Australian Government
Australian Radiation Protection and Nuclear Safety Agency

Assessment of Ionising & Non-ionising Radiation Levels at Atherton Fire Station, Queensland.

17th – 18th April 2008

Report: 5th May 2008

PO Box 655
MIRANDA NSW 1490
Phone +612 9541 8333
Fax +612 9541 8314

E-mail: info@arpansa.gov.au **Web:** www.arpansa.gov.au
Freecall: 1800 022 333 (a free call from fixed phones in Australia)

619 Lower Plenty Road
YALLAMBIE VIC 3085
Phone +613 9433 2211
Fax +613 9432 1835

Assessment of Ionising & Non-ionising Radiation Levels at Atherton Fire Station, Queensland.

1 Introduction

Following the occurrence of several cases of cancer among Queensland Fire and Rescue Service (QFRS) officers at the Atherton Fire Station, ARPANSA was invited by the Queensland Department of Emergency Services to undertake measurements of radiation as part of an overall environmental assessment. Measurements were made of ionising and non-ionising radiation in the fire station, itself, and in a neighbouring house that had previously been used to provide overnight accommodation for officers.

2 Summary

Two scientific officers from ARPANSA visited Atherton on the 17th and 18th April, 2008 and undertook measurements of:

- Extremely low frequency (ELF) magnetic fields as produced by electrical infrastructure and electrical appliances;
- Radiofrequency (RF) electromagnetic radiation (EMR) and fields (EMF) as produced by external sources such as AM, FM and TV broadcast services and by personal and vehicle radios used by emergency services;
- Ionising gamma-ray radiation as produced by naturally occurring radioactive isotopes in soil and building materials but also by man-made radioactive sources used for a variety of purposes;
- Radioactive radon gas produced by naturally occurring radioactive isotopes in soil and building materials.

ELF magnetic fields were low in comparison with levels found in homes and offices. Levels in commonly occupied areas of rooms were lower than in most homes in Melbourne and magnetic fields near appliances were within the expected range.

Ambient levels of RF EMR from external sources were low in comparison with levels found in capital cities and very far below Australian and international health standards. Peak levels of RF EMR in the vicinity of vehicles while vehicle radios were in use were measured to be lower than the limits for time-averaged public exposure. They were consistent with levels expected within a few metres of a typical mobile vehicle transmitter of ~50 W . Taking into account the low duty cycle of transmission, the levels were well below public exposure limits.

Peak levels of RF electric field near an example waist-worn personal radio were within time-averaged public exposure limits at distances of 30 cm and at the head. An assessment of the exposure of the body of the user from a personal radio requires measurement of specific absorption rate (SAR) and was beyond the capabilities of the equipment used in this assessment. Under Schedule 5 of the ARPANSA Standard (ARPANSA 2002), the evaluation of mobile or portable transmitting equipment for compliance is not required when the equipment is used in an appropriate manner by an aware user. It is expected that the Motorola RP339 personal radios as

used by the QFRS would qualify for this exemption. Nevertheless, SAR assessments of three variants of this model of radio have been provided by the manufacturer and forwarded to the QFRS.

Levels of gamma-ray dose rate were consistent with natural background radiation from the ground and from building materials, such as concrete and brick, and were generally low. An exception to the generally low level was found in the south-west corner of the lecture room where a modest increase in level was observed. This was traced to an obsolete smoke detector, probably containing radium, kept for demonstrations. Advice on how to treat and dispose of this is to be provided separately.

Concentrations of naturally occurring radon gas were not able to be detected, indicating levels considerably less than the average value in Australian homes. Low levels of radon are expected in well ventilated buildings.

3 Extremely Low Frequency Magnetic Fields

Indoor extremely low frequency magnetic field levels were assessed by noting the levels measured near the centre of each room of the fire station and neighbouring house. Magnetic fields from electrical appliances were measured separately at a distance of approximately 30 cm. A magnetic field meter with recording capability was worn at the waist of an ARPANSA officer throughout the visit to provide an indication of average levels and variability likely to be encountered during duties within the fire station. Magnetic field levels are given in the commonly used unit of milligauss (mG). The SI unit is microtesla (μT). Numerical values in milligauss may be divided by 10 to obtain values in microtesla.

3.1 Equipment

Extremely Low Frequency Magnetic Field Meter

Instrument:	EMDEX II (Enertech Consultants, Campbell CA), tri-axial.
Serial number:	B1/3098 (Logging), B2/3099 (Spot measurements).
Frequency response:	40 to 800 Hz.
Sampling rate:	One measurement every 1.5 s.
Uncertainty:	Instrument calibration factors at 50 Hz within ± 4%.
Calibration Date:	12 November 2007.

3.2 Spot Measurements – Centre of Rooms

The highest ELF magnetic field level observed in the central part of each room are shown in table 1. Levels were generally uniform or slowly varying except near electrical equipment or walls where wiring was expected.

Table 1 ELF Magnetic fields measured in centre of room.

Location	ELF Magnetic Fields values in centre of room. (mG)
Main Fire Station	
Lecture Room (general)	0.2
Gym	0.1
Breathing Apparatus Filling Room	0.1
Appliance Bay (West – clothing store)	0.1 – 0.2
Duty Office	0.3
Stationery Store	0.2
Locker Room	0.1
Kitchen	0.1
"FireCom"	0.3
Office (Large - North)	0.2
Office (Small – South, previously bedroom)	0.1
Female Toilet/Washroom	0.1
Male Toilet/Washroom	0.1
Exterior	
South East Corner of land	0.1
Rear concreted area	0.1
Neighbouring House (power disconnected)	
North-west Corner Room	0.2
South-west Corner Room	0.2
North-central Room	0.1
North-east Corner Room	0.1
East central Room	0.1
South-east Corner Room	0.1

3.3 Logged Data at Waist Level

The magnetic field was recorded at waist level of an ARPANSA officer over a period of 3 hours 46 minutes while conducting measurements in rooms and near appliances. The summary statistics of the record are shown in table 2 and the variation with time is shown in figure 1. The levels shown are typical of, or lower than, those found in residences. The maximum value of nearly 13 mG occurred near the time the electric stove was being measured with a single element turned on.

Table 2 Summary statistics of magnetic field at waist level logged during tour of Atherton Fire Station and adjoining house.

Statistic	ELF Magnetic Fields (mG)
Minimum	0.01
Maximum	12.62
Arithmetic Mean	0.29
Standard Deviation	0.57
Median	0.18
Geometric Mean	0.17
99th percentile	2.11

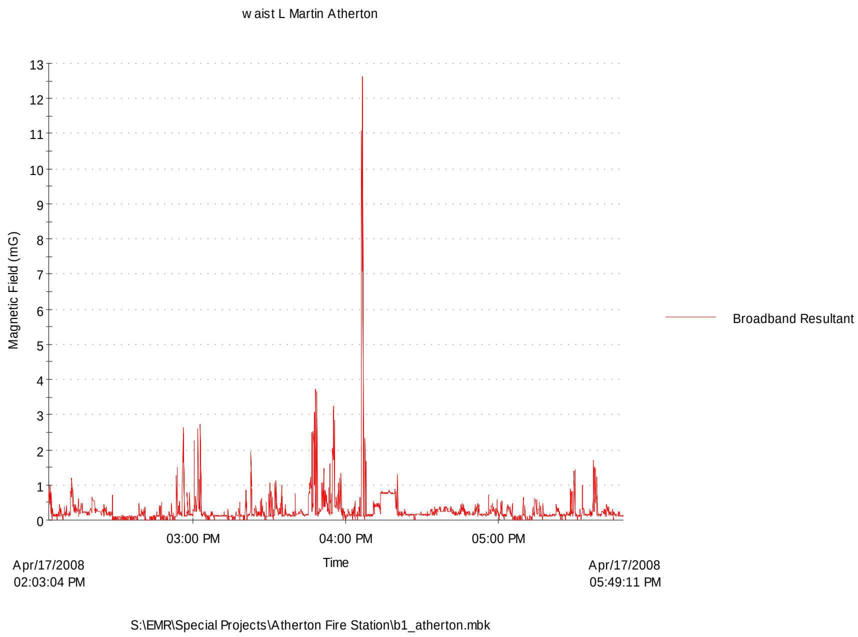

Figure 1 Extremely low frequency magnetic field at waist of person touring buildings and measuring appliances.

3.4 Magnetic Fields near Electrical Appliances

Magnetic fields were measured in the vicinity of electrical appliances, including specialized equipment and appliances similar to that used in residences. Table 3 shows values observed at a distance of 30cm or at a typical sitting position and other distances of possible significance. Figures 2 – 11 show examples of the equipment measured.

As expected, localised high fields of ~800 mG were measured within centimetres of the electric stove element when turned on.

Table 3 Magnetic field measured at 30 cm and various locations near electrical appliances.

	Magnetic Field at Specified Location (mG)			
Electrical Appliance	**At 30 cm**	**At sitting position**	**At keyboard**	**In contact**
Appliance bay equipment, figure 2	3.4 – 4.8			
South office data cabinet, figure 3	0.4			
South office computer desk, figure 4		0.8	1.1	4 – 10
Main office computer desk, figure 5		0.1	0.3	0.5 – 1.7
Main office battery charger, figure 6	4.6	1.3	10 (at phone)	90
Main office photocopier, figure 7	0.2			
Comms room, facing Vernon St., figure 8		0.3		
Comms room, facing west		1.1		
Comms room pico cell	1.1			
Comms room monitored premises rack	0.7 – 1.0			
Appliance bay switchboard, figure 9	2 - 9			
Kitchen, figure 10		0.1		
Kitchen, microwave oven (off)	1.1			
Kitchen, microwave oven (on)	36 - 60			
Kitchen, electric stove (1 element on)	10			
West appliance bay (clothing store) refrigerator	0.1 – 0.2			

Figure 2. South-east corner main appliance bay.

Figure 3. South office, data cabinet.

Figure 4. south office, computer desk.

Figure 5. Main office, computer desk.

Figure 6. Main office, radio battery charger on desk.

Figure7. Main office, photocopier.

Figure 8. "Comms" room, "pico cell" and protected premises communication rack.

Figure 10. Kitchen, microwave oven, electric stove.

Figure 9. North-east corner, main appliance bay, switchboard.

Figure 11. West appliance bay used for clothing storage.

Typical ranges of values of magnetic field near household appliances are listed in table 4 for comparison.

Table 4 Summary statistics for magnetic field from selected appliances measured at a nominal 30cm separation (Pilot Study of Residential Power Frequency Magnetic Fields in Melbourne, Ken K Karipidis and Lindsay J Martin) , http://www.arpansa.gov.au/pubs/technicalreports/tr142.pdf

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

4 Radiofrequency Electromagnetic Radiation

Radiofrequency electromagnetic radiation is used for communication, including broadcast services and the specialised systems used by emergency services. Ambient levels of power flux density were assessed by means of a calibrated spectrum analyser. Localised maximum electric and magnetic fields (according to frequency range) were also measured near vehicle and personal radios during calls. The signal level from the “pico cell” paging system installed on the building was measured during a test page sent out for the purpose.

4.1 Equipment

Portable Spectrum Analyser

Instrument: SRM 3000 Selective Radiation Meter (Narda Safety Test Solutions, Pfullingen Germany).
Serial number: J-0007
Calibration Date: 10 May 2006

Electric Field Probe: Isotropic Frequency response – 75 MHz to 3 GHz
Serial number: G-0159
Calibration Date: 25 April 2006

Magnetic Field Probe: Isotropic Frequency response – 100 kHz – 250 MHz
Serial number: B-0059
Calibration Date: 14 March 2008

Instrument Uncertainty Better than +2.4 dB / - 3.7 dB quoted by manufacturer.

4.2 Ambient Levels from External Sources

Ambient levels of RF EMR from external sources, such as broadcast AM, FM and TV, and paging and mobile phone transmissions, were measured in the "comms" room (or "fire-com" room) at the north-east corner of the fire station. Signals were detected in the AM, FM and UHF Band V television bands as well as in the 800 MHz and 900 MHz mobile phone bands. All levels were very low compared with the relevant exposure limits for the public. Table 5 shows the results together with the most restricting exposure limit for each frequency band.

Table 5. Ambient levels of Radiofrequency Electromagnetic Radiation from External Sources. Signals were detectable in frequency bands shown bold.

Frequency Range [MHz]	Description	Power Flux Density (mW/m^2)	Limit for Public Exposure (mW/m^2)
0.5 - 1.6	**AM Radio**	**0.003**	**12,500**
45 - 70	VHF Band I Television	< 0.005	2,000
70 - 85	VHF Mid Band	< 0.003	2,000
88 - 108	**FM Radio**	**0.002**	**2,000**
174 - 230	VHF Band III Television	< 0.003	2,000
403 - 520	UHF Paging	< 0.003	2,015
526 - 582	UHF Band IV Television	< 0.001	2,630
582 - 820	**UHF Band V Television**	**< 0.001**	**2,910**
870 - 890	**CDMA800 & WCDMA**	**< 0.001**	**4,350**
935 - 960	**GSM900**	**< 0.001**	**4,675**
1805 - 1880	GSM1800	< 0.003	9,025
2110 - 2170	UMTS2100	< 0.004	10,000

Note: Exposure limits are given for the more critical end of each frequency range.

4.3 Ambient Levels in Rooms

Integrated spectrum E-field measurements (75 MHz – 3 GHz) were obtained in the following rooms: lecture room, old appliance bay (clothing store), gym, breathing apparatus (b/a) room, kitchen, duty office, appliance bay, comms room, main office, south office, toilet and laundry. Values ranged from 0.005 - 0.012 mW/m^2 (equivalent plane wave power flux density). The limit for public exposure is 2,000 mW/m^2 , or greater, depending on frequency.

4.4 Microwave Oven

Exposure levels in the vicinity of the microwave oven in the kitchen were assessed by scanning the electric field probe over accessible locations within 30 cm of the oven while accumulating a "maximum-hold" spectrum. The oven was operated normally with a cup of water as a load.

The maximum power flux density obtained while scanning the probe was 5.4 W/m^2, representing an over estimate of actual levels due to the frequency shifting of the microwave generator. The Australian Standard (AS/NZS 2002) for domestic microwave ovens permits a power flux density of 50 W/m^2 at a distance of 5 cm.

4.5 Vehicle Radios

The fire appliances were fitted with VHF or UHF radios with antennas mounted on the cabin roof towards the driver's side of the vehicle. The maximum electric field- (for UHF) and magnetic field- (for VHF) strength in various locations in and around the fire truck radios were measured during short test transmissions with the vehicles parked inside the appliance bay. These are shown in table 6 and 7 and give an indication of likely exposures compared to the limits for public exposure. The observed values shown are maximum values whereas the exposure limits are for an average over 6 minutes. All measured values were less than the public exposure limit at the locations measured. The expected low transmit duty cycle in the emergency services environment would reduce exposures even further A comprehensive test of compliance with the relevant standards would require further measurements that could not be undertaken with the field portable equipment available. Further advice on this may be obtained from the manufacturer or installer of the equipment.

Table 6 Measurements of Maximum 465.55 MHz Electric Field in vicinity of QFRS Unit 852 while UHF Radio was in use.

Location	Maximum E-Field (V/m)	Public Exposure Limit (V/m)	Occupational Exposure Limit (V/m)
Outside passenger door	5.00	29.6	66.2
Front passenger seat, doors open	5.63	29.6	66.2
Front passenger seat, doors closed	5.94	29.6	66.2
Rear passenger seat, door closed, driver door open	5.85	29.6	66.2
Outside rear drivers side door	14.19	29.6	66.2
Rear drivers side seat, doors closed	7.66	29.6	66.2

Table 7 Measurements of Maximum 72.72 MHz Magnetic Field in vicinity of QFRS Unit 955 while VHF Radio was in use.

Location	Maximum H-Field (A/m)	Public Exposure Limit (A/m)	Occupational Exposure Limit (A/m)
Outside passenger door	0.0231	0.0729	0.163
Outside rear drivers side door	0.0289	0.0729	0.163
Rear seat on drivers side, doors closed	0.0098	0.0729	0.163
Front passenger seat, doors closed	0.0147	0.0729	0.163

4.6 Personal Radios

The QFRS makes use of Motorola GP339 personal radios, typically attached to the belt and fitted with a lapel microphone. In addition, a microphone and speakers fitted to breathing apparatus are sometimes connected through the lapel microphone. As with the vehicle radios, measurements of radiofrequency electric fields were made in the vicinity of a radio. A comprehensive assessment of compliance of a body worn transmitter requires measurement of specific absorption rate (SAR) which is beyond the capabilities of the field-portable instrumentation available.

Maximum values during short test transmission were recorded and are shown in table 8. For comparison, the limits on 6 minute average exposure for members of the public are also shown.

Table 8 Measurement of Maximum 465.55 MHz Electric field near QFRS Personal Radio (DMcK) – Motorola GP339 (465.55 MHz)

Location	Maximum E-Field (V/m)	Public Exposure Limit (V/m)	Occupational Exposure Limit (V/m)
~1m from personal radio	5.49	29.6	66.2
~30cm from personal radio	15.10	29.6	66.2
Beside ear	3.67	29.6	66.2
In truck cabin, beside operator	6.60	29.6	66.2

SAR assessment reports supplied by the manufacturer of the GP339 (model numbers PMUE1478A, PMUD1674A and PMUE1439A) show the devices are compliant with the ARPANSA SAR limit for public exposure when operated at 12% transmit duty cycle.

4.7 "Pico-Cell" Paging Transmitter

A VHF paging system for auxiliary fire officers, operated by Cairns control, was located in the Comms room and connected to an antenna on the roof of the fire station. Measurements were made in the Comms room during several test paging signals initiated from Cairns control. Table 9 shows the maximum value recorded compared with the relevant 6 minute average limit for public exposure.

Table 9 Measurement of Maximum 148.6375 MHz Power Flux Density in Comms room during paging signal transmission.

Location	Maximum Power Flux Density (mW/m2)	Public Exposure Limit (mW/m2)
Comms room	0.3	2,000

5 Indoor Ionising Radiation

Ionising radiation was assessed by noting the maximum gamma-ray dose rate in each room of the fire station and neighbouring house while walking slowly through the buildings. An air sampling radon monitor was operated for several hours in the locker room of the fire station and overnight in the north-east bedroom of the neighbouring house.

5.1 Equipment

External Gamma Radiation Monitor

Instrument:	Canberra Inspector 1000
Probe:	NaI(Tl) Ipros-2
Probe Serial Number:	03069915
Calibration Date:	6 December 2007

Radon-222 Monitor

Instrument:	RAD7 radon detector, Durridge
Maximum Measurement Time:	3 hours
Serial Number:	1953
Calibration Date:	29 May 2007

5.2 External Gamma Radiation Results

Measurements of gamma-ray dose rate within the fire station were observed generally in the range 0.064 - 0.090 μSv per hour. In the neighbouring house the levels were lower and in the range 0.038 – 0.050 μSv per hour. Outside the buildings values of 0.040 and 0.062 μSv per hour were observed. An somewhat elevated level of 0.190 μSv per hour was observed in the south-west corner of the lecture room. Table 10 gives the values measured in each location.

Table 10. Maximum observed gamma-ray dose-rates

Location	Maximum observed Gamma-ray Dose-rate µSv/h
Main Fire Station	
Lecture Room (general)	0.075
Lecture Room (SW corner)1	0.190
Gym	0.090
Breathing Apparatus Filling Room	0.064
Duty Office	0.081
Stationery Store	0.070
Locker Room	0.070
Kitchen	0.066
Appliance Bay (East)	0.070
"FireCom"	0.084
Office (Large - North)	0.077
Office (Small – South, previously bedroom)	0.079
Female Toilet/Washroom	0.090
Male Toilet/Washroom	0.086
Exterior	
South East Corner of land	0.040
Outside Gym/Lecture Room	0.062
Neighbouring House	
North-west Corner Room	0.050
South-west Corner Room	0.038
North-central Room	0.043
North-east Corner Room (concrete floor)	0.039

5.3 Radon-222 Results

Radon was not detected at either measurement location The maximum value was estimated to be less than 6 Bq m^{-3} inside the fire station and less than 2 Bq m^{-3} in the house.

5.4 Interpretation of Results

Inside both the station and the house levels of external gamma radiation were less than the Australian average. The higher levels measured in the station compared to the house are due to the radionuclides present in the mineral based materials used to construct the station.

An exception to the generally low level was found in the south-west corner of the lecture room where a modest increase in level was observed. This was traced to an obsolete smoke detector, shown in figure 12, probably containing radium, kept for demonstrations. Advice on how to treat and dispose of this is provided separately.

1 The elevated level in the SW corner of the lecture room was traced to an obsolete smoke detector stored in a cupboard.

Figure 12. Obsolete smoke detector responsible for elevated gamma-ray dose rate in SW corner of the lecture room..

Radon-222 gas levels were not detected above a level of 6 Bq m^{-3} inside the station. Due to the open construction of the station, it is likely the large exchange of air would result in low radon-222 concentrations inside. Inside the house, radon was not detected above a level of 4 Bq m^{-3}. Typically with floorboard constructions, there is good ventilation resulting in low levels of radon-222 gas.

There are two key ionising radiation exposure pathways that occur naturally inside a dwelling: exposure from external gamma radiation and inhalation of radon gas.

Naturally occurring radionuclides are ubiquitously distributed in rocks, soils and sediments making up the Earth's crust. Often this raw material is used to produce many building products like bricks, concrete and plaster board. It is the gamma emitting radionuclide present in building materials and the surrounding soil and rock that contribute to the external gamma radiation exposure.

Two of these naturally occurring radionuclides, thorium-232 and uranium-238, each produce isotopes of the radioactive gas radon. Radon gas is very mobile and can diffuse from the site of production into the open air. Inhalation of the radioactive decay products of radon-222 has been shown to lead to an increase in lung cancer risk. High levels of radon-222 are often found in cellars where there is a poor exchange of air.

In 1990, a nationwide survey of Australian homes to determine the average radiation dose to the Australian population from exposure to radon-222 and terrestrial and radiation, indoors. The technical details of this survey have been reported elsewhere, Langroo (1991)

In Australia the average values of the external radiation in homes is 0.100 μSv per hour. The average per state and territory ranges from 0.080 to 0.140 μSv per hour. The average annual radon-222 concentration averaged 11 Bq m^{-3} with a state and territory average ranging from 6 to 16 Bq m^{-3}. The global average indoor value is 40 Bq m^{-3} (UNSCEAR, 1993).

6 Acknowledgements

ARPANSA would like to acknowledge the hospitality and willing cooperation of the QFRS officers at Atherton.

7 References

AS/NZS (2002) "Australian/New Zealand Standard AS/NZS60335.2.25:2002 Household and similar electrical appliances – Safety Part 2.25: Particular requirements - Microwave ovens".

ARPANSA (2002) "Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields - 3 kHz to 300 GHz", Australian Radiation Protection and Nuclear Safety Agency (2002) http://www.arpansa.gov.au/publications/Codes/rps3.cfm

Langroo (1991) "A Nationwide Survey of 222Rn and Gamma Radiation Levels in Australian Homes", M. K. Langroo; K. N. Wise; J. C. Duggleby; L. H. Kotler, Health Physics, Vol. 61, No. 6, 1991.

UNSCEAR (1993) "UNSCEAR 1993 REPORT, SOURCES AND EFFECTS OF IONIZING RADIATION", United Nations Scientific Committee on the Effects of Atomic Radiation, http://www.unscear.org/unscear/en/publications/1993.html