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Measurement of Electromagnetic Field Radiation in Locations Designated for The Darling Exchange Building, Sydney, NSW.

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1. Introduction

The Darling Exchange is a 6 storey circular building to be located at the northern end of Darling Square (the building marked by letter N in Fig.1). It is a mixed use building comprising retail at Ground and Level 1, City of Sydney Library on level 2 and 3, childcare centre (90 capacity) on level 3 and 4, and a rooftop restaurant on level 5..

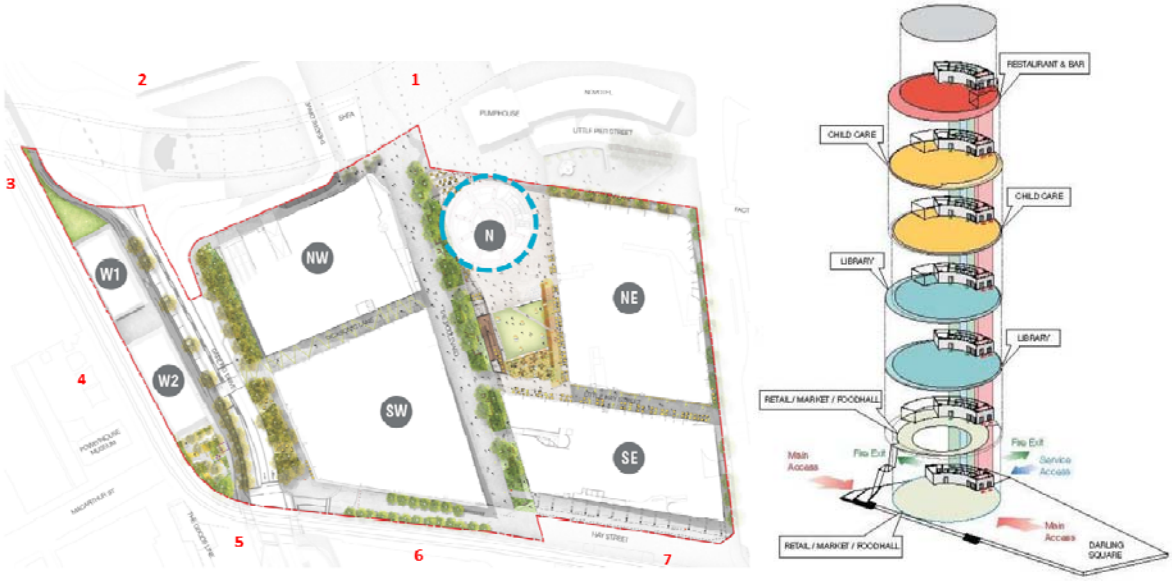

Figure 1 Proposed development in the Darling Square Precint

Clause 4.4.4.3 of the Child Care Centres Development Control Plan issued the City of Sydney Council in 2012 states that: The location of a Child Care Centre is to take into consideration any environmental health hazard or risk relevant to the site and/or existing buildings within the site or in the surrounding area, having regard to the following: (iv) existing and potential on and off-site electromagnetic fields (50Hz and radio frequency fields 3KHz – 300GHz);

This report summarises the results of RF measurements within the proposed redevelopment area and provides comparison of the measured results against the national and international standard for safe RF exposure.

2. Background Information

In Australia, the largest digital mobile communication service operates in the frequency range of 890-960 MHz. However, there are also services and equipment that operate in the range of 1710-1880 MHz and in more resent times some services that operate in the range of 1920–2170 MHz. Some retranslation stations of high capacity RF trunking system receive, amplify and transmit the amplified communication signals at even higher frequencies of the electromagnetic spectrum. The antennas used for such retranslation service are usually in the form of parabolic dishes.

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Concerns about human health effects from the exposure to RF signals from hand-held cellular phones exist because the antennas of these phones can deliver large amounts of RF energy to very small areas of the user's body. The Base Stations and their antennas, however, are usually located far away from users of the mobile phones, so the potential safety issues concerning the mobile phones usually less applicable to the base stations. Antennas of the mobile phones and base stations are the main sources of RF emission from this type of equipment.

The radio waves from some transmitters, particularly from FM and VHF-TV broadcasting stations, are absorbed more by humans than the radio waves from the sources such as mobile phone or mobile phone base stations as they operate in different spectrum of frequencies. The frequency is the rate at which the electromagnetic field changes direction and is measured in Hertz (Hz), where 1 Hz is one cycle (change in direction) per second, and 1 MegaHertz (MHz) is one million cycles per second. In addition, FM and TV transmitters are 100 to 5000 times more powerful than the cellular phone base station antennas.

Antennas of mobile phones and their base stations produce radio-frequency radiation. This RF radiation is "non-ionising", and its biological effects are fundamentally different from the "ionising" radiation produced by x-ray machines.

The interaction of biological material with an electromagnetic source depends on the frequency of the source. X-rays, radio waves and "EMF" from power lines are all part of the electromagnetic spectrum and each is characterised by its own frequency.

Electric power supply systems in Australia are operating at frequency of 50 Hz. AM radio has a frequency of around 1 MHz, FM radio has a frequency of around 100 MHz, microwave ovens have a frequency of 2450 MHz, and X-rays have frequencies above one million MHz.

X-rays damage the genetic material of cells as the electromagnetic particles have sufficient energy to break chemical bonds and cause ionisation, potentially leading to some pathological changes such as cancer or birth defects. At lower frequencies, such as radio waves, the energy of the particles is much too low to break chemical bonds and, therefore, the radio waves are "non-ionising".

2.1 RF Exposure Standards

There are safety guidelines for human exposure to the RF radiation produced by cellular phone and base station antennas. The most widely accepted standards are those developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

The standard specifies the occupational and general public *exposure* limits to RF radiation that regulate the rate at which the electromagnetic field energy is absorbed by human body. This is known as the specific absorption rate (SAR).

The SAR limit for all the mobile phones types, cordless phones and satellite phone handsets for sale in Australia is 1.6 watts per kilogram (averaged over 1 gram).

The basic parameter used in setting the limits is the lowest RF exposure level, confirmed by independent laboratory studies that show adverse biological effects in animals due to such exposure.

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This biological effect was found to occur as a rise in body temperature by 1° C during the exposure. This is measured as Specific Absorption Rate (SAR). SAR is the rate at which RF energy is absorbed by a specified mass of biological tissue. The measurement is expressed in watts per kilogram (W/kg).

However, SAR cannot be easily and readily measured. Therefore, the RF exposure limits are expressed in so called *reference levels*. These are expressed in "unperturbed RMS field strength in V/m (volt per metre) and A/m (amps per metre)" for measurements very close to the sources – *near field* measurements and "plane wave power density measured in mW/cm^2 (milliwatts per square centimetre)" for measurements sufficiently far from the source – *far field* measurements.

At the frequency of the mobile phone communication signal the electromagnetic field exposure is usually measured in mW/cm^2.

In 1998 the International Commission on Non-Ionising Radiation Protection (ICNIPR) issued the "Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz)". In the guidelines the safe exposure limits to RF radiation in the frequency range of 400-2000 MHz is:

For general public

- $1.375 \cdot f^{0.5}$ V/m, (at 900 MHz = 41.3 V/m)
- $0.0037 \cdot f^{0.5}$ A/m (at 900 MHz = 0.111 A/m
- or $f/200$ W/m^2 (at 900 MHz = 4.5 W/m^2)

For occupational exposure

- $3 \cdot f^{0.5}$ V/m, (at 900 MHz = 90 V/m)
- $0.008 \cdot f^{0.5}$ A/m (at 900 MHz = 0.24 V/m)
- $f/40$ W/m^2 (at 900 MHz = 22.5 W/m^2)

where: *f* is frequency in MHz.

> ***Occupational exposure*** *- Exposure to radiofrequency radiation under controlled conditions, in the course of and intrinsic to the nature of their work, of a population consisting of adults who are trained or informed to be aware of potential risks and to take appropriate precautions. The duration of occupational exposure is limited to the duration of the working day or duty shift per 24 hours and the duration of the working lifetime.*

Recently produced and published by ARPANSA Australian RF Exposure Standard specifies the exposure limits as listed in the table below.

REFERENCE LEVELS FOR TIME AVERAGED EXPOSURE TO
RMS ELECTRIC AND MAGNETIC FIELDS (UNPERTURBED FIELDS)

Exposure category	**Frequency range**	**E-field strength (V/m rms)**	**H-field strength (A/m rms)**	**Equivalent plane wave power flux density S_{eq} (W/m^2)**
Occupational	100 kHz – 1 MHz	614	1.63 / *f*	—
	1 MHz – 10 MHz	614 / *f*	1.63 / *f*	1000 / f^2 (see note 5)
	10 MHz – 400 MHz	61.4	0.163	10 (see note 5)

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	400 MHz – 2 GHz	3.07 x $f^{0.5}$	0.00814 x $f^{0.5}$	f / 40	
	2 GHz – 300 GHz	137	0.364	50	
General public	100 kHz – 150 kHz	86.8	4.86	—	
	150 kHz – 1 MHz	86.8	0.729 / f	—	
	1 MHz – 10 MHz	86.8 / $f^{0.5}$	0.729 / f	—	
	10 MHz – 400 MHz	27.4	0.0729	2	(see note 6)
	400 MHz – 2 GHz	1.37 x $f^{0.5}$	0.00364 x $f^{0.5}$	f / 200	
	2 GHz – 300 GHz	61.4	0.163	10	

NOTES:

1. f is the frequency in MHz.
2. For frequencies between 100 kHz and 10 GHz, $S_{eq,}$ E^2 and H^2 must be averaged over any 6 minute period.
3. For frequencies exceeding 10 GHz, S_{eq}, E^2 and H^2 must be averaged over any $9.6 \times 10^4 / f^{1.05}$ minute period (see note 1).
4. Spatial averaging of the time averaged reference levels of Table 6 should be performed according to the requirements of clause 2.7.
5. For occupational exposure, E and H reference levels of Table 6 are given in plane wave ratio at frequencies greater than or equal to 1 MHz. However, for many occupational exposure situations, equivalent plane wave power flux density is not an appropriate metric if “far field” exposure conditions do not apply. Survey meters may be calibrated in terms of W/m^2, but both E and H will generally require independent measurement and evaluation if measured in the near field.
6. For public exposure E and H reference levels of Table 6 are given in plane wave ratio at frequencies greater than or equal to 10 MHz. However, equivalent plane wave power flux density is not an appropriate metric if “far field” exposure conditions do not apply. Survey meters may be calibrated in terms of W/m^2, but both E and H will generally require independent measurement and evaluation if measured in the near field.

The international EMF project of WHO has completed a standards database limiting exposure to EMF. From this database it can be easily seen that the public safety level E field ranges between 3 V/m to 46.35 V/m for 900 MHz and between 6 V/m to 61.40 V/m for 1800 MHz. Some of the developed countries prefer to make their EMF standard as low as technically possible with "precautionary approach". For 900 MHz cellular phone frequency the E field limit value is 3 V/m in China, 3.88 V/m in Switzerland, 4 V/m in Italia, 0.614 V/m in Salzburg, Austria, 6.14 V/m in Bulgaria and Russia, and 10 V/m - 41.25 V/m in Turkey, 46.35 V/m in America, Canada and England and 41.25 V/m in other European Countries. Disparities in EMF standards around the world have now arisen the question that should all countries take the precautionary approach into consideration.

It should be noted that the mandatory standard that was enforced in 1984 in the former USSR for the RF exposure limit for general public is much more stringent. For the RF frequency range of 300-300000 MHz the standard sets the exposure limit in terms of the equivalent power flux density to 0.01 mW/cm^2 (0.1 W/m^2). This is $1/100^{th}$ of the safe exposure level as given in the ARPANSA standard.

The public exposure standards apply to the power densities averaged over relatively short periods to time. Where there are multiple antennas, these standards apply to the total power produced by all antennas.

It should also be noted that performance of some bio-medical implants such as pacemakers and defibrillators can be affected by RF fields. The effects of RF fields on these devices are not covered by the exposure standards.

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2.2 Cell Phone Base Stations

Exposure to radio waves can be hazardous if the exposure is sufficiently intense. Possible injuries include cataracts, skin burns, deep burns, heat exhaustion and heat stroke.
Biological effects of exposure to RF are proportional to the rate of energy absorption.

A low-gain cellular base station antenna, mounted 10m or more off the ground and operated at the maximum possible intensity, may produce a power density as high as 0.02 mW/cm^2 on the ground near the antenna site; but ground level power densities will more often be in the 0.0001 to 0.005 mW/cm^2. These power densities are below the ICNIRP safe exposure limit, and the safety limit itself was set far below the level where potentially hazardous effects have been observed.

Within about 150m of the base of the antenna site, the power density may be greater at elevations above the base of the antenna site (for example, at the second floor of a building or on a hill). Even with multiple antennas on the same tower, power densities will be less than 2% of the guidelines at all heights and at all distances of more than 50m from an antenna site. Further than about 150m from the antenna site power density does not rise with increased elevation.

Reported in the technical literature power densities measured around cell phone base stations show that for the 1600 W low-gain antennas on towers that ranged from 40 to 75 m in height, the maximum power density on the ground was 0.002 mW/cm^2, and the maximum was measured at 15-75m distance from the base of the towers. Within 100m of the base of the towers, the average power density was less than 0.001 mW/cm^2.

Generally, base station antennas are mounted on a 15 to 50 metre high tower, or on rooftops. These antennas typically emit a fan-shaped beam of RF that is roughly parallel to the ground.

Because of the narrow vertical spread of the beam, the RF field intensity on the ground directly below the antennas is low: at points where the public is likely to be exposed, emissions are usually 10,000 times below the level at which significant heating can occur.

There are some circumstances under which an improperly designed cellular phone and base station antenna could violate safety standards. Safety standards for uncontrolled (public) exposure could be violated if antennas were mounted in such a way that the public could gain access to areas within 10m (horizontal) of the antennas themselves. This could arise for antennas mounted on, or near, the roofs of buildings.

3. Frequency Band for Mobile Telecommunication Services in Australia

The frequency band allocated in Australia for the digital mobile communication service, known as GSM service, is as follows:

- GSM mobile transmit band (mobile hand sets)
  - Telstra 890.0-898.4 MHz
  - Optus 898.5-906.8 MHz
  - Vodafone 906.9-915.0 MHz
- GSM mobile base transmit band (base station transmitter)
  - Telstra 935.0-943.4 MHz
  - Optus 943.5-951.8 MHz

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- Vodafone 951.8-960.0 MHz

The difference between 'send' and 'receive' frequencies is 45 MHz.

4. Electromagnetic Field Measurements

The RF radiation measurements were conducted on Thursday, 1st September 2016 in several discrete locations around the construction site. Although the proposed Childcare Centre will be located on the upper floors of the building all the radio frequency measurements were made at the ground level as the building has not been constructed yet.

Visual inspection of all adjacent buildings, especially the visible parts of building roofs revealed no obvious placements of mobile network base station antennas.

The RF meter used during the measurements was:

Lutron Model EMF-839 RF Electromagnetic Field Meter designed to measure the radio frequency electromagnetic field in the wide range of frequencies

- Frequency range: 100kHz – 3000 MHz
- Accuracy: < 2 dB
- Probe structure: 3 Axis
- Probe Type: EP-03H: 50 MHz – 3000 MHz
  EP-04L: 100 kHz – 100 MHz
- Frequency Selection: 100 kHz, 200 kHz, 500 kHz, 1 MHz, 10 MHz, 13.56 MHz, 100 MHz, 900 MHz, 1 GHz, 1.8 GHZ, 2.4 GHz, 2.45 GHz, 3 GHz
- Strength Range: 0 – 200 V/m with 0.01 V/m resolution
  0 – 99.999 W/m^2 with 0.001 W/m^2 resolution
  0 – 9.9999 mW/cm^2 with 0.0001 mW/cm^2 resolution
- Input impedance: 50Ω

This meter is specifically designed for assessment of RF levels from various high frequency sources. The meter shows the frequency of the measured signal and the signal strength.

In addition, measurements of the low frequency magnetic field were also carried out around all sites of the development. The purpose of these measurements was to determine the presence of strong sources of the power frequency magnetic field located above or below ground in close proximity of the development site. The magnetic field meter used for these measurements was HMI-1 magnetic field survey meter with the following characteristics:

- Number of axes 3
- Measuring range 0.1-6000mG
- Resolution 0.1mG
- Accuracy Error ±(2% + 1 digit)
- Frequency Response 50-1000Hz
- Calibration Frequency 50Hz
- Measurement type true RMS

The results of the measurements are summarised in the table below. The values in mW/cm^2 were converted from the V/m readings of the Lutron meter as the measurements were made in the far field region (for distances between the RF source and point of measurements

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greater than $\lambda/2\pi$, where λ is the wavelength in metres) where conversion between the electric (E) and magnetic (H) fields is through the wave impedance Z = E/H =377 ohms:

The RF and Low Frequency measurements were taken along all sides of the development area shown in Fig.1. The results are summarised in the table below.

Location	Frequency band	RF EMF in mW/cm^2	Low Frequency EMF milliGauss (mG)
1	10 - 200 MHz	0.04 mW/cm^2	3.5 mG
	750 – 3000 MHz	0.02 mW/cm^2	
2	10 - 200 MHz	0.07 mW/cm^2	2.1 mG
	750 – 3000 MHz	0.025 mW/cm^2	
3	10 - 200 MHz	0.08 mW/cm^2	0.3 mG
	750 – 3000 MHz	0.027 mW/cm^2	
4	10 - 200 MHz	0.10 mW/cm^2	0.4 mG
	750 – 3000 MHz	0.015 mW/cm^2	
5	10 - 200 MHz	0.08 mW/cm^2	0.7 mG
	750 – 3000 MHz	0.021 mW/cm^2	
6	10 - 200 MHz	0.09 mW/cm^2	1.2 mG
	750 – 3000 MHz	0.018 mW/cm^2	
7	10 - 200 MHz	0.07 mW/cm^2	1.1 mG
	750 – 3000 MHz	0.023 mW/cm^2	

As can be seen from the results in the above table, the measured RF values within the proposed construction site area for the building that Child Care Centre were well below both, the occupational and general public RF EMF exposure limits.

Measurements of the power frequency – extra low frequency (ELF) magnetic field in all locations within the proposed development area also revealed very low levels in all locations.. The sources of such field were either the low and high voltage underground cables or metallic water pipes that can carry the 50 Hz current due to the equipotential bonding of the electrical earting system to the water pipes.

5 Conclusions and Recommendations

In all locations within the proposed Child Care Centre where the RF and ELF measurements were taken the measured values were well below the permissible limit for occupational and general public exposure as set out in ICNIRP and ARPANSA RF exposure guidelines. Please note that all RF and ELF exposure measurements were taken at 1-1.5m height above the ground.

Small variations in RF strength in different locations around the site can be attributed to the RF shielding effect of the adjacent buildings.

The electricity power supply and reticulation system for the Darling Exchange building should be designed and installed such as to avoid placement of an indoor substation, heavy current switchboards and heavy current cables in the areas near the proposed Child Care centre or near the play area. It is recommended that the design of the electrical power supply and reticulation system be checked by the qualified EMF consultant prior to its implementation.

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It is also recommended that no mobile base station antennas be placed on the roof top buildings marked as NW, SW, NE and SE in Fig.1 such that they in close proximity and are facing the Darling Exchange building.

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