

8. Although there are a number of pamphlets and information sheets available from public health and other bodies regarding the level of EME emissions from AMIs in relation to standards (typically given as percentages of the limits given in the Table) very few are based on actual measurements. For example, a report prepared for Hydro One Networks Inc, Ontario, Canada [5] essentially treats the AMI as a RF antenna or aerial. There is a standard formula (see page 5 of this document) to predict the far field PD at a specified distance given several pieces of information: the transmitted output power of the device, the 'antenna gain' which characterises the maximum enhancement in a particular direction due to the antenna design, the expected enhancement due to reflections from nearby structures and the duty cycle. The graph on page 10 of the document shows that at 1 m the PD for the power meter transmitter would be 0.01 W/m^2 approximately, or 0.1% of the limit at 2,400 MHz (the relevant frequency for this particular AMI). At 3 m (or 10 ft) this falls to 0.001 W/m^2, or 0.1$\mu W/cm^2$, the latter figure being quoted by [6] and also other utility websites. Unfortunately, insufficient details are given to assess the assumptions made in this estimate. On page 3 the transmitted output power is given as 1 W, the duty cycle 3.3% and on Page 5 the reflection factor of 2.56. This implies an antenna gain factor of 1.4, which is close to the value of 1.6 quoted by some antenna manufacturers for WiMax applications (see Panorama Antennas Product Data Sheet TCD-23-UF). Note that this analysis assumes that the PD follows an inverse square law (hence the straight lines in the graph on page 10). The duty cycle value is that supplied by the manufacturer, and it is difficult to comment on what period of time was used to estimate this (i.e whether 6 min, 30 min or 24 hours).
9. Advice issued by the US State of Maine (see http://www.maine.gov/dhhs/boh/documents/smart-meters-faq.pdf) also includes an estimate of PD at various distances from the AMI. For example, at 36", the PD is given as 0.381 W/m^2, or 0.32 W/m^2 at 1 m (3.2% of the limit). This includes a reflection factor of 4 (100% reflection) an antenna gain of 1 (assuming a transmitted power of 1W) but more importantly a duty cycle of 100%.
10. An assessment report of the WiMax Interval Meter carried out in Melbourne for SP AusNet (see http://www.spausnet.com.au/CA2575630006F222/Lookup/SmartMeters/$file/RF EME Analysis Predictions Report - Interval Meter Rev4a.pdf.) assumes a transmitted power of 0.5 W, an antenna gain of 1.6, no reflections and a duty cycle (based on 6 min) of 8.3%. At 1 m this corresponds to 0.0051 W/m^2.
11. From the previous three paragraphs (where PD estimates at 1 m range by a factor of over 60) it is apparent that there are two factors which need to be clarified in order to assess a worst case scenario: duty cycle and reflection factor. Before going on to consider studies in which actual field measurements have been made, further discussion on these factors is in order.
12. A recent report from Sage Associates [7] has quoted two studies by Hondou [8, 9] to raise the possibility of multiple reflections leading to reflection factors greater than 4 (which corresponds to 100% reflection). The later of the two papers includes experimental data obtained in a metal-lined lift car and a refrigerator container. Enhancements of over several hundred-fold over free-field values at particular distances of were obtained in the lift even with two people present and the door open. In the refrigerator container one isolated spot was 2000 times the expected value at that distance for an inverse square law. Leaving aside for the moment the question of whether the data can be independently reproduced, these large enhancement factors only refer to large separation distances between source and detector. As pointed out

in a comment from the Electric Power Research Institute (EPRI) it is incorrect to apply this enhancement factor at all distances [10] as the Sage report does. Scaling to 1W of transmitted power would imply a maximum PD of 7.3 W/m^2, which is still within the limits at 2,400 MHz (although just above at the frequency used in this experiment, 1,200 MHz). However, this is assuming a 100% duty cycle and a constant value over the specified spatial averaging area, which in the case of RPS33 is a square of 24 cm on the side centred on the point of maximum measurement (to realistically represent coupling to the human body). Given the data presented in [9], the averaged value would be considerably less than 1.1 W/m^2 and with a conservative 6-min duty cycle estimate of 10% the safety margin would be at least 20 and possibly more. The other consideration is that a lift car would not be representative of a smart meter set against an external wall, even if the dwelling were clad in sheet metal. This is discussed further in [10]. Direct measurement has shown that for the WMN system (which operates at a higher power than the HAN system) the PD at the back of the meter is around 10% of that at the front. In summary, it is highly unlikely that multiple reflections from metallic surfaces will lead to situations where the AMI meter will be out of compliance with RPS3.

Appropriate duty cycle considerations

13. The second consideration is the appropriate duty cycle to apply. The rationale behind the 6 minute averaging time in RPS3 is given in paragraph 4 above. In most 6 minute time intervals the transmission is either zero or extremely short. Every few hours the meter is programmed to download consumption information to the network. At the moment the burst of data download is reported to take a few seconds. If we assume a scenario of 10 s download, the duty cycle would be 10/360 x 100 = 2.8%. There has been some speculation that in the future this duty cycle could increase. It is unlikely, however, that the duty cycle could reach 100%, since part of the time during any 6 min period will be spent in receive rather than transmit mode (in a similar way to mobile phone traffic). Some of the reports give duty cycles based on a 24 hour period. For example, a measurement study carried out by EPRI [11] gives the maximum duty cycle associated with any meter (of the type studied) to be 5%, based on a 24 hour period. This implies 4320 s per day and it is impossible to determine how much of this would fall within a particular 6 min period. For example, if it were to occur in 4 x 6 hourly bursts, then each burst would last 1080 s, which would imply a 100% duty cycle in several 6 min periods during the day. Clearly, this is unrealistically high, since at a 100 kb/s transmit rate the data transferred in that time would be over 100 Mb and it is difficult to imagine a need to transfer that amount of data on a regular basis, even if the meter were acting as a relay. Even if it were the case, there would be pauses to receive data during the 6 min period. There is evidence that partial network deployment could contribute to higher than optimal traffic, which will reduce once the network it complete. The issue of appropriate duty cycle has been clarified to a certain extent by the detailed analysis of data traffic presented in this report, showing 2.5% to be the “worst case” duty cycle by measurement. Measurement studies
14. Turning now to surveys in which actual field levels have been monitored, there appears only to have been one major study, that carried out by Richard Tell Associates for EPRI [12] and which is summarised in [11]. This is a comprehensive study with several components, including in-house measurements, measurements from test racks with arrays of 10 meters, the effects of ground reflections and the effectiveness of shielding materials. The report also contains comparisons with other household RF transmitters, such as cordless phones and wireless routers. Some of the results from this report can be adapted to estimate compliance with RPS3, with the following caveats: a 6 minute rather than a 30 minute averaging time needs to be applied and the RPS3 limits in the 900 MHz band are 1.33 times lower than the FCC limits. Of particular interest is the graph shown as Figure 6 in [11], which represents what could realistically be taken as a worst case scenario, a test bank of 10 meters each transmitting continuously. This shows that even at 0.3 m from the bank the RF emissions would still be 13.3% of the RPS3 limit. At 1 m this would be around 1% of this limit (compare this value with 0.1%, 3.2% and 0.05% given in

paragraphs 8 – 10 above). Given that the likely worst case duty cycle (at 900 MHz) is 2.5 %, then the effective safety margin is 4,000 at 1 m.

15. Another useful result from this study is that 0.2 m behind the bank of 10 meters the maximum reading for continuous emission was 0.8% of the RPS3 limit. This distance could be taken as representative of the distance to someone's head in a bed in an adjacent room. This figure is over-pessimistic for a number of reasons: i) the likely worst-case duty cycle just referred to; ii) the intermittent nature of transmissions in normal operating modes (most duty cycles would be far less than 2.5%); iii) the high likelihood that not all of the meters would be transmitting simultaneously (in a bank like this only 1 or 2 meters might be acting as a relay, the others operating on low transmit power to the relay, if transmitting at all); iv) in actual homes or apartments the plasterboard or meter box material serving to attenuate the field levels further.
16. This survey shows that in comparison with other RF-emitting devices within the home, the AMI meter is a relatively minor source of exposure. For example, the averaged exposure 0.3 m from a wireless router within the home was found to be two or three times the value measured against the internal wall behind the AMI.
17. The results of this survey should be applied with caution, because the models of AMI employed within Victoria are different from those used in the EPRI survey.
18. Although the Sage report [7] is suggesting that meters and meter banks in situations where reflections and reverberations could occur would exceed the FCC limits by several-fold, the analysis presented is flawed in at least four ways, some of the ways already mentioned in paragraph 12 above but discussed in detail in [10].Summary
19. I would thus have high confidence in stating that AMI meters will comply with Australian standards in locations normally accessed[4] by the general public even under worst-case operating scenarios.

Section B: a review of the best available evidence from Australian and International studies on the safety and health effects of AMI meter EMF.

Reviews of possible 'non-thermal' effects at low levels

1. There are those who maintain that since international and Australian standards are only designed to protect the body from heat injury, any interactions of RF fields with tissue that do not involve heating (the so-called 'non-thermal' effects) could lead to adverse health effects, particularly in the long term.
2. Annex 4 of RPS3 reviews research into RF bioeffects at low levels of exposure (up to 2002). The main conclusion is that 'exposures leading to SAR values below the basic restrictions… do not lead to unambiguous biological effects indicative of adverse physiological or psychological function or to increased susceptibility to disease'. Similar conclusions were drawn in Annex 3 in relation to epidemiological data available at the time, but since there have been a number of significant studies in the research literature since the date RPS3 was published, it will be useful to briefly survey these study findings here.
3. It is also important to emphasise that the characteristics of emissions from AMIs are not significantly different from those emitted by mobile phone handsets, mobile phone base-stations, Wireless routers and cordless phone handsets and base-stations. Indeed, both the 900 and 2,400 MHz bands are shared with both mobile phone and cordless phone operations. The vast body of literature devoted to assessing RF bioeffects and epidemiological studies in relation to mobile phone use are thus broadly applicable to assessing AMI safety. Further, since microwave ovens and other microwave devices operate at 2,450 MHz, there is a body of research literature stretching back to the 1940s on safety at that frequency. The Information Ventures database of research into EMF (which includes other frequencies than RF) currently has over 39,000 records. The relevant literature has been reviewed many times, the more important recent reviews being ICNIRP [13] and SCENIHR [14]. The latter report is quite clear on concluding 'Animal studies have shown that RF fields …. Alone or in combination with known carcinogenic factors are not

carcinogenic in laboratory rodents'; '..in vitro studies regarding genotoxicity fail to provide evidence for an involvement of RNA exposure to DNA damage' and 'further studies are required to identify whether considerably longer term …exposure might pose some cancer risk'

4. For non-cancer outcomes: the document concluded that there was: 'Some evidence that RF fields can influence EEG patterns & sleep' but furthermore that the ''Nocebo' effect may play a role in symptom formation' ('Nocebo' refers to a subjective expectation of harm, as opposed to 'placebo' where there is an expectation of benefit). However, the experimental conditions involved are typically of continuous exposure to RF for 30 minutes or more with levels at 10% of the limit value or more.

Epidemiological studies in relation to RF

5. Epidemiological studies of mobile phone users have been published at an increasing rate in the years since 2002 (when the RPS3 review was concluded). The major concern has centred on three specific types of brain cancer: glioma, meningioma and acoustic neuroma. A major international study (INTERPHONE), involving case-control studies in 13 different countries has recently been concluded. A combined analysis of the first two cancer types was published in 2010 [15]. In summary: *'overall, no increase in risk of glioma or meningioma was observed with use of mobile phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation. The possible effects of long-term heavy use of mobile phones require further investigation'.*
6. Very recently, the results of the companion paper on the risk of acoustic neuroma has been published [16]. Essentially the results were similar to the 2010 paper, with no evidence of a dose-response relationship but a suggestion of a raised risk for cumulative call time greater than 1640 hours.
7. It should be understood that in order to achieve the equivalent of 1640 hours of RF equivalent to a phone from an AMI (4 mins per day) would take 67 years, even if the fields were the same strength as from a phone (which they are not).
8. Weaknesses in these types of study include: ensuring that the participation rate of cases matches that of control and ensuring that the subjective recall of frequency of handset use and side of head used can be validated in some way. Although the study carried out many additional analyses to try to address these potential weaknesses, it was impossible to rule out their affecting the overall result. Recently, the Epidemiology Sub-Committee of ICNIRP has published a review of INTERPHONE study [17], concluding that '*Although there remains some uncertainty, the trend in the accumulating evidence is increasingly against the hypothesis that mobile phone use can cause brain tumours in adults*'.
9. There have been some recent articles in which the amount of EME deposited into the brain has been compared with the site at which tumours occur (the hypothesis being that they will tend to occur where the RF energy absorption is highest). Although the reanalysis of some of the INTERPHONE data (from 5 countries) seem to support this hypothesis [18-21], another analysis of data from 7 countries does not [22]. Thus the issue seems far from settled.
10. In addition to the 13 groups just mentioned, an independent Swedish group [23] has carried out several studies on brain cancer patients in the Swedish population in relation to the use of several types of phone, including cordless and have identified a much higher risk than the Interphone study would indicate. The question of whether young (less than 18 year old) users (who were excluded from the Interphone study) would show a greater susceptibility. There are two recent publications (from the same study) which aim to fill this gap [24, 25]. In summary, there is no evidence of raised risk of brain tumours in children.

Evaluation by International Agency for Research on Cancer (IARC)

11. In June of this year, the International Agency for Research on Cancer (IARC) considered the whole area of RF and possible influence on cancer and the decision of the working group was to include RF in the category 2B (possibly carcinogenic), along with several agents/activities which would be considered benign (carpentry & joinery, coffee, dry cleaning, pickled vegetables). The reasons for this decision have

recently been published [26]. Ten years ago, IARC placed Extremely Low Frequency (power frequency) magnetic fields in the same category. One of the recommendations of the Stakeholder Advisory Group on ELF EMFs in the UK was that since the older rotating disk meters were identified as a significant source of ELF magnetic fields they should be phased out and replaced by AMIs (see http://www.rkpartnership.co.uk/sage/Public/SAGE first interim assessment.pdf)

Summary

12. Thus in summary, although IARC have categorised RF as 'possibly carcinogenic' they have done so despite anomalies in the epidemiological data and also the lack of: i) substantive evidence from laboratory or animal experiments of such a link; ii) any convincing mechanism of interaction between RF and biological systems at levels not expected to cause significant thermal effects. Since exposures from AMIs are well below those from mobile phone handsets (which were the subject of the INTERPHONE and Swedish studies) it can be said that there is no substantive evidence for health effects from exposure to AMI RF fields.

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1 The terms Electromagnetic Fields (EMF), Electromagnetic Energy (EME) and Electromagnetic Radiation (EMR) have the same meaning for the purposes of this report.

2 Narrowband measurements discriminate the actual frequency of the RF transmission as opposed to Broadband measurements which measure the sum of all frequency components within the range of the measurement instrument

3 According to RPS3, the method of spatial averaging above and below 1000 MHz is different. See this document (p16) for further information

4 Normally the AMI will be enclosed in a meter box accessed only by utility personnel. I have not considered in detail unlikely situations where the head were to be placed against the antenna, but I have considered the possibility of someone's head being placed against the internal wall behind the meter box.