



# TECHNICAL REPORT

## RADIO FREQUENCY EME EXPOSURE LEVELS - PREDICTION METHODOLOGIES

Section 1 Introduction – Overview of prediction methodology .....	2
Section 2 Power density equations .....	2
Section 3 Determining compliance with relevant exposure limits .....	3
Section 4 Site configuration .....	3
Section 5 Report format.....	5
Section 6 Shared Mobile Phone Base Station Sites.....	5

## Section 1

### Introduction – Overview of prediction methodology

Radio frequency Electromagnetic Energy (RF EME) emitted from cellular telephone base stations must comply with safety limits. The purpose of this technical report is to provide a protocol which allows a prediction of the estimated exposure levels to show compliance with the ARPANSA Radiation Protection Standard limits that specify limits for continuous exposure of the general public to RF transmissions at frequencies used by mobile phone base stations. prior to installation of the antenna. The assessment is a prediction of RF EME levels that are a result of line-of-sight propagation from the antenna to a point that is considered to be in the centre of the horizontal beam pattern. Relevant information needed for the prediction is to be based on the base station configuration required to meet the network needs for the foreseeable future. The predicted levels are for a base station operating at its highest telephone call capacity and assumes that all transmitters are working at full rated power. Although it is reasonable to expect that average transmitter duty cycles would be less than the maximum used for the prediction, a “maximum site configuration” approach is used in this methodology. The equipment configuration which forms the basis of the “maximum site configuration” prediction should be that which could be reasonably expected of the site given the design lay out at the time of commissioning. This information must be obtained from the mobile telephone carrier.

The formula for calculating power density is described in the Australian Standard AS2772.2: 1988, “Radiofrequency Radiation, Principles and Method of Measurement of --300 kHz to 100 GHz”. This estimation is for the maximum level of RF EME at 1.5m above the ground from the existing antennas. The estimated levels have been calculated on the maximum mobile phone call capacity anticipated for this site. This estimation does not include possible radio signal attenuation due to buildings and the general environment. The actual EME levels will generally be significantly less than predicted due to path losses and the base station automatically minimising transmitter power to only serve established phone calls.

The EME predictions in the report assume a maximum site configuration:

- base station transmitters operating at maximum power (no automatic power reduction)
- simultaneous telephone calls on all channels
- an unobstructed line of sight view to the antennas.

In practice the maximum site configuration is rarely the case, and there are often trees and buildings in the immediate vicinity, and cellular networks automatically adjust transmit power to suit the actual telephone traffic. For these reasons, care should be taken when comparing prediction reports & actual measurements, as the predicted levels will often be considerably higher.

## Section 2

### Power density equation

Appendix B of AS2772.2 provides a method of calculating on-axis power density from a large-aperture antenna. The basic equation used for calculating fields in the far-field is:

$$S = \frac{PG}{4 \pi d^2}$$

Where  $S$  = power flux density, in watt per metre square

$P$  = is transmitted power in watts

$G$  = far field gain expressed as a power ratio with an isotropic reference antenna

$d$  = distance from an antenna to the point of interest - in metre

Note: power flux density is commonly expressed microwatt per centimetre squared, the conversion factor from watt per metre squared to microwatt per centimetre squared is 100.

In the majority of situations power density levels will be required to be calculated for locations which are not on the bore-sight axis of the radiating antenna. In this instance the off-axis gain will need to be obtained. The off-axis gain is obtained by referring to the antenna manufacturer's antenna pattern. In the case of base station antenna emissions predictions, a conservative approach for horizontal patterns is recommended; only the on-axis horizontal gain is to be used and no allowance is to be made for gain reduction that occurs off-axis. Vertical gain patterns must be referred to; off-axis gain for the point in interest is found by using trigonometry to find the off-axis angle. Knowledge of the vertical and horizontal separation between the antenna centre-point and the point of interest is the basis of the off-axis gain calculation.

The transmitting power  $P$  is the power into the antenna and is determined by subtracting all known losses from the transmitter output power, which would normally include cable loss and combiner loss. The total power into the antenna must take into account the number of transmitters in the site configuration. It is not uncommon for configuration to vary from sector to sector, in this case a prediction may be needed for each base station sector. The distance  $d$  used in the equation is the line-of-sight separation between the antenna mid point and the point of interest. The distance is simply calculated by trigonometry using the vertical and horizontal separations.

### **Section 3                      Determining compliance with relevant exposure limits**

The Australian Communications Authority (ACA) mandates exposure limits for continuous exposure of the general public to RF EME from mobile phone base stations. The limits at the time of writing this report are based on AS/NZS2772.1(Int):1998. This Standard has a constant public exposure limit for all frequencies above 9.5 MHz, with the limit being 200 microwatt per centimetre squared ( $\mu\text{W}/\text{cm}^2$ ). Because of this, when compliance is being determined for a point of interest under multiple frequency exposure conditions, the power densities created by all transmitting antenna may simply be added and the total compared with the 200  $\mu\text{W}/\text{cm}^2$  limit and expressed as a percentage of the limit.

The ARPANSA limit expressed in the unit of microwatt per centimetre squared for frequencies above 400 MHz continually increases at the rate of  $f/2$  up to 2,000 MHz. The limit is 200  $\mu\text{W}/\text{cm}^2$  at 400 MHz and 1000  $\mu\text{W}/\text{cm}^2$  at 2,000 MHz. The varying exposure limit across the band of frequencies used by mobile phone base stations does not allow the simple addition of power densities as was the case with AS/NZS2772.1(Int.):1998 limits described above. When applying the ARPANSA limits, compliance is determined by first calculating the percentage of the limit for each transmitter frequency and adding the individual percentages together to determine the cumulative exposure. Compliance is achieved if the sum of the individual percentages is less than 100%. Because each mobile phone carrier operates over a band of frequencies for simplicity the midband frequency may be used when determining the compliance limit. It is also reasonable to simply use the exposure limit at 900 MHz when referring to GSM 900 or CDMA 800 and the limit for 1800 MHz when referring to GSM 1800.

### **Section 4                      Site configuration**

Each base station is designed with particular equipment configuration to provide radio coverage over a geographical area (cell) for a specific number of users at any given time. The equipment configuration is the mix of antenna power, number of radio transmitters, antenna type, height and orientation, which have been brought together at a unique site to meet the service requirements of the cell. This information must be provided by the base station design engineers to enable a prediction of RF EME to be made. The configuration details should be filled out in a table that can be given as an appendix to a prediction report, the table should be made available on request and appropriately filed. The table should have the following title information and include the columns of data defined

below:

**Site Configuration Data For Carrier, Location and Base Station number:**

**GSM Summary (CDMA and other carriers as required)**

Sector Details	No. of Transmitters	Freq (MHz)	Transmitter Power (W)	System Loss (dB)	Antenna Type	Antenna mid Pt. Height (m)	Antenna Bearing ( <sup>o</sup> T)	Antenna Downtilt (deg)
Sector 1	<b>4</b>	<b>900</b>	<b>45</b>	<b>6.2</b>	<b>PD10189</b>	<b>10.7</b>	<b>0</b>	<b>3</b>
Sector 2	<b>4</b> <b>n/a</b>	<b>900</b> <b>1800</b>	<b>45</b> <b>n/a</b>	<b>6.2</b> <b>n/a</b>	<b>MTPA89</b> <b>0-V4</b> <b>n/a</b>	<b>10.7</b> <b>n/a</b>	<b>150</b> <b>n/a</b>	<b>2</b> <b>n/a</b>
Sector 3	<b>4</b> <b>n/a</b>	<b>900</b> <b>1800</b>	<b>45</b> <b>n/a</b>	<b>6.2</b> <b>n/a</b>	<b>MTPA89</b> <b>0-V4</b> <b>n/a</b>	<b>10.7</b> <b>n/a</b>	<b>270</b> <b>n/a</b>	<b>2</b> <b>n/a</b>

Table 1 Example of Site Configuration data

Sector Details

Generally, all sectors will be treated as if the same and only one prediction of a sector will need to be made. However, if there are significant variations in either topography or configuration for a given sector over the others, it will require individual sector predictions to be made. Variations in exposure levels greater than 3 dB should necessitate an individual calculation.

Number of transmitters

This is the number of transmitters able to feed RF power to a particular antenna, which for GSM may be as little as one or as many as six.

Transmitter power

This may be given in dBm or watts and is the power coming from the transmitter cabinet, it does not include system losses.

Frequency

The nominal mid band frequency for the range of frequencies used by the carrier should be given.

System Loss

The total RF loss must be given or determined, these include cable loss and combiner loss. System losses are subtracted from the transmitter power to give the level of RF power transmitted from the antenna.

Antenna Type

The type of antenna will make it possible to obtain the antenna patterns associated with each antenna. As antennas have unique gain properties, a polar or rectangular antenna pattern is required before off-axis gain can be determined. Before gain can be used in the power equation it must first be expressed as dBi before conversion to power ratio. Where antenna patterns are given in voltage ratios they must be converted to dB. Intrinsic electrical tilt will show in the antenna pattern.

### Antenna Mid-point Height

The height of the antenna mid-point above the ground level at the point below the antenna must be given. This will form the basis for vertical distances to all other points of interest to be determined. Elevation drawings or tables showing antenna mountings and height above ground or a common reference level are required. Topographical maps may be required in areas of sloping land. Other alternative methods may be used to determine the vertical separation between the antenna mid-point and point of interest.

### Antenna Bearing

Antenna in a particular sector should be identified by the bore-sight bearing and given the bearing in degrees true north.

### Antenna down-tilt

If an antenna has any tilt other than  $0^0$  it must be stated and the angle used in the calculation of line-of-sight distance and off-axis gain.

## **Section 5 Report format**

The layout for the report of the estimated RF EME levels should follow the format of the ARPANSA document "Summary of Estimated EME Levels Around Proposed Mobile Phone Base Stations ..." this can be found at <http://www.arpansa.gov.au/template.pdf> . The recommended report provides estimates of RF EME levels at 5, 50, 100, 200, 300, 400 and 500 metres from the base of the antenna, an estimate of the highest level at any distance and any points of particular interest at certain distances or elevations.

## **Section 6 Shared Mobile Phone Base Station Sites**

Where other Mobile Telephone Carriers share the same site a calculation should be performed of the total RF EME from all mobile phone services. This will require a calculation the same as that described above for all individual services and the levels summed to obtain the level at the specific distances described above. As maximum levels for individual carriers most probably occur at different distances it is inappropriate to simply add the maximums.

An estimate of the combined maximum level will required a more detailed analysis of the EME levels from individual services. When a proposed site is to be co-located with and existing base station a calculation of the cumulative levels is to be performed in the manner described above.

Michael Bangay

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**EMR and Optical Radiation Section**

**Non-ionizing Radiation Branch**

**ARPANSA – Yallambie Office**