Ministry of Defence

Deep Space Advanced Radar Capability (DARC)

Environmental Statement Volume 3: Appendices

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Ministry of Defence

ES Appendix 15.1: Defence Scientific Expert Group (DSEC) (2025) Evaluation of Radiation Hazards Associated with the DARC Radar

Evaluation of Radiation Hazards Associated with the DARC Radar

Defence Scientific Expert Group (DSEC)

7 February 2025

Executive Summary

This report first considers potential radiation hazards of the DARC radar to humans. It reviews the various sources of information, the means used to calculate the power incident as a function of distance and of the radar parameters, and hence the minimum safe distance for a human from a transmitter.

Three US reports produced under the auspices of the 85th Engineering Installation Squadron assess the radiation hazards to humans, fuel and ordnance. In particular, the third of these presents practical measurements of radiation level as a function of distance. These are for two DARC transmit antennas rather than six, but show that the radiation level should be safe, outside a relatively small area which can be protected by fences and by hazard warning signs. A fourth US report using a more rigorous approach shows that these results are an overestimate, and that, at a range of 40 m, the transmitted power density is 16 dB (a factor of 40) less than the maximum level specified by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

A letter from the US Department of Defense (Annex A of this report) confirms that the DARC installation at Cawdor Barracks is designed to be in full compliance with international guidelines.

A UK report produced by the Defence Electromagnetic Authority (DEMA) calculates that occupational exposure the minimum safe distance of a person from an antenna is approximately 25 m, and for the general public approximately 80 m. These results are conservative and make several worst-case assumptions. It is recommended that they should be validated by formal H&S measurements. Signs and fences should be put in place to ensure that these limits are adhered to. This report considers that that the method employed in the DEMA report to calculate these minimum safe distances is appropriate, and that the results are reliable, though conservative.

This report goes on to consider radiation hazards to birds, bats and insects. The method by which these are assessed and results for the DARC radar and various types of bird, bat and insect targets are considered in a quantitative manner. Also considered are the effects of magnetic fields on the ability of birds to navigate. In all cases it is shown that the effects should be negligible, unless the birds, bats or insects are very close to the radar (10 m or less).

Finally, a number of broadly equivalent high-power radars worldwide are considered, to see if there is any evidence of adverse effects on humans or on wildlife. These include the Ballistic Missile Defence (BMD) radar at RAF Fylingdales on the North York Moors, and the TIRA radar at the Fraunhofer Institute at Wachtberg, Germany (which is higher power, in terms of Effective Isotropic Radiated Power) than DARC. In no case has any evidence been found of any adverse effects on humans or on wildlife.

1. Introduction

1.1 The Defence Science Expert Committee (DSEC) has been tasked to provide a review of aspects of the Deep Space Advanced Radar Capability (DARC) programme.

1.2 DSEC is the Ministry of Defence's key source of independent advice on non-nuclear science, technology, engineering, analysis and mathematics issues, and is an Expert Committee reporting to the MOD Chief Scientific Advisor (CSA), supporting the derivation and delivery of the Department's Science and Technology (S&T) Strategy[1].

1.3 This report considers potential radiation hazards of the DARC radar to humans. It reviews the various sources of information, the means used to calculate the power incident as a function of distance and of the radar parameters, and hence the minimum safe range for a human from a transmitter.

1.4 It goes on to consider radiation hazards to birds, bats and insects. The method by which these are assessed, and results for the DARC radar and various types of bird, bat and insect are considered in a quantitative manner. Also considered are the effects of magnetic fields on the ability of birds to navigate. In all cases it is shown that the effects should be negligible, unless the birds, bats or insects are very close (perhaps 10 m or less) to the radar.

2. The DARC Radar

2.1 The US Space Force (USSF) DARC system aims to connect three globally dispersed, but interconnected ground-based radar sites, to deliver a significant improvement in our understanding and awareness of activity in the Geostationary Earth Orbit (GEO) belt. This will enhance our ability to identify, track and attribute hostile objects in Space.

2.2 The project was announced by the Secretary of State for Defence on 2 December 2023[2]. The overall system is planned to use three radar installations: in the USA (Texas), in Western Australia, and in the UK. The principal contractor is Northrop Grumman.

2.3 The UK node is proposed to be located at Cawdor Barracks in Pembrokeshire. The radar consists of six 15.6 m diameter dish antennas on transmit, and 21 15.6 m diameter dish antennas on receive, disposed over the site, and pointing nominally to the south i.e. towards objects above the equator. The antenna beams point upwards (Figure 1). There is a certain minimum elevation angle (5 degrees) below which the antenna beam cannot point, so the beam can never point directly at a person or at wildlife on the ground.

2.4 The proposed spatial disposition of the six transmit antennas is shown in Figure 2. The dish antennas are steered mechanically, both in azimuth (side to side) and elevation (up and down) to point at the objects of interest. The pointing directions of the antennas, and the signals that they radiate, are arranged so that they only overlap, and hence combine coherently, at very long range. The radar will look in a particular

[1] https://www.gov.uk/government/groups/defence-science-expert-committee-dsec
[2] https://www.gov.uk/government/news/new-deep-space-radar-will-transform-uk-security

direction for about five seconds, then move to look in a different direction, and so on, gradually building up a picture of space objects.

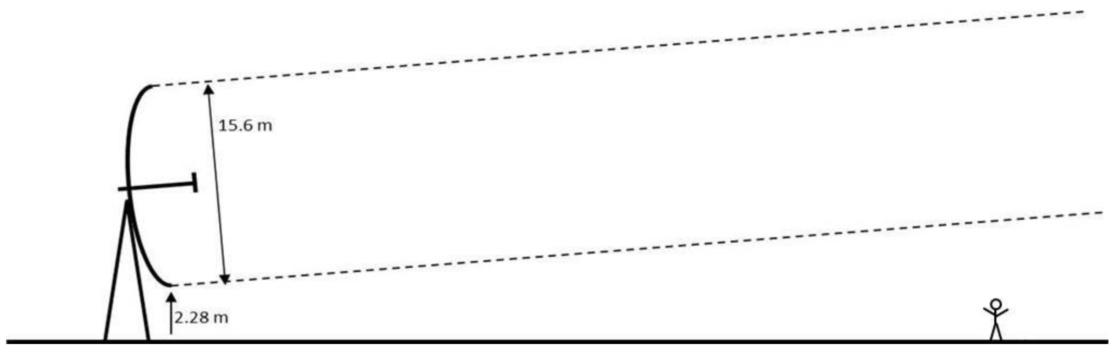

Figure 1 Single DARC antenna and its beam.

Figure 2: Disposition of the six transmit antennas. North is indicated by a compass sign towards the top left, and the antennas radiate southwards. The spacing between antennas is about 60 m.

2.5 The antenna beam is described as a 'pencil beam', with a very narrow beamwidth (approximately 0.4 degrees). The beam from the antenna is not fully formed until a distance of about 4.8 km (the 'far field'). The frequency of operation is at S-band (in the band 3.1 – 3.4 GHz). Each transmit antenna will radiate a peak power of 340 kW, with a duty cycle of 16%. Figure 3 shows three such antennas, at the White Sands Missile Range (WSMR), New Mexico.

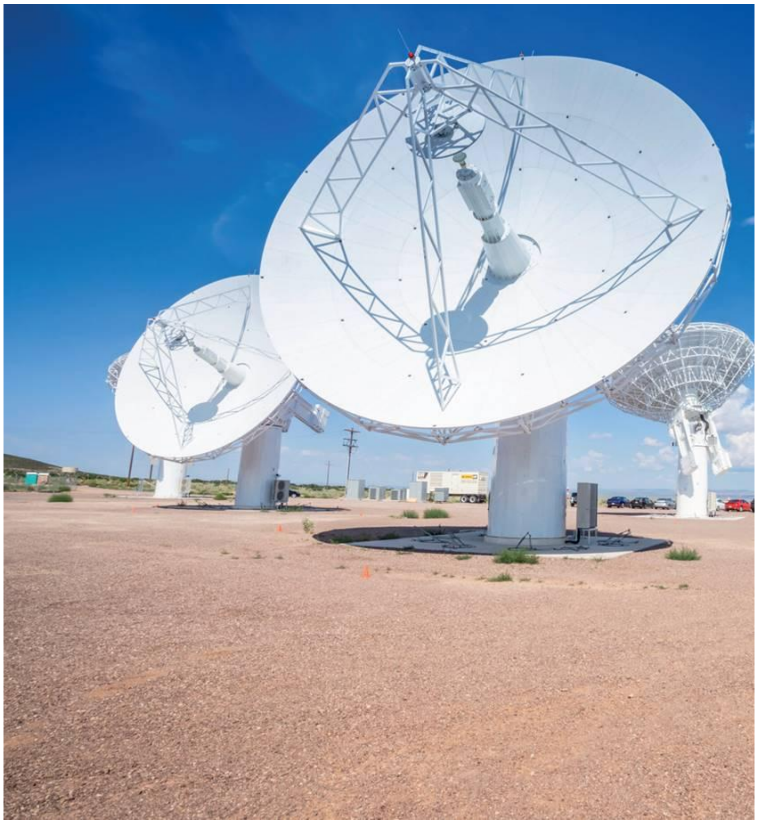

Figure 3: Three DARC dish antennas, at the White Sands Missile Range, New Mexico.

Ground distance	Height above horizontal	Beam height above ground (incl. antenna pedestal)
85 m	7.44 m	17.52 m (57.5 ft)
250 m	21.9 m	32 m
500 m	43.7 m	53.7 m
750 m	65.6 m	75.7 m
1000 m	87.5 m	97.6 m

Table 1: Beam height above ground (including the antenna pedestal) as a function of range, at the minimum elevation angle.

3. Radiation Hazards to Humans

US Assessments

3.1 The radiation safety of the DARC radar to humans has been assessed in three reports from the USA. The first of these[3] was prepared in 2019 by the 85th Engineering Installation Squadron at Kessler AFB, MS. This derives Safe Separation Distances (SSDs) for Personnel (HERP), Ordnance (HERO) and Fuel (HERF) based on IEEE Standard C95[4] (2005). A revised version of this IEEE Standard was produced in 2019, but is not significantly different.

3.2 The standard draws a distinction between upper tier levels and lower tier levels. Upper tier levels are defined as exposure limits for personnel who are aware of the potential for electromagnetic field (EMF) exposures conjoined with their employment or duties. Lower tier levels are exposure limits set for individuals who have no knowledge or control of their exposure. The power density for lower tier exposure is 10 W/m2 (= 1 mW/cm2), and that for upper tier exposure is 100 W/m2 (=10 mW/cm2).

3.3 The second[5] is a review of the first document, undertaken by radar engineers at the Johns Hopkins University Applied Physics Laboratory (JHU-APL) and dated March 2021. This corrects some minor misapprehensions in the first reference, and recommends that practical measurements should be undertaken – which is certainly good scientific practice.

3.4 The third[6] presents the results of such measurements, undertaken at WSMR, and is dated August 2021. The measurements, though, are made on the radiation from two DARC transmit antennas, rather than six. It recommends:

> *The 85 EIS recommends that the data presented in this report be used by the WSMR safety office as verification that the DARC-TD (Technology Demonstrator) does not exceed the hazards of electromagnetic radiation to personnel (HERPs) in the tested areas.*

3.5 These three reports have not been cleared for public release.

3.6 The calculations in the three reports are based on standard transmission formulae. Strictly, these assume that the power density is evaluated at a sufficiently far distance (the 'far field' – see para 2.5) that the wavefront may be considered planar (Figure 4). In practice this is not the case, so the results over-estimate the power density. The reason for this may be understood by considering the wavefront as made up of a very large number of incremental contributions, the phase of each determined by the path

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[3] 85 EIS Technical Report: Electromagnetic Radiation Hazard Desktop Survey For the Deep Space Advanced Radar Capability, 12 November 2019.

[4] IEEE Standard C95: IEEE Standards for Safety Levels with Respect to Human Exposure to Electric, Magnetic, and Electromagnetic Fields, 0 Hz to 300 GHz,

[5] Applied Physics Laboratory (APL) Review of 85 RADHAZ Report for Deep Space Advanced Radar Capability (DARC), 18 March 2021.

[6] 85 EIS Technical Report: Electromagnetic Radiation Hazard Survey for the Deep Space Advanced Radar Capability Tech Demo at White Sands Missile Range, NM, 23 August 2021.

length from the antenna to the wavefront. Only when the distance from the antenna is very large do the contributions add in phase and give a maximum; at closer range the contributions do not add perfectly in phase.

3.7 Recently, a fourth report has become available which uses finite-element modelling to evaluate the power density. This is more rigorous, and takes the far field effect into account. It shows that the power densities calculated by the three reports over-estimate the power density, and that at a range of 40 m, the transmitted power density is 16 dB (a factor of 40) less than the maximum level specified by ICNIRP.

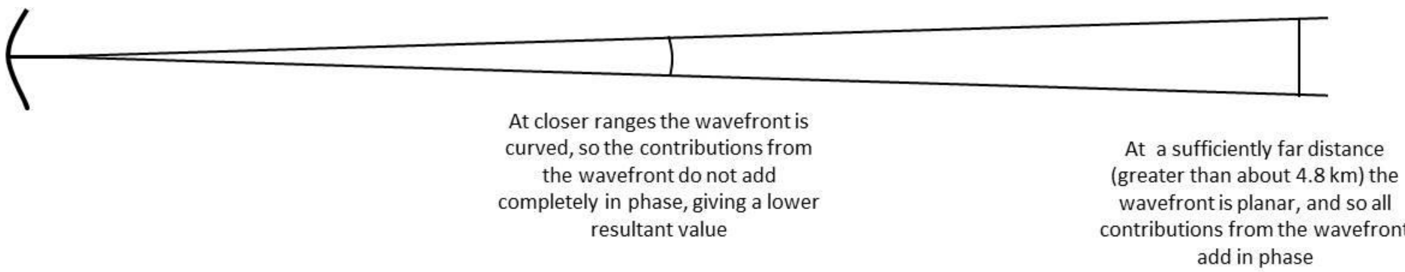

Figure 4: The effect of wavefront curvature.

3.8 Although finite element modelling is more accurate, it is not often used, because it requires substantially higher computing power than conventional methods.

3.9 Annex A presents a letter from the US Department of Defense which confirms that the DARC installation at Cawdor Barracks is designed to be in full compliance with international guidelines.

UK Assessment

3.10 The radiation safety of the DARC radar in the UK to humans has been assessed in a report prepared in 2024 by the Defence Electromagnetic Authority (DEMA)7. This report (henceforth referred to as the 'DEMA report') makes reference to three standards:

(i) Advice on Limiting Exposure to Electromagnetic Fields (0 to 300 GHz)[8]

(ii) JSP 392 Management of Radiation Protection in Defence[9]

(iii) The Control of Electromagnetic Fields at Work Regulations[10]

3.11 A more recent version of (i) was published in March 202011 based on the work of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), with less

[7] Theoretical Electromagnetic Field (EMF) Safety (RADHAZ) Assessment of Project-DARC, DEMA report, 16 August 2024 (O).

[8] Advice on limiting exposure to electromagnetic fields (0 to 300 GHz), National Radiological Protection Board, 2004.

[9] JSP 392 'JSP 392'Management of radiation protection in defence', part 2 chapter 35: Radio frequency radiations, republished December 2020.

[10] The Control of Electromagnetic Fields at Work Regulations (CEMFAW), 2016.

stringent levels. For the purpose of this work we note the existence of that report, but use the levels given in (i).

3.12 The first of these standards provides guidance relating to safe limits of human exposure to non-ionising radiation, which is appropriate to these frequencies, including the scientific basis on how these limits are derived. This information is used to ensure, for example, that radiation from mobile phones or mobile phone basestations is safe to humans. The second relates specifically to defence and has less technical detail, and the third is a legal document. Although they differ in the way that they present the results, they are saying essentially the same things, and are also consistent with IEEE Standard C95.

3.13 For most frequencies (non-ionising radiation) the effect of the radiation on the body is to raise the temperature (for example radiation from electric fires), but for some frequencies (ionising radiation) – for example ultra-violet radiation from strong sunlight or from suntan beds, or from X-rays – the radiation is known under some circumstances to cause cancer. For that reason we are encouraged to use suitable sunscreen products when we go outdoors in strong sunlight, the maximum UV radiation from sunbeds is limited by law, and when your dentist takes an X-ray he or she leaves the room.

3.14 In exactly the same way as the 85 EIS reports, the distinction is drawn between occupationally-exposed individuals and members of the public. Occupationally-exposed individuals are adults who are exposed under controlled conditions associated with their occupational duties, and will have undergone appropriate training and be aware of the appropriate risk assessments and precautions. The levels for exposure of members of the public are more stringent and are appropriate also (for example) to exposure of children or pregnant women. The standards are periodically reviewed, and updated if necessary.

3.15 The DEMA report assesses the potential radiation hazard of the DARC radar to humans. This is done by calculating the power density of the signal radiated horizontally, as a function of range, using standard equations.

3.16 The results in the DEMA report are presented in terms of the worst-case minimum safe range of a human from a transmitter. Because of the separation of the antennas, it is not possible to be close to more than one antenna simultaneously. The results indicate that for occupational exposure the minimum safe distance of a person from an antenna is approximately 25 m, and for the general public approximately 80 m.

3.17 For completeness, the DEMA report also considers the minimum safe distance for flammable fuels and for explosives.

3.18 The DEMA report recommends that these results should be validated by practical measurements, which is certainly good scientific practice, as well as providing assurance that values predicted by the far-field calculations are adequate. Such measurements are regarded as essential.

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[11] ICNIRP Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz), *Health Phys* 118(5): 483–524, 2020, https://www.icnirp.org/en/activities/news/news-article/rf-guidelines-2020-published.html

3.19 It also recommends that warning notices (an example is given in the DEMA report) should be displayed in suitable locations to warn the public not to approach closer than the minimum safe distance.

3.20 It is interesting to compare the radiation level corresponding to lower tier (general public) exposure (10 W/m2) with the values quoted for mobile phones held next to the head (roughly about 200 W/m2)[12]. This reference is the report from a study conducted for the UK Government, chaired by Sir William Stewart, who was Government Chief Scientific Adviser from 1990 to 1995.

3.21 In summary, based on these considerations, it is concluded that the approach employed in the DEMA report to calculate these minimum safe distances is appropriate, and the results are reliable, though err on the side of caution.

3.22 If a person should experience greater exposure than the prescribed limit, for example by deliberately entering the prohibited area, the effect would be that he or she would experience discomfort due to the rise in temperature. In fact this is the basis of a non-lethal crowd control device developed in the USA[13]. The power density from this device is estimated to be a thousand times greater than the lower tier (general public) limit for DARC.

4 Radiation Hazards to Birds, Bats and Insects

4.1 There is relatively little in the scientific literature on the effect of electromagnetic radiation on birds, bats and insects. A review paper from the EU HORIZON programme EKLIPSE[14] gives a summary, and points to some relevant publications.

Birds

4.2 In the 1960s the British radar engineer Eric Eastwood described the phenomenon of 'ring angels', which were expanding rings on a radar display that were observed to occur around dawn. These were found to be due to flocks of starlings, disturbed from their roosts by the rising Sun and flying radially outwards. He published a book *Radar Ornithology* on this and other work and was elected FRS in 1968 and knighted in 1973. In one of his publications[15] he considered, on the basis of observations from a high-power air surveillance radar located at Bushy Hill, Essex, whether the behaviour of birds might be influenced by radar signals. He concluded:

> *Although some of the most powerful radar equipment ever built has been used in these observations, and sensitive photographic recording devices have been*

[12] *Mobile Phones and Health*, Independent Expert Group on Mobile Phones, 2000, para 4.28.

[13] https://www.youtube.com/watch?v=kzG4oEutPbA

[14] Malkemper, E.P., Tscheulin, T., Vanbergen, A.J., Vian, A., Balian, E. and Goudeseune, L. (2018). *The impacts of artificial electromagnetic radiation on wildlife (flora and fauna). Current knowledge overview: a background document to the web conference. A report of the EKLIPSE project*.

[15] Eastwood, E. and Rider G.C., 'The influence of radio waves upon birds', *British Birds*, Vol.57, No,11, pp445-458, November 1964.

> *employed to observe the tracks of the birds, no perturbing effects of the beams upon the birds have been observed.*

Since then, some significantly more powerful radars have been built and operated.

4.3 The same methodology as was used in the DEMA report can readily be used to estimate the effect of the DARC radar signal on birds, bats and insects. This methodology is detailed in Annex A.

4.4 It is important to bear in mind here that the beamwidth of the antennas is very narrow – approximately 0.4 degrees in the far field, and there is a certain minimum elevation angle of the beam, as shown in Figure 1. In the approach presented in Annex A we consider the worst case of the bird or bat being within the narrow beam, recognising that this will only rarely and briefly be the case. Even in such a worst case the temperature rises are a small fraction of a degree, which would be imperceptible to the bird.

4.5 A survey has been carried out of bird species in the vicinity of the Cawdor Barracks site[16]. For the purposes of this assessment we have taken two representative species: the herring gull *Larus argentatus* and the skylark *Alauda arvensis*. The effect is actually greater for the smaller bird, since the cross section varies as a^2, while the volume, and hence the mass, varies as a^3. The smaller bird therefore has smaller thermal mass, giving a greater temperature rise for a given incident energy.

4.6 A bird (or bat) that is perching or resting will necessarily be close to the ground, and hence not within the main beam of the radar. The worst case would be when a bird is perched on top of one antenna, with one behind pointing over at the minimum elevation angle, and in exactly the right azimuth direction. Such a situation would be very rare. In any case, the effect would be that the bird would experience discomfort, in a similar way to that described in paragraph 3.13, and would simply fly away.

Magnetic Fields

4.7 It is known that some birds use the Earth's magnetic field to navigate. The Earth's magnetic field is static, and has a value of approximately 50 μT (microTeslas). For comparison, the magnetic field under a power pylon (at 50 Hz) is about 100 μT.

4.8 An electromagnetic wave propagates as an interchange of energy between electric and magnetic fields, oscillating at (in the case of DARC) approximately 3.2×10^9 cycles per second. The magnitude of the magnetic field is related to the power density I (in W/m^2) as

$$0.06\sqrt{I}\ \mu T$$

which at a range of 1 km from the radar has a value of 9.6 μT. So if the bird is within the beam of the transmitter at that range, it would experience the static Earth's

[16] Breeding Birds: Project DARC – Cawdor Barracks (Draft), SWECO, March 2024.

magnetic field, plus an oscillating component approximately one-fifth of the static component.

If the bird were closer, the magnetic field that it experiences would be greater, but the duration within the beam would be correspondingly briefer. The effect would therefore be a brief (less than a second) perturbation, and therefore unlikely to be significant.

Bats

4.9 Bats will be of broadly similar sizes to birds, though their flight patterns may be different. The same considerations as for birds should apply to their interaction with the radiation from the radar.

Insects

4.10 Annex B shows that because insects are smaller than the DARC radar wavelength (by a factor of ten or more), the effective area to a radar signal is much smaller (by a factor of approximately 10,000) than the physical area, and so the effect of the radiation on the insect will be very small indeed.

5 Comparison with Other High-Power Radars

5.1 It is instructive to compare DARC with other high-power radars worldwide. Annex B describes a number of such radars about which it has been possible to find information.

5.2 The radiated power can be quantified in terms of the Effective Isotropic Radiated Power (EIRP), which is the product of the transmitted power and the antenna gain. This can be evaluated in terms of the peak EIRP, or the mean EIRP - which averages the power over the duty cycle of the radar. The table below presents this information for the DARC radar and for the other radars in Annex C, ordered according to peak EIRP. Values are given both for a single DARC transmit antenna and for all six combined coherently, but it is the single antenna value which is relevant here because the individual antenna beams do not physically overlap until much greater ranges. This value is highlighted in the table.

5.3 It can be seen that the DARC radar is by no means the highest power radar in the list, and several have significantly higher peak transmit powers than DARC.

	peak EIRP (W)	mean EIRP (W)
Marconi radar, Bushy Hill	2.44×10^{7}	—
AN/FPS-132 RAF Fylingdales	4.35×10^{9}	1.09×10^{9}
EISCAT UHF (Longyearbyen)	3.0×10^{10}	7.5×10^{9}
EISCAT VHF (Tromsø)	6.4×10^{10}	8.0×10^{9}
DARC (one antenna)	5.4×10^{10}	8.6×10^{9}
DARC (six antennas)	3.2×10^{11}	5.2×10^{10}
TIRA (L-band)	3.4×10^{11}	—
Millstone Hill radar (L-band)	3.5×10^{11}	—
TIRA (Ku-band)	4.6×10^{11}	—
AN/FPS-85 (UHF)	6.5×10^{11}	—
HUSIR (X-band)	2.8×10^{12}	—

Table 2: Peak EIRPs of radars in Annex C.

5.4 We have attempted to find any information that might indicate that there is a radiation hazard problem with any of these radars, either to humans or to wildlife. Of course, such information is somewhat anecdotal, and cannot be considered to provide scientific proof. Nevertheless, the results are of interest.

5.5 For the TIRA radar, it is evident from the picture in Annex C that the radar is quite close to the buildings and roads. The Director of the Institute, Dr Peter Knott, has provided the following comments:

For protection of our employees and people in the neighbourhood during operation of TIRA, we have taken the following measures:

Ray-Tracing Simulations of EM propagation on our premises and regular measurements of the exposure situation have been conducted for verification (carried out by independent bodies).

We make also sure that exposure limits are fulfilled outside of the institute (where general EU regulations apply).

Inside the institute there are higher limits for a professional environment and we have checked the field levels in most buildings. Some windows have been fitted with better window panes or absorbing film to lower the fields below threshold.

Outside of buildings on the campus we simply assume that neither the antenna nor the persons will stand still for a longer period so that critical exposure is avoided.

5.6 For the Fylingdales radar, we have made contact with the Commanding Officers of the base, over many years, to ask whether there has been any issue with radiation hazards. Kevin Phillips – Station Safety and Environmental Advisor – responded:

We have never had any issues or enquiries regarding wildlife and the potential effect from the RADAR. If anything people are interested in the conservation work and the moorland protection that we provide on the site.

It may be noted that the picture of the Fylingdales radar in Annex B includes sheep grazing in the foreground, seemingly unperturbed by the radar.

5.7 Peleg and co-workers have published a paper[17] which asserts that Israeli Defence Force (IDF) soldiers who have worked on the Iron Dome surface-to-air missile system have an increased risk of cancer. However, this paper does not establish a causal relationship between radiation from the Iron Dome radar and cancer, since there may well be other factors associated with operating Iron Dome (the exhaust gases from the missiles, for example, or any of a number of other factors that have not been considered in the paper, and the assertion is made on the basis of a relatively small (46), self-selected group of individuals. Further, the *Jerusalem Post* has published an article[18] that refutes Peleg's findings, saying that: '… the IDF view is that despite the prominence of the publications, they lack the vastly larger data that the IDF possesses to perform comparisons between those who say they were harmed and "control" subjects', and 'Whereas the civilian journal publications compare dozens of cancer patients allegedly harmed by their IDF service with Iron Dome and other radars systems to the civilian populations, the IDF has the benefit of comparing the dozens of individuals in question to thousands of IDF personnel who served at similar bases as those with cancer, but who did not deal directly with the same radar systems'.

5.8 As the final version of this report was being prepared, another relevant report was identified[19]. This relates to the PAVE PAWS radar located in the upper Cape Cod region, Massachusetts, which is essentially the same as the Fylingdales radar. It was prepared by experts from the National Academies of the USA. It is long and detailed, but its conclusions can be summarised as (p4):

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[17] Peleg, M., Berry, E.M., Deitch, M., Nativ, O. and Richter, E., 'On radar and radio exposure and cancer in the military', *Environmental Research*, vol. 216, part 2, 1 January 2023.

[18] IDF rejects allegations that soldiers working with radar, Iron Dome risk cancer, *Jerusalem Post*, 9 January 2023.

[19] An Assessment of Potential Health Effects from Exposure to PAVE PAWS Low-Level Phased Array Radiofrequency Energy (2005), National Academies Press, https://www.nae.edu/25641/An-Assessment-of-Potential-Health-Effects-from-Exposure-to-PAVE-PAWS-LowLevel-PhasedArray-Radiofrequency-Energy

There is no risk of cancer, reproductive or developmental effects, or neurobehavioral effects based on a comprehensive review of animal studies or studies in other biological systems. A few statistically significant biological changes have been reported from RF exposures, but the relevance of those biological changes is not known and may or may not have any impact on human health.

If there is no risk of cancer due to radiation from PAVE PAWS, which is a large and high-power radar, it is difficult to conclude that there should be any risk of cancer from the Iron Dome radar, which is smaller and lower-power.

6 Discussion and Conclusions

6.1 This report has considered potential radiation hazards of the DARC radar to humans. It has reviewed the various sources of information, the means used to calculate the power incident as a function of distance and of the radar parameters, and hence the minimum safe distance for a human from a transmitter.

6.2 Three US reports produced under the auspices of the 85th Engineering Installation Squadron assess the radiation hazards to humans, fuel and ordnance. In particular, the third of these presents practical measurements of radiation level as a function of distance. These are for two DARC transmit antennas rather than six, but show that the radiation level should be safe, outside a relatively small area which can be protected by fences and by hazard warning signs.

6.3 A report produced by the Defence Electromagnetic Authority (DEMA) in the UK calculates that occupational exposure the minimum safe distance of a person from an antenna is approximately **25 m**, and for the general public approximately **80 m**. These results are conservative and make several worst-case assumptions. Nevertheless, it is recommended that they should be validated by experimental measurements. Signs and fences should be put in place to ensure that these limits are adhered to. This report considers that the approach employed in the DEMA report to calculate these minimum safe distances is appropriate, and the results should be reliable. These conclusions are consistent with those reached by the 85th Engineering Installation Squadron.

6.4 A fourth US report, using finite element modelling (which is more accurate, but which uses substantially higher computing power) concludes that at a range of 40 m, the transmitted power density is 16 dB (a factor of 40) less than the maximum level specified by ICNIRP.

6.5 This report goes on to consider radiation hazards to birds, bats and insects. The method by which these are assessed, and results for the DARC radar and various types of bird, bat and insect targets are considered in a quantitative manner. Also considered are the effects of magnetic fields on the ability of birds to navigate. In all cases it is shown that the effects should be negligible, unless the birds, bats or insects are very, very close to the radar, in which case the bird would experience discomfort, in a similar way to that described in paragraph 3.13, and most likely would simply fly away.

6.6 Finally, a number of broadly equivalent high-power radars worldwide are considered, to see if there is any evidence of adverse effects on humans or on wildlife. These include the Ballistic Missile Defence (BMD) radar at RAF Fylingdales on the North York Moors, and the TIRA radar at the Fraunhofer Institute at Wachtberg, Germany (which is higher power, in terms of Effective Isotropic Radiated Power) than DARC. In no case has any evidence been found of any adverse effects on humans or on wildlife.

6.7 In summary, in terms of radiation hazards to humans, three different approaches have been taken: (i) theoretical predictions, (ii) practical measurements, and (iii) comparison with other high-power radars worldwide. None of these approaches by themselves is totally satisfactory, but all three taken together give strong confidence that, with the precautions described, the DARC radar is safe to humans.

Annex A: Letter from US Department of Defense

DEPARTMENT OF THE AIR FORCE
UNITED STATES SPACE FORCE
SPACE SYSTEMS COMMAND

08 October 2024

Declaration of Conformity with ICNIRP Public Exposure Guidelines ("ICNIRP Declaration")

Space Systems Command Space Domain Awareness Ground Sensors (SSC/SZGG)
290 W. Duluth Avenue, Bldg. 504
Peterson SFB, CO 80914

Declares that the proposed equipment and installation as detailed in the DARC Site 2 planning application at:

Cawdor Barracks
Brawdy
Haverfordwest
Wales
SA62 6NN

Is designed to be in full compliance with the 2020 International Commission on Non-Ionizing Radiation (ICNIRP) Guidelines For Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz) requirements for both occupational and public radio frequency (RF) exposure.

BORAH.JON.HOWARD.1091818562 Digitally signed by BORAH.JON.HOWARD.1091818562 Date: 2024.11.08 13:53:58 -07'00'

JON BORAH, Capt, USSF
DARC Deputy Lead Engineer

Annex B: Calculations of Radiation Hazards to Birds, Bats and Insects

The approach used here is to calculate the power density incident on a bird at a particular range, and hence the energy absorbed, and hence the rise in temperature. The calculation uses the far-field approximation, but the results should be close. The bird is treated as a water-filled sphere of radius *a*. For the lark we take *a* = 2.5 cm, giving a cross-sectional area $\sigma = 2 \times 10^{-3}$ m^2 and a mass of 65 g.

Assume that all of the energy is absorbed by the bird. In practice this will not be the case, so this calculation represents a worst case.

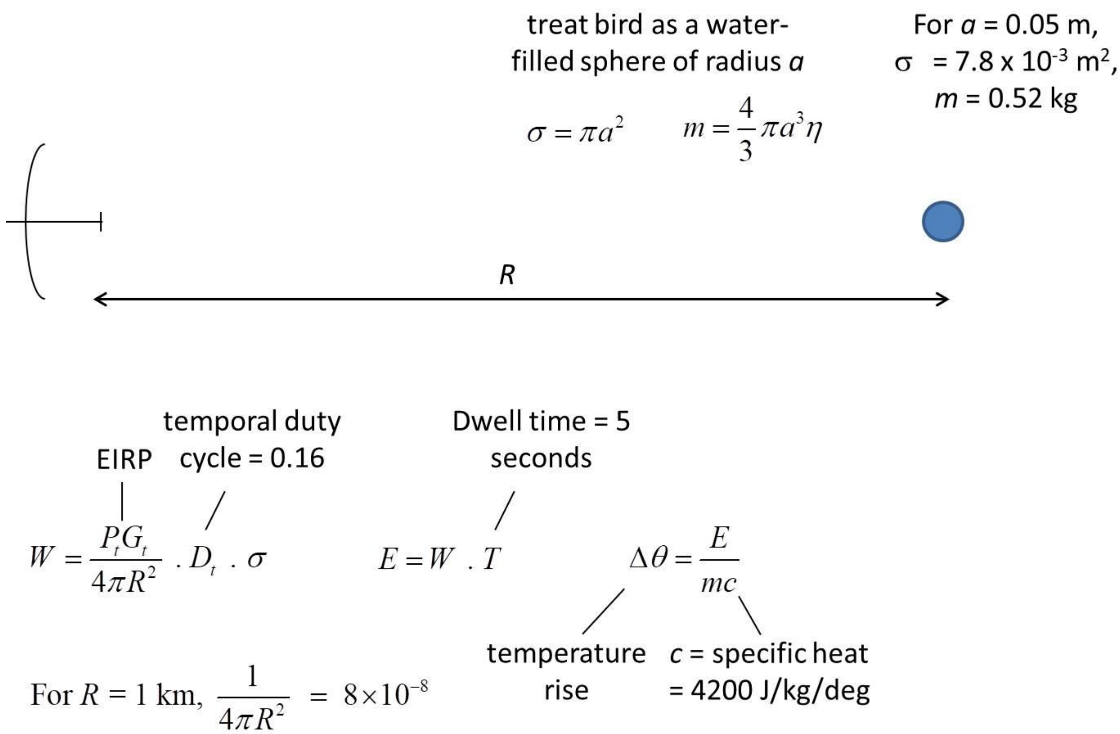


Figure A1: Methodology for calculation of effect of radiation on a bird, using numerical values for a lark at a range of 1 km and an irradiation time of 5 seconds.

The energy absorbed by the bird depends on the time for which it is irradiated. Firstly, the peak EIRP from Table 2 must be multiplied by the duty factor of the radar (16%). Next, that value is multiplied by the time for which the bird is irradiated (dwell time) to give the incident energy. From that, knowing the mass and specific heat of the bird, the temperature rise can be calculated.

The dwell time of the beam for the DARC radar (in other words the duration for which the beam points in a particular direction before moving on to a different direction) is taken to be 5 seconds. This gives a temperature rise of 0.012 degrees, which is unlikely to be perceptible.

If the range is reduced to 100 m, the power density becomes greater (by a factor of 100 and the temperature rise is then 1.2 degrees, which is still unlikely to be perceptible.

Much closer to the transmit antenna it is possible that the bird would perceive the temperature rise. The worst case might be when a bird is perched on one antenna, with another antenna (which would be about 60 m away) pointing directly at it. It is judged that this would only occur very rarely.

Herring Gull For a herring gull, we take a = 0.07 m, giving σ = 0.015 m^2 and m = 1.4 kg. At 1 km and again assuming 5 second exposure, the temperature rise is 9×10^{-3} degrees. Compared to the lark, the cross section varies as a^2, while the mass varies as a^3, so the effect is smaller for the larger bird.

Birds or bats that are perching on a fence or resting on the ground (refer to Figure 1 and Table 1) will be below the main beam of the radar, even when this is at its lowest elevation.

A recent reference[20] discusses the mechanisms by which birds regulate their temperature. Birds are endothermic (warm-blooded), so are able to actively regulate their temperature.

We conclude that unless the bird is at very, very close range (closer than about 10 metres), the temperature rises should be imperceptible to the bird.

Bats For bats, the results will be essentially the same as for birds. We emphasise that these results relate to the situation where the bird or bat is within the very narrow beam. Outside of the beam, the effects are even more negligible. Bats, too, are endothermic.

Insects For insects, the method is the same, but because the size of the insect is small compared with the radar wavelength (which is about 10 cm), the effective size to the radar of the insect is significantly smaller.

The effect is shown in Figure A2, which is well-known to radar engineers. This plots the effective scarring area of a sphere as a function of frequency. The vertical axis is logarithmic, and is the ratio of the scattering cross section σ to the physical area πa^2. The horizontal scale is also logarithmic, and is the ratio of the circumference of the sphere $2\pi a$ divided by the wavelength.

[20] Lewdon, A., Bishop, C.M. and Askew, G.N., 'How birds dissipate heat before, during and after flight', *J.R. Soc. Interface*, **20**, 2023.

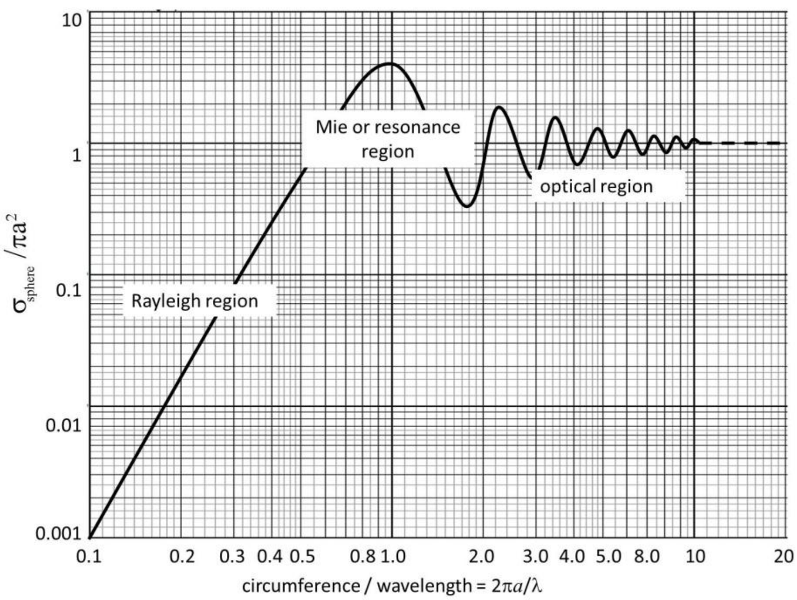


Figure A2: Scattering properties of a sphere as a function of frequency.

It can be seen that once the sphere is small compared to the wavelength (which will certainly be the case for insects), the scattering cross section falls very rapidly, as the fourth power of the frequency (so-called Rayleigh scattering). So for an insect of size 1 cm (one-tenth of a wavelength) the scattering cross section will be a factor of approximately 10^4 less than its peak value.

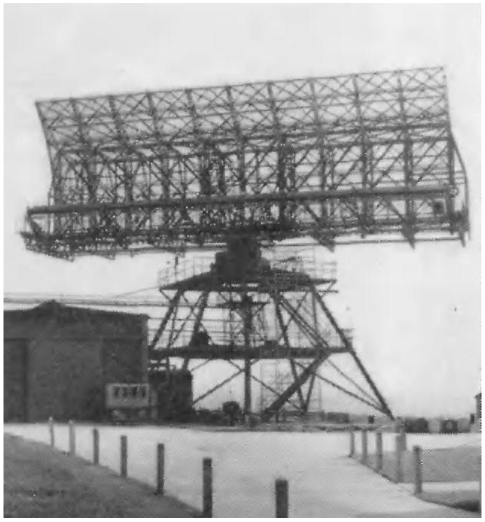
This is borne out by a publication describing experimental measurements at the Royal Signals and Radar Establishment (RSRE), Malvern, in the 1980s[21]. This shows a graph very similar in form to Figure A2, though it should be noted that since the frequency of these measurements is 10 GHz (λ = 3 cm), the results should be shifted by a factor of about three (the ratio of the wavelengths) to enable a true comparison.

The same consideration as with birds can then be applied to calculate the temperature rise, which will certainly be very small. The thermal mass of an insect will be smaller than would be the case if it were assumed to be composed of water, but not so small as to compensate for the 10^4 dependence on frequency.

[21] Riley, J.R., 'Radar cross section of insects', *Proc. IEEE*, Vol.73, No.2, pp228-232, 1985

Annex C: Other High-Power Radars Worldwide

C1: Marconi Radar, Bushy Hill, Essex (1964)



This is the same radar as described in paragraph 4.2 of this report. The radiated power is quantified in the paper:

> *At the ten-mile point the radiation intensity on the axis is 7.6 x 10^{-3} Watts per square metre, corresponding to a peak electric field strength of 48 volts per metre …*

C2: AN/FPS-132 – RAF Fylingdales

The AN/FPS-132 Ballistic Missile Defence (BMD) radar has operated at RAF Fylingdales, on the north York moors, since 1992. It operates at 420 – 450 MHz and the antenna diameter is

22.1 m. The peak transmit power is 600 kW. The antenna is a phased array, which allows the beam to be scanned in angle almost instantaneously.

C3: Tracking and Imaging Radar (TIRA)

TIRA is an experimental radar for surveillance of space objects, located at the Fraunhofer Institute at Wachberg, just south of Bonn, Germany. The radome houses a 34 m diameter mechanically-steered dish antenna which operates at L-band (1.333 GHz) and Ku-band (16.7 GHz), with transmit powers of 1.5 MW (L-band) and 3 kW (Ku-band).

C4: European Incoherent Scatter Scientific Association (EISCAT) Radars

The EISCAT radars are used for scientific research on the ionosphere, and are located in Tromsø, Norway (left) and the island of Spitzbergen (right). The radar at Tromsø operates at

222.8 – 225.4 MHz (VHF) with a peak power of 1.6 MW, and that at Spitzbergen (Svalbard) operates at 498 – 502 MHz (UHF) with a peak power of 1 MW. They normally point vertically upwards, so the issue of radiation hazards is not paramount.

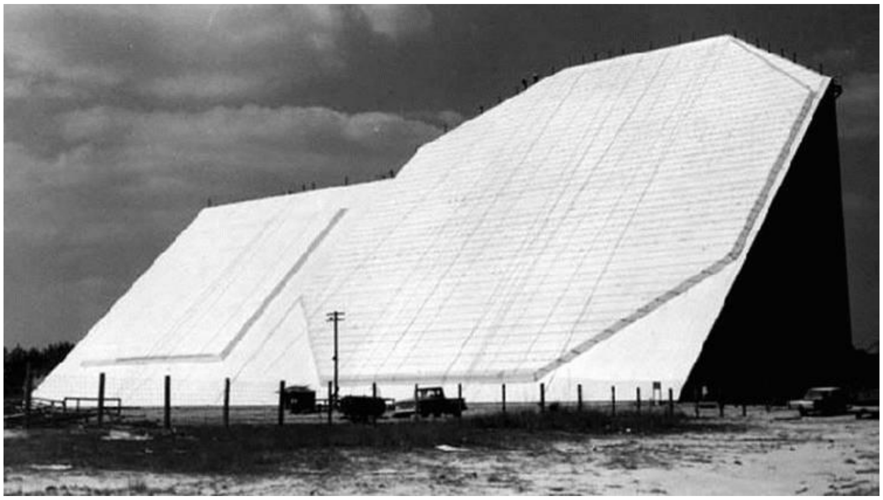
C5: SAMPSON

The SAMPSON radar on the RN type 45 destroyer operates at S-band and uses a rotating two-face array. The picture on the right (taken from Google maps) shows the shore-based test facility at Portsdown, viewed from the road, about 100 m from the radar..

C6: Haystack Ultrawideband Satellite Imaging Radar (HUSIR)

The HUSIR radar is operated by MIT Lincoln Labs and is located at Westford, MA. It operates at X-band, with a 36 m reflector and 0.2 MW transmit power.

C7: AN/FPS-85



The AN/FPS-85 radar is located at Eglin AFB, Florida. It operates at UHF (442 MHz and has separate transmit and receive antennas. The transmit antenna (left) is approximately 50 m x 50 m. Its peak transmit power is 35 MW.

C8: Millstone Hill radar

The Millstone Hill radar is operated by MIT Lincoln Labs and is located at Westford, MA. It operates at L-band, with a 25 m reflector and 3 MW transmit power.

Ministry of Defence

ES Appendix 15.2: DARC RADHAZ report

RF EME SURVEY REPORT
DARC S1 AUGUSTA TX SITE
BACKGROUND LEVELS

MURAT ROAD
NORTH WEST CAPE WA 6707

November 2025

PO Box 680
CLAREMONT WA 6910
www.t-r-s.com.au

08 9381 7199 (phone)
info@t-r-s.com.au (email)

RF EME SURVEY REPORT

For

Northrop Grumman Australia Pty Limited
Level 5, 197 Coward Street
Mascot NSW 2020

At

DARC S1 Agusta TX Site
Murat Road
North West Cape WA 6707

Measurement Date: 4th to 5th November 2025

Reference No: 5144 – 8584

Approved Signatory

P. J. Knipe

Name: Dr Phillip Knipe
Title: Consultant Physicist
Date: 19/11/2025
Total Radiation Solutions

NATA Accredited Laboratory Number: 15096

This document is issued in accordance with requirements for compliance with ISO/IEC 17025-Testing.

The results of the measurements included in this document are traceable to Australian / National Standards.

NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration, inspection, proficiency testing scheme providers and reference materials producers reports and certificates.

Contents

1. Introduction

Northrop Grumman Australia Pty Limited (NGA) is commissioning a radar system at the Naval Communications Station, Harold E. Holt (NCSHEH), located on Murat Road, North West Cape, WA, 6707.

Consequently, NGA requested that Total Radiation Solutions (TRS) conduct a radiofrequency frequency (RF) electromagnetic energy (EME) survey.

The purpose of this survey is to determine the RF EME levels of the 2 to 4 GHz frequency band at a specified location of interest ,over a 24 hour period.

2. Regulatory Exposure Limits

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), an agency of the Commonwealth Department of Health has established a Radiation Protection Standard (RPS S-1) specifying limits for continuous exposure to RF EME transmissions (Tables 1). Further information can be gained from the ARPANSA web site at http://www.arpansa.gov.au.

The Australian Communications and Media Authority (ACMA) mandates exposure limits for continuous exposure of the general public to RF EME. Further information can be found at the ACMA website at http://www.acma.gov.au.

Table 1 Reference levels for whole body exposure, averaged over 30 minutes, to RF electromagnetic fields from 100 kHz to 300 GHz (unperturbed rms values)

Exposure Scenario	Frequency Range	Incident E-Field Strength E_{inc} (V/m)	Incident H-Field Strength (A/m)	Incident Power Density S_{inc} (W/m^2)
Occupational	0.1 – 6.943 MHz	ES	$4.9 / f_M$	NA
	>6.943 – 30 MHz	$660 / f_M^{0.7}$	$4.9 / f_M$	NA
	30 – 400 MHz	61	0.16	10
	400 – 2000 MHz	$3 f_M^{0.5}$	$0.008 f_M^{0.5}$	$f_M / 40$
	>2 – 300 GHz	NA	NA	50
General Public	0.1 – 6.27 MHz	ES	$2.2 / f_M$	NA
	>6.27 – 30 MHz	$300 / f_M^{0.7}$	$2.2 / f_M$	NA
	>30 – 400 MHz	27.7	0.073	2
	>400 – 2000 MHz	$1.375 f_M^{0.5}$	$0.0037 f_M^{0.5}$	$f_M / 200$
	>2 – 300 GHz	NA	NA	10

Notes:

1. 'NA' signifies 'not applicable' and does not need to be taken into account when determining compliance.
2. 'ES' signifies that no reference level is available, as it would be greater than the reference level for spatial peak and temporal peak field strengths based on electrostimulation effects shown in Table 7 of ARPANSA RPS S-1.
3. f_M is frequency in MHz; f_G is frequency in GHz.
4. S_{inc}, E_{inc} and H_{inc} are to be averaged over 30 minutes, over the whole-body space. Temporal and spatial averaging of each of E_{inc} and H_{inc} must be conducted by averaging over the relevant square values (see ICNIRP 2020a for details).
5. For frequencies of 100 kHz to 30 MHz, regardless of the far-field/near-field zone distinctions, compliance is demonstrated if neither E_{inc} nor H_{inc} exceeds the above reference level values.
6. For frequencies of >30 MHz to 2 GHz: a) within the far-field and radiating near-field zones: compliance is demonstrated if either S_{inc}, E_{inc} or H_{inc}, does not exceed the above reference level values (only one is required); S_{eq} derived from either E_{inc} or H_{inc} may be substituted for S_{inc}; b) within the reactive near-field zone: compliance is demonstrated if both E_{inc} and H_{inc} do not exceed the above reference level values; S_{inc} cannot be used to demonstrate compliance, and so basic restrictions must be assessed.
7. For frequencies of >2 GHz to 300 GHz: a) within the far-field and radiating near-field zones: compliance is demonstrated if S_{inc} does not exceed the above reference level values; S_{eq} derived from either E_{inc} or H_{inc} may be substituted for S_{inc}; b) within the reactive near-field zone, reference levels cannot be used to determine compliance, and so basic restrictions must be assessed.
8. There are additional applicable limits for exposure to RMS electric and magnetic fields (unperturbed fields). These limits are less restrictive than the limits specified in Table 1 or do not apply and as a result are not referenced in this measurement report.

3. Measurement Methodology

Measurements were conducted from 10.39am on the 4th of November to 11.15am on the 5th of November.

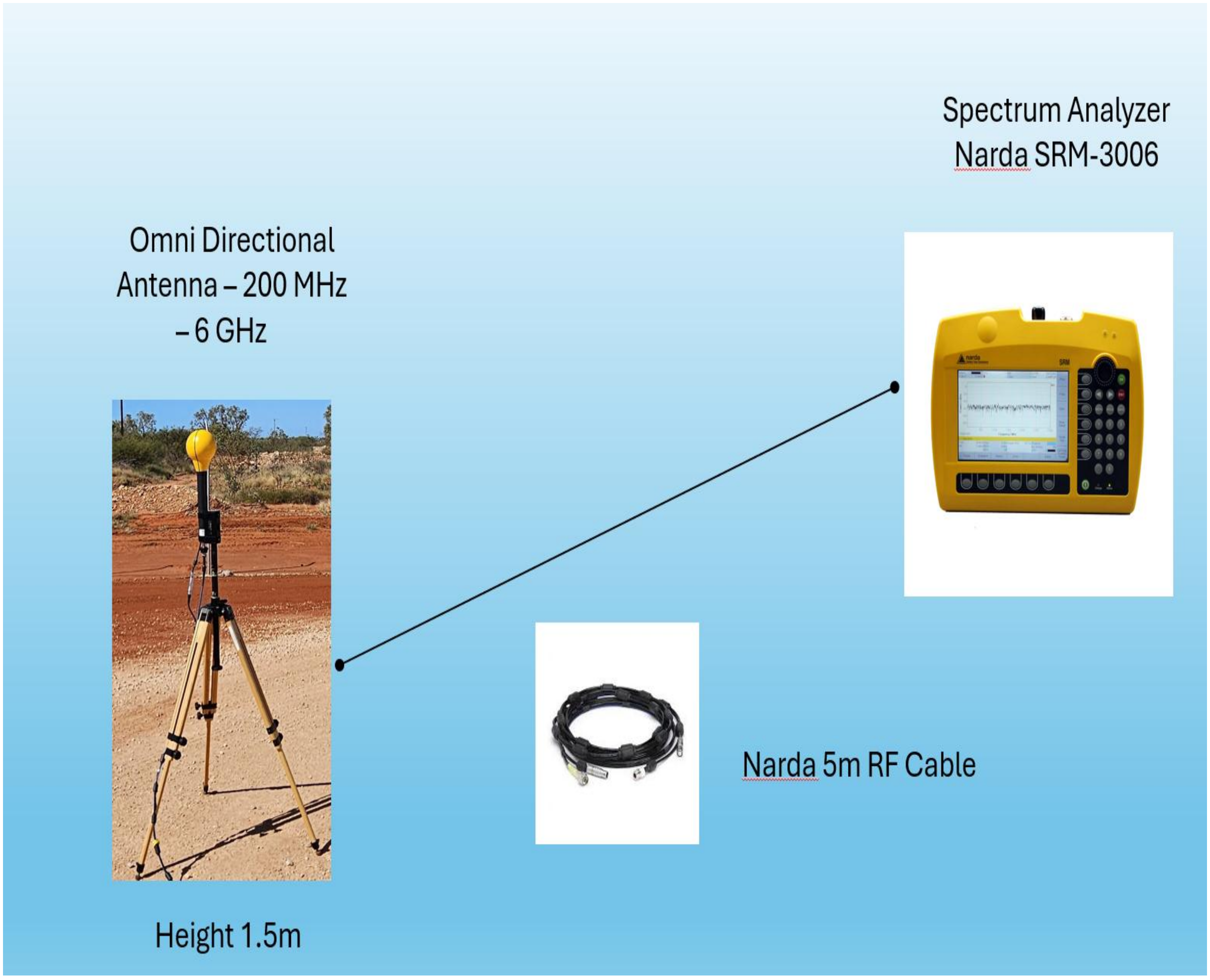
Using a NARDA SRM-3006 Selective Radiation Meter with an E-Field probe (200 MHz to 6 GHz) and 5m RF-Cable (9 kHz – 6 GHz) the background RF EME levels for the bands of interest (Table 2) were measured.

- The spectrum analyser was set to safety evaluation mode.
- It was set to measure the 1 minute average, max and minimum for a 24 hour period.
- The probe was mounted vertically on a non-conductive tripod.
- The probe height was 1.5m above the relative standing height.
- The measurement location was selected in consultation with a NGA representative.
- All measurements determined the representative RF EME level present at the time of measurement, for the selected location.

Table 2 Bands of Interest

Frequency Band (GHz)	Band Description
2 – 3.1	Out of Band (OB A)
3.1 – 3.5	In-Band
3.5 - 4	Out of Band (OB B)

Figure 1 – Measurement Equipment Setup



4. Measurement Equipment

- NARDA SRM-3006 Selective Radiation Meter
  Frequency Range 9 kHz – 6 GHz
  Model Number 3006-01
  Serial Number K-0092
  Calibration 11-10-2024

- NARDA 3-Axis Antenna
  Frequency Range 200 MHz – 6 GHz
  Model Number 3502-01
  Serial Number G-0299
  Calibration 11-10-2024

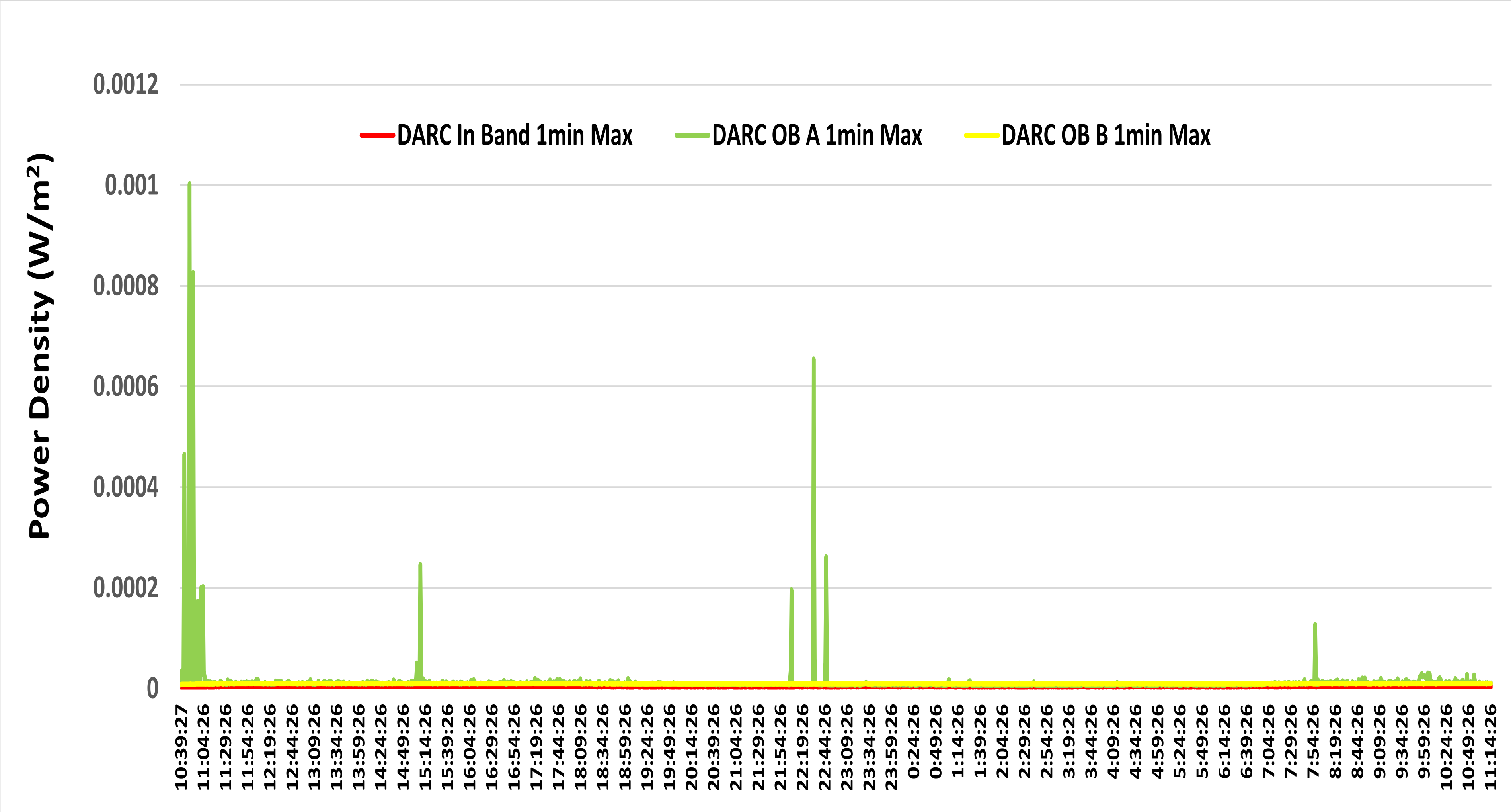
- NARDA RF-Cable SRM, Length 5m, 50 Ohms
  Frequency Range 9 kHz – 6 GHz
  Model Number 3602-02
  Serial Number AC-0385
  Calibration 11-10-2024

5. Measurement Results

The measured RF EME levels are summarised in Figure 2.

See Appendix A for measurement data.

Figure 2 Plot of Measured BG RF EME Levels Over 24 Hours



NOTES:

1. The recorded measurements were taken from the SRM-3006 for the bands of interest.
2. The measurements were taken as per Australian/New Zealand Standard AS/NZS 2772.2 Radiofrequency fields Part 2: Principles and methods of measurement and computation–3 kHz to 300 GHz.
3. The measurements conducted with the SRM-3006 instrument with a non-conductive pole mounted probe and 5m cable have an expanded uncertainty of + 3 dB. See uncertainty excel spreadsheets in the specific job folder for the calculations.
4. The coverage factor (k) value used to give an upper one-sided expanded uncertainty with a 95% confidence interval was 1.64.
5. The recorded measurements taken from the SRM-3006 were power density (W/m^2).
6. The ARPANSA RPS S-1 reference level for whole body exposure limit, averaged over 30 minutes for the general public (10 W/m^2) and occupational persons (50 W/m^2) were used for comparison.
7. TRS permanently stores all measurement equipment calibration details, site maps and recorded measurement scans.

6. Summary

The highest RF EME level was 0.001 W/m^2. This was measured for the out-of-band A (2 – 3.1GHz) at 10:49:26am on the 4th of November 2025.

This level and all other levels were below the general public whole body, time averaged (30 minutes) reference exposure limits (Table 1) specified by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Standard for Limiting Exposure to Radiofrequency Fields – 100 kHz to 300 GHz, (RPS S-1).

APPENDIX A –Measurement Data

Table A.1 – Measured Maximum (1 min) Power Density (W/m²)

Date	Time	In Band	OB A	OB B
04.11.2025	10:39:27	0.000002969	0.000006930	0.000007766
04.11.2025	10:40:26	0.000003155	0.000034795	0.000008634
04.11.2025	10:41:26	0.000003143	0.000011475	0.000008493
04.11.2025	10:42:26	0.000003058	0.000018256	0.000008474
04.11.2025	10:43:26	0.000003124	0.000465168	0.000008497
04.11.2025	10:44:26	0.000003107	0.000070013	0.000008808
04.11.2025	10:45:26	0.000003189	0.000075821	0.000008770
04.11.2025	10:46:26	0.000003190	0.000008947	0.000008606
04.11.2025	10:47:26	0.000003183	0.000019378	0.000008674
04.11.2025	10:48:26	0.000003144	0.000145200	0.000008711
04.11.2025	10:49:26	0.000003134	0.001002936	0.000008771
04.11.2025	10:50:26	0.000003192	0.000079781	0.000009018
04.11.2025	10:51:26	0.000003153	0.000009998	0.000008684
04.11.2025	10:52:26	0.000003210	0.000015655	0.000008700
04.11.2025	10:53:26	0.000003217	0.000826320	0.000008826
04.11.2025	10:54:26	0.000003237	0.000037448	0.000008864
04.11.2025	10:55:26	0.000003196	0.000009938	0.000008812
04.11.2025	10:56:26	0.000003196	0.000021331	0.000009013
04.11.2025	10:57:26	0.000003270	0.000036709	0.000008907
04.11.2025	10:58:26	0.000003251	0.000172788	0.000009059
04.11.2025	10:59:26	0.000003231	0.000026598	0.000009163
04.11.2025	11:00:26	0.000003238	0.000012764	0.000008976
04.11.2025	11:01:26	0.000003279	0.000009772	0.000008964
04.11.2025	11:02:26	0.000003278	0.000200376	0.000009208
04.11.2025	11:03:26	0.000003275	0.000028222	0.000008976
04.11.2025	11:04:26	0.000003313	0.000202092	0.000009206
04.11.2025	11:05:26	0.000003305	0.000034808	0.000009091
04.11.2025	11:06:26	0.000003288	0.000022348	0.000009222
04.11.2025	11:07:26	0.000003346	0.000009375	0.000009104
04.11.2025	11:08:26	0.000003354	0.000012566	0.000009095
04.11.2025	11:09:26	0.000003386	0.000013900	0.000009125
04.11.2025	11:10:26	0.000003285	0.000009662	0.000009314
04.11.2025	11:11:26	0.000003296	0.000008769	0.000009373
04.11.2025	11:12:26	0.000003351	0.000013226	0.000009302
04.11.2025	11:13:26	0.000003333	0.000010721	0.000009309
04.11.2025	11:14:26	0.000003371	0.000011613	0.000009389
04.11.2025	11:15:26	0.000003357	0.000007998	0.000009335
04.11.2025	11:16:26	0.000003365	0.000011579	0.000009484
04.11.2025	11:17:26	0.000003378	0.000009229	0.000009270

04.11.2025	11:18:26	0.000003381	0.000011799	0.000009549
04.11.2025	11:19:26	0.000003369	0.000009632	0.000009456
04.11.2025	11:20:26	0.000003424	0.000009179	0.000009445
04.11.2025	11:21:26	0.000003555	0.000011072	0.000009491
04.11.2025	11:22:26	0.000003351	0.000010825	0.000009389
04.11.2025	11:23:26	0.000003461	0.000009999	0.000009714
04.11.2025	11:24:26	0.000003399	0.000014916	0.000009511
04.11.2025	11:25:26	0.000003396	0.000012640	0.000009600
04.11.2025	11:26:26	0.000003400	0.000009456	0.000009420
04.11.2025	11:27:26	0.000003494	0.000010015	0.000009441
04.11.2025	11:28:26	0.000003464	0.000010230	0.000009519
04.11.2025	11:29:26	0.000003435	0.000008972	0.000009520
04.11.2025	11:30:26	0.000003437	0.000009053	0.000009608
04.11.2025	11:31:26	0.000003427	0.000008833	0.000009520
04.11.2025	11:32:26	0.000003481	0.000017081	0.000009703
04.11.2025	11:33:26	0.000003487	0.000013240	0.000009581
04.11.2025	11:34:26	0.000003494	0.000009278	0.000009639
04.11.2025	11:35:26	0.000003453	0.000014718	0.000009823
04.11.2025	11:36:26	0.000003519	0.000012681	0.000009567
04.11.2025	11:37:26	0.000003470	0.000009728	0.000009784
04.11.2025	11:38:26	0.000003470	0.000009958	0.000009623
04.11.2025	11:39:26	0.000003494	0.000009175	0.000009666
04.11.2025	11:40:26	0.000003469	0.000010437	0.000009600
04.11.2025	11:41:26	0.000003543	0.000012639	0.000009732
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04.11.2025	11:43:26	0.000003482	0.000010293	0.000009756
04.11.2025	11:44:26	0.000003447	0.000010602	0.000009652
04.11.2025	11:45:26	0.000003470	0.000010099	0.000009615
04.11.2025	11:46:26	0.000003482	0.000009619	0.000009728
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04.11.2025	11:50:26	0.000003519	0.000012375	0.000009864
04.11.2025	11:51:26	0.000003482	0.000009736	0.000009996
04.11.2025	11:52:26	0.000003559	0.000009674	0.000009760
04.11.2025	11:53:26	0.000003594	0.000013292	0.000009731
04.11.2025	11:54:26	0.000003472	0.000009673	0.000009641
04.11.2025	11:55:26	0.000003542	0.000011664	0.000010053
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04.11.2025	12:03:26	0.000003575	0.000009520	0.000009744
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04.11.2025	12:07:26	0.000003490	0.000011005	0.000009793
04.11.2025	12:08:26	0.000003528	0.000010568	0.000009984
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04.11.2025	12:11:26	0.000003536	0.000009555	0.000009852
04.11.2025	12:12:26	0.000003552	0.000009211	0.000009812
04.11.2025	12:13:26	0.000003481	0.000009686	0.000009916
04.11.2025	12:14:26	0.000003523	0.000011862	0.000009796
04.11.2025	12:15:26	0.000003602	0.000009826	0.000009736
04.11.2025	12:16:26	0.000003589	0.000009769	0.000009905
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05.11.2025	9:24:26	0.000003436	0.000009792	0.000009528
05.11.2025	9:25:26	0.000003490	0.000011521	0.000009586
05.11.2025	9:26:26	0.000003411	0.000010609	0.000009504
05.11.2025	9:27:26	0.000003481	0.000013200	0.000009728
05.11.2025	9:28:26	0.000003498	0.000010935	0.000009500
05.11.2025	9:29:26	0.000003406	0.000011077	0.000009517
05.11.2025	9:30:26	0.000003460	0.000019325	0.000009460
05.11.2025	9:31:26	0.000003534	0.000010920	0.000009447
05.11.2025	9:32:26	0.000003493	0.000009915	0.000009521
05.11.2025	9:33:26	0.000003420	0.000009792	0.000009567
05.11.2025	9:34:26	0.000003447	0.000010608	0.000009573
05.11.2025	9:35:26	0.000003495	0.000013093	0.000009529
05.11.2025	9:36:26	0.000003476	0.000011184	0.000009398
05.11.2025	9:37:26	0.000003450	0.000010510	0.000009480
05.11.2025	9:38:26	0.000003481	0.000010023	0.000009559
05.11.2025	9:39:26	0.000003437	0.000016988	0.000009694
05.11.2025	9:40:26	0.000003449	0.000016804	0.000009409
05.11.2025	9:41:26	0.000003477	0.000010004	0.000009666
05.11.2025	9:42:26	0.000003441	0.000014876	0.000009486
05.11.2025	9:43:26	0.000003481	0.000010462	0.000009595
05.11.2025	9:44:26	0.000003483	0.000011231	0.000009497
05.11.2025	9:45:26	0.000003472	0.000009860	0.000009562
05.11.2025	9:46:26	0.000003414	0.000011558	0.000009635
05.11.2025	9:47:26	0.000003407	0.000010817	0.000009907

05.11.2025	9:48:26	0.000003518	0.000012652	0.000009532
05.11.2025	9:49:26	0.000003457	0.000012124	0.000009505
05.11.2025	9:50:26	0.000003466	0.000011719	0.000009565
05.11.2025	9:51:26	0.000003420	0.000009987	0.000009684
05.11.2025	9:52:26	0.000003478	0.000009687	0.000009479
05.11.2025	9:53:26	0.000003460	0.000012395	0.000009540
05.11.2025	9:54:26	0.000003411	0.000011937	0.000009489
05.11.2025	9:55:26	0.000003447	0.000024156	0.000009641
05.11.2025	9:56:26	0.000003454	0.000024301	0.000009571
05.11.2025	9:57:26	0.000003498	0.000029423	0.000009632
05.11.2025	9:58:26	0.000003472	0.000023153	0.000009636
05.11.2025	9:59:26	0.000003419	0.000025120	0.000009331
05.11.2025	10:00:26	0.000003495	0.000026387	0.000009454
05.11.2025	10:01:26	0.000003431	0.000022070	0.000009550
05.11.2025	10:02:26	0.000003453	0.000020064	0.000009537
05.11.2025	10:03:26	0.000003474	0.000019892	0.000009497
05.11.2025	10:04:26	0.000003423	0.000030413	0.000009487
05.11.2025	10:05:26	0.000003445	0.000025872	0.000009511
05.11.2025	10:06:26	0.000003468	0.000028987	0.000009924
05.11.2025	10:07:26	0.000003495	0.000010629	0.000009612
05.11.2025	10:08:26	0.000003509	0.000013636	0.000009536
05.11.2025	10:09:26	0.000003493	0.000012438	0.000009581
05.11.2025	10:10:26	0.000003506	0.000010886	0.000009575
05.11.2025	10:11:26	0.000003449	0.000011648	0.000009740
05.11.2025	10:12:26	0.000003478	0.000011583	0.000009647
05.11.2025	10:13:26	0.000003522	0.000010967	0.000009443
05.11.2025	10:14:26	0.000003490	0.000012231	0.000009600
05.11.2025	10:15:26	0.000003505	0.000011563	0.000009570
05.11.2025	10:16:26	0.000003450	0.000018216	0.000009482
05.11.2025	10:17:26	0.000003519	0.000021239	0.000009647
05.11.2025	10:18:26	0.000003538	0.000018414	0.000009604
05.11.2025	10:19:26	0.000003466	0.000015800	0.000009592
05.11.2025	10:20:26	0.000003425	0.000011031	0.000009604
05.11.2025	10:21:26	0.000003518	0.000010420	0.000009563
05.11.2025	10:22:26	0.000003498	0.000010453	0.000009598
05.11.2025	10:23:26	0.000003495	0.000010516	0.000009649
05.11.2025	10:24:26	0.000003400	0.000012770	0.000009513
05.11.2025	10:25:26	0.000003388	0.000012223	0.000009592
05.11.2025	10:26:26	0.000003425	0.000010493	0.000009466
05.11.2025	10:27:26	0.000003452	0.000009872	0.000009596
05.11.2025	10:28:26	0.000003547	0.000013385	0.000009525
05.11.2025	10:29:26	0.000003462	0.000009794	0.000009567
05.11.2025	10:30:26	0.000003404	0.000010980	0.000009555
05.11.2025	10:31:26	0.000003453	0.000010725	0.000009627
05.11.2025	10:32:26	0.000003464	0.000011224	0.000009636

05.11.2025	10:33:26	0.000003486	0.000011797	0.000009508
05.11.2025	10:34:26	0.000003453	0.000013253	0.000009793
05.11.2025	10:35:26	0.000003507	0.000019919	0.000009691
05.11.2025	10:36:26	0.000003489	0.000014282	0.000009525
05.11.2025	10:37:26	0.000003524	0.000011810	0.000009525
05.11.2025	10:38:26	0.000003464	0.000013385	0.000009472
05.11.2025	10:39:26	0.000003489	0.000011513	0.000009538
05.11.2025	10:40:26	0.000003507	0.000010609	0.000009674
05.11.2025	10:41:26	0.000003435	0.000012288	0.000009544
05.11.2025	10:42:26	0.000003518	0.000011302	0.000009631
05.11.2025	10:43:26	0.000003406	0.000016262	0.000009534
05.11.2025	10:44:26	0.000003503	0.000011231	0.000009583
05.11.2025	10:45:26	0.000003439	0.000010809	0.000009546
05.11.2025	10:46:26	0.000003493	0.000009965	0.000009460
05.11.2025	10:47:26	0.000003433	0.000010684	0.000009649
05.11.2025	10:48:26	0.000003482	0.000027786	0.000009752
05.11.2025	10:49:26	0.000003510	0.000010701	0.000009591
05.11.2025	10:50:26	0.000003476	0.000009785	0.000009538
05.11.2025	10:51:26	0.000003411	0.000010956	0.000009528
05.11.2025	10:52:26	0.000003444	0.000012980	0.000009771
05.11.2025	10:53:26	0.000003449	0.000012462	0.000009742
05.11.2025	10:54:26	0.000003439	0.000010073	0.000009701
05.11.2025	10:55:26	0.000003419	0.000010780	0.000009508
05.11.2025	10:56:26	0.000003516	0.000027086	0.000009753
05.11.2025	10:57:26	0.000003435	0.000014441	0.000009455
05.11.2025	10:58:26	0.000003408	0.000010192	0.000009548
05.11.2025	10:59:26	0.000003526	0.000010761	0.000009546
05.11.2025	11:00:26	0.000003436	0.000009823	0.000009573
05.11.2025	11:01:26	0.000003489	0.000009887	0.000009603
05.11.2025	11:02:26	0.000003516	0.000012401	0.000009594
05.11.2025	11:03:26	0.000003466	0.000009781	0.000009608
05.11.2025	11:04:26	0.000003473	0.000010308	0.000009558
05.11.2025	11:05:26	0.000003433	0.000010561	0.000009563
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05.11.2025	11:07:26	0.000003515	0.000010383	0.000009709
05.11.2025	11:08:26	0.000003522	0.000009905	0.000009723
05.11.2025	11:09:26	0.000003478	0.000011578	0.000009764
05.11.2025	11:10:26	0.000003510	0.000009402	0.000009512
05.11.2025	11:11:26	0.000003462	0.000011451	0.000009559
05.11.2025	11:12:26	0.000003530	0.000010184	0.000009676
05.11.2025	11:13:26	0.000003485	0.000010668	0.000009666
05.11.2025	11:14:26	0.000003454	0.000010369	0.000009656
05.11.2025	11:15:26	0.000003464	0.000010941	0.000009512

TOTAL RADIATION SOLUTIONS

NATA
WORLD RECOGNISED ACCREDITATION

RF EME SURVEY REPORT
DARC S1 AUGUSTA TX SITE
MEASUREMENT A

MURAT ROAD
NORTH WEST CAPE WA 6707

November 2025

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RF EME SURVEY REPORT

For

Northrop Grumman Australia Pty Limited
Level 5, 197 Coward Street
Mascot NSW 2020

At

DARC S1 Agusta TX Site
Murat Road
North West Cape WA 6707

Measurement Date: 5th November 2025

Reference No: 5144 – 8751

Approved Signatory

P. J. Knipe

Name: Dr Phillip Knipe
Title: Consultant Physicist
Date: 18/11/2025
Total Radiation Solutions

NATA Accredited Laboratory Number: 15096

This document is issued in accordance with requirements for compliance with ISO/IEC 17025 - Testing.

The results of the measurements included in this document are traceable to Australian / National Standards.

NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration, inspection, proficiency testing scheme providers and reference materials producers reports and certificates.

Contents

1. Introduction

Northrop Grumman Australia Pty Limited (NGA) is commissioning a radar system at the Naval Communications Station, Harold E. Holt (NCSHEH), located on Murat Road, North West Cape, WA, 6707.

Consequently, NGA requested that Total Radiation Solutions (TRS) conduct a radiofrequency frequency (RF) electromagnetic energy (EME) survey.

The purpose of this survey is to determine the RF EME levels at specified locations of interest.

2. Regulatory Exposure Limits

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), an agency of the Commonwealth Department of Health has established a Radiation Protection Standard (RPS S-1) specifying limits for continuous exposure to RF EME transmissions (Tables 1). Further information can be gained from the ARPANSA web site at http://www.arpansa.gov.au.

This Standard is based on the 2020 guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for RF electromagnetic fields. ICNIRP is the peak international body developing and disseminating science-based advice on health protection in relation to exposure to non-ionising radiation and is recognised by the World Health Organization for its independence and expertise in this area. The ICNIRP guidelines reflect international best practice on what constitutes a high level of protection for all people against substantiated adverse health effects from exposures to both short- and long-term, continuous and discontinuous RF fields. Further, the principles for protection against adverse health effects of exposure to RF fields in this Standard are based on the ICNIRP Principles for Non-Ionising Radiation Protection, published in 2020.

The UK adheres to the RF EMF exposure limits recommended by ICNIRP, which set guideline values for limiting exposure from 0 Hz to 300 GHz.

The Australian Communications and Media Authority (ACMA) mandates exposure limits for continuous exposure of the general public to RF EME. Further information can be found at the ACMA website at http://www.acma.gov.au.

Table 1 Reference levels for whole body exposure, averaged over 30 minutes, to RF electromagnetic fields from 100 kHz to 300 GHz (unperturbed rms values)

Exposure Scenario	Frequency Range	Incident E-Field Strength E_{inc} (V/m)	Incident H-Field Strength (A/m)	Incident Power Density S_{inc} (W/m^2)
Occupational	0.1 – 6.943 MHz	ES	$4.9 / f_M$	NA
	>6.943 – 30 MHz	$660 / f_M^{0.7}$	$4.9 / f_M$	NA
	30 – 400 MHz	61	0.16	10
	400 – 2000 MHz	$3 f_M^{0.5}$	$0.008 f_M^{0.5}$	$f_M / 40$
	>2 – 300 GHz	NA	NA	50

General Public	0.1 – 6.27 MHz	ES	$2.2 / f_M$	NA
	>6.27 – 30 MHz	$300 / f_M^{0.7}$	$2.2 / f_M$	NA
	>30 – 400 MHz	27.7	0.073	2
	>400 – 2000 MHz	$1.375 f_M^{0.5}$	$0.0037 f_M^{0.5}$	$f_M / 200$
	>2 – 300 GHz	NA	NA	10

Notes:

1. 'NA' signifies 'not applicable' and does not need to be taken into account when determining compliance.
2. 'ES' signifies that no reference level is available, as it would be greater than the reference level for spatial peak and temporal peak field strengths based on electrostimulation effects shown in Table 7 of ARPANSA RPS S-1.
3. f_M is frequency in MHz; f_G is frequency in GHz.
4. S_{inc}, E_{inc} and H_{inc} are to be averaged over 30 minutes, over the whole-body space. Temporal and spatial averaging of each of E_{inc} and H_{inc} must be conducted by averaging over the relevant square values (see ICNIRP 2020a for details).
5. For frequencies of 100 kHz to 30 MHz, regardless of the far-field/near-field zone distinctions, compliance is demonstrated if neither E_{inc} nor H_{inc} exceeds the above reference level values.
6. For frequencies of >30 MHz to 2 GHz: a) within the far-field and radiating near-field zones: compliance is demonstrated if either S_{inc}, E_{inc} or H_{inc}, does not exceed the above reference level values (only one is required); S_{eq} derived from either E_{inc} or H_{inc} may be substituted for S_{inc}; b) within the reactive near-field zone: compliance is demonstrated if both E_{inc} and H_{inc} do not exceed the above reference level values; S_{inc} cannot be used to demonstrate compliance, and so basic restrictions must be assessed.
7. For frequencies of >2 GHz to 300 GHz: a) within the far-field and radiating near-field zones: compliance is demonstrated if S_{inc} does not exceed the above reference level values; S_{eq} derived from either E_{inc} or H_{inc} may be substituted for S_{inc}; b) within the reactive near-field zone, reference levels cannot be used to determine compliance, and so basic restrictions must be assessed.
8. There are additional applicable limits for exposure to RMS electric and magnetic fields (unperturbed fields). These limits are less restrictive than the limits specified in Table 1 or do not apply and as a result are not referenced in this measurement report.

3. Equipment Under Test

Antenna	Transmit Dish 2
Power (Peak)	350 kW
Dish Diameter	15.6m
Centre Frequency	3.4 GHz
Pulse Width	1ms
PRI	6.25 ms
PRF	160 pulses per second
Duty Cycle	16%
Transmit Band Width	5 MHz
Elevation	5°
Azimuth – Locations 1 – 18	97°
Azimuth – Locations 19 – 38	220°

4. Measurement Methodology

Measurements were conducted from 1.00 to 3.30pm on the 5th of November.

Using a NARDA SRM-3006 Selective Radiation Meter with an E-Field probe (200 MHz to 6 GHz) and 5m RF-Cable (9 kHz – 6 GHz) the RF EME levels due to the transmitting equipment was measured.

- The spectrum analyser was set to be used in level recorder mode.
- The meter was set to measure the x, y and z-axis manually and then provide the isotropic value.
- To ensure that the maximum level was generated for each of the axes, the meter readout was observed until the maximum level stabilised.
- The isotropic maximum level was then recorded.
- The probe was mounted vertically on a non-conductive pole.
- The probe height was either 2 or 4 metres above the top of the concrete base for the dish foundations.
- Distance from dish support to measurement location C was 17.7m.
- These measurements determined the representative RF EME level present at the time of measurement at the selected locations.
- All measurements determined the representative RF EME signals present at the time of measurement, for the selected locations.

Diagram 1 – Measurement Equipment Setup

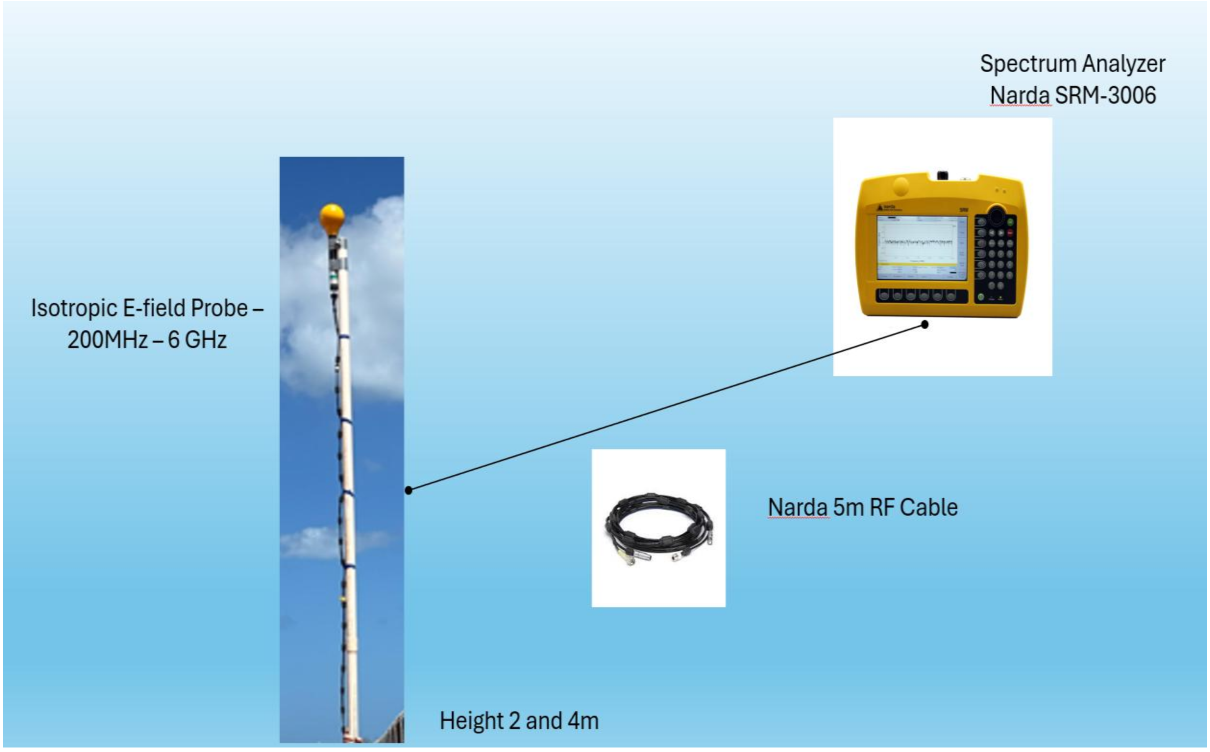


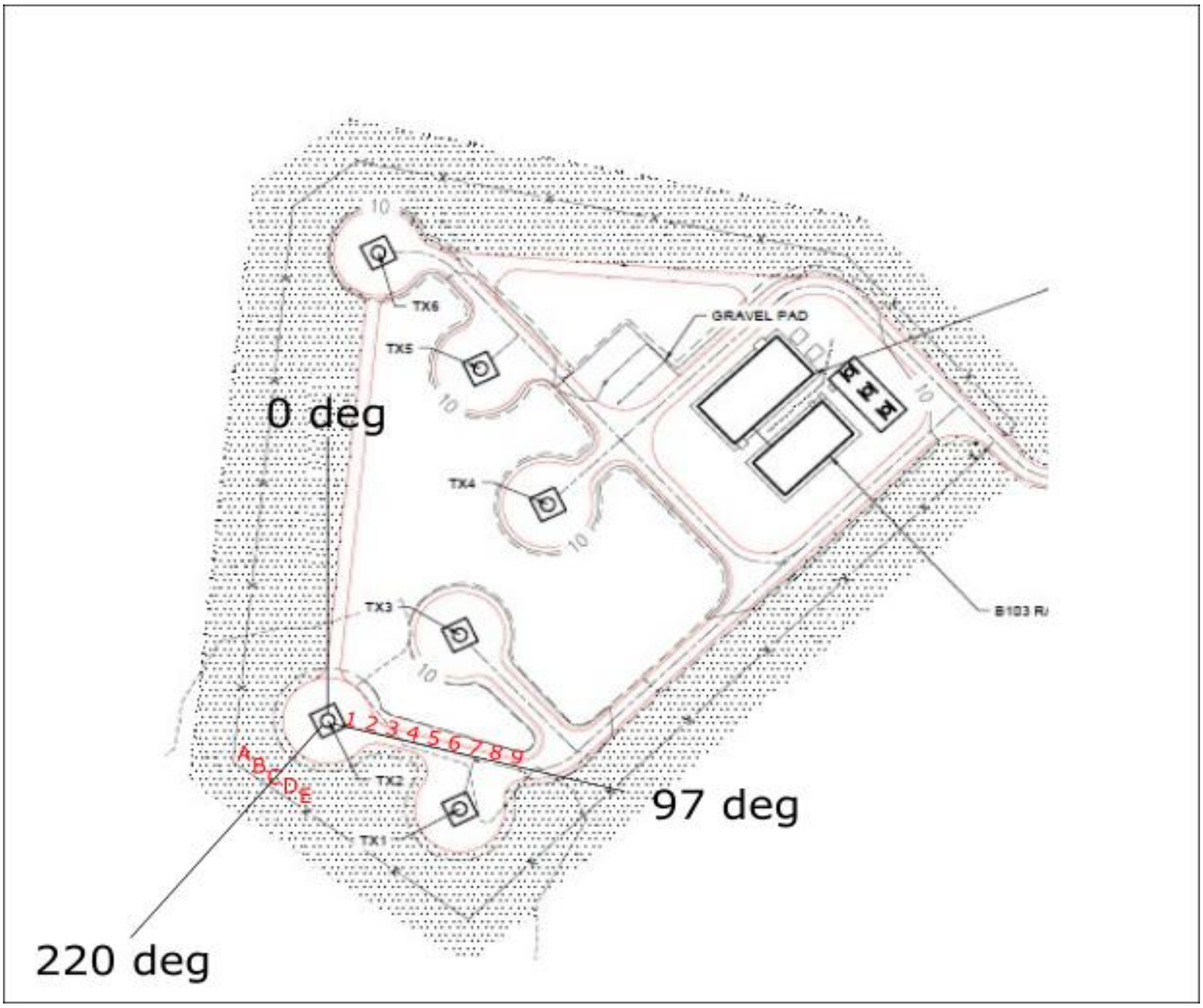
Table 2 Measurement Location Description

Measurement ID	Measurement Location Description	Reference
1	Centreline of dish, 0m out from dish, 2m height	1
2	Centreline of dish, 5m out from dish, 2m height	2
3	Centreline of dish, 10m out from dish, 2m height	-
4	Centreline of dish, 15m out from dish, 2m height	-
5	Centreline of dish, 20m out from dish, 2m height	-
6	Centreline of dish, 25m out from dish, 2m height	-
7	Centreline of dish, 30m out from dish, 2m height	-
8	Centreline of dish, 35m out from dish, 2m height	-

9	Centreline of dish, 40m out from dish, 2m height	3
10	Centreline of dish, 0m out from dish, 4m height	4a, 4b
11	Centreline of dish, 4m out from dish, 4m height	-
12	Centreline of dish, 10m out from dish, 4m height	-
13	Centreline of dish, 15m out from dish, 4m height	-
14	Centreline of dish, 20m out from dish, 4m height	-
15	Centreline of dish, 25m out from dish, 4m height	-
16	Centreline of dish, 30m out from dish, 4m height	-
17	Centreline of dish, 35m out from dish, 4m height	-
18	Centreline of dish, 40m out from dish, 4m height	-
19 (C)	1m out from fenceline, on centreline of dish, 4m height	5
20 (D)	1m out from fenceline, 4m left of centreline of dish, 4m height	-
21 (E)	1m out from fenceline, 8m left of centreline of dish, 4m height	-
22 (B)	1m out from fenceline, 4m right of centreline of dish, 4m height	-
23 (A)	1m out from fenceline, 8m right of centreline of dish, 4m height	-
24	1m out from fenceline, right side corner post of dish, 4m height	Annex B
25	1m out from fenceline, centre of 1st fence panel to left, 4m height	Annex B
26	1m out from fenceline, in-line with 1st post to left, 4m height	Annex B
27	1m out from fenceline, centre of 2nd fence panel to left, 4m height	Annex B
28	1m out from fenceline, in-line with 2nd post to left, 4m height	Annex B
29	1m out from fenceline, centre of 3rd fence panel to left, 4m height	Annex B
30	1m out from fenceline, in-line with 3rd post to left, 4m height	Annex B

31	1m out from fenceline, centre of 4th fence panel to left, 4m height	Annex B
32	1m out from fenceline, in-line with 4th post to left, 4m height	Annex B
33	1m out from fenceline, centre of 5th fence panel to left, 4m height	Annex B
34	1m out from fenceline, in-line with 5th post to left, 4m height	Annex B
35	1m out from fenceline, centre of 6th fence panel to left, 4m height	Annex B
36	1m out from fenceline, in-line with 6th post to left, 4m height	Annex B
37	1m out from fenceline, centre of 7th fence panel to left, 4m height	Annex B
38	1m out from fenceline, in-line with 7th post to left, 4m height	Annex B

Figure 1 Measurement Location Map



5. Measurement Equipment

- NARDA SRM-3006 Selective Radiation Meter
  Frequency Range 9 kHz – 6 GHz
  Model Number 3006-01
  Serial Number K-0092
  Calibration 11-10-2024

- NARDA 3-Axis Antenna
  Frequency Range 200 MHz – 6 GHz
  Model Number 3502-01
  Serial Number G-0299
  Calibration 11-10-2024

- NARDA RF-Cable SRM, Length 5m, 50 Ohms
  Frequency Range 9 kHz – 6 GHz
  Model Number 3602-02
  Serial Number AC-0385
  Calibration 11-10-2024

6. Measurement Results

The measured RF EME levels are shown in Table 3 below.

Table 3 Measurement Results – Power Density (W/m^2)

Measurement ID	Transmitter Power (kW)	Measured Max Level	Time Average Level	Level for 350kW Power
1	270	18.27	2.92	3.79
2	270	1.54	0.25	0.32
3	270	2.12	0.34	0.44
4	270	3.28	0.52	0.68
5	270	8.40	1.34	1.74
6	270	7.56	1.21	1.57
7	270	5.64	0.90	1.17
8	270	5.82	0.93	1.21
9	270	1.18	0.19	0.25
10	270	325.91	52.15	67.60
11	277	122.51	19.60	24.77
12	270	21.87	3.50	4.54
13	270	6.19	0.99	1.28

14	270	8.77	1.40	1.82
15	270	NM	-	-
16	270	4.84	0.77	1.00
17	270	4.13	0.66	0.86
18	270	NM	-	-
19 (C)	270	25.62	4.10	5.31
20 (D)	270	24.70	3.95	5.12
21 (E)	270	2.20	0.35	0.46
22 (B)	270	41.58	6.65	8.62
23 (A)	270	3.65	0.58	0.76
24	270	1.21	0.19	0.25
25	270	1.47	0.23	0.30
26	270	2.16	0.35	0.45
27	270	6.86	1.10	1.42
28	270	15.69	2.51	3.26
29	270	10.24	1.64	2.12
30	270	8.14	1.30	1.69
31	270	4.90	0.78	1.02
32	270	5.64	0.90	1.17
33	270	7.60	1.22	1.58
34	270	8.36	1.34	1.73
35	270	1.20	0.19	0.25
36	270	2.42	0.39	0.50
37	270	1.40	0.22	0.29
38	270	1.103	0.176	0.23

NOTES:

1. The recorded measurements were taken from the SRM-3006 for the 5 MHz transmit channel centred at 3.4 GHz.
2. The measurements were taken as per Australian/New Zealand Standard AS/NZS 2772.2 Radiofrequency fields Part 2: Principles and methods of measurement and computation–3 kHz to 300 GHz.

3. The measurements conducted with the SRM-3006 instrument with a non-conductive pole mounted probe and 5m cable have an expanded uncertainty of + 3 dB. See uncertainty excel spreadsheets in the specific job folder for the calculations.
4. The coverage factor (k) value used to give an upper one-sided expanded uncertainty with a 95% confidence interval was 1.64.
5. A duty cycle of 16% was used to determine the time averaged level.
6. The recorded measurements taken from the SRM-3006 were power density (W/m^2).
7. NM – Measurement result was incorrectly stored.
8. Measurement location 11 result was completed on the 6/11/2025. The distance from the dish was 4m and the height was 4m.
9. The ARPANSA RPS S-1 reference level for whole body exposure limit, averaged over 30 minutes for the general public (10 W/m^2) and occupational persons (50 W/m^2) were used for comparison.
10. TRS permanently stores all measurement equipment calibration details, site maps and recorded measurement scans.

Figure 3 Plot of Max-Average Levels Vs Distance from Centre of Dish

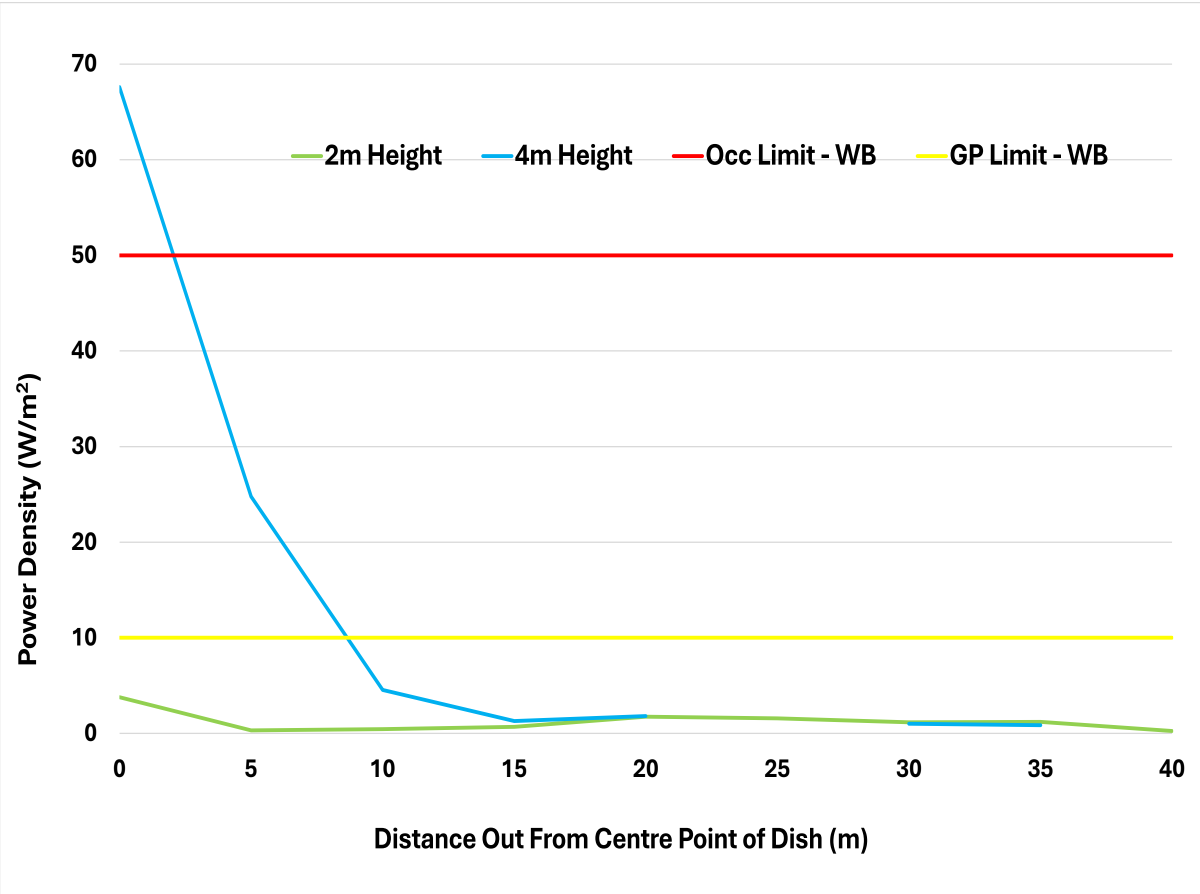
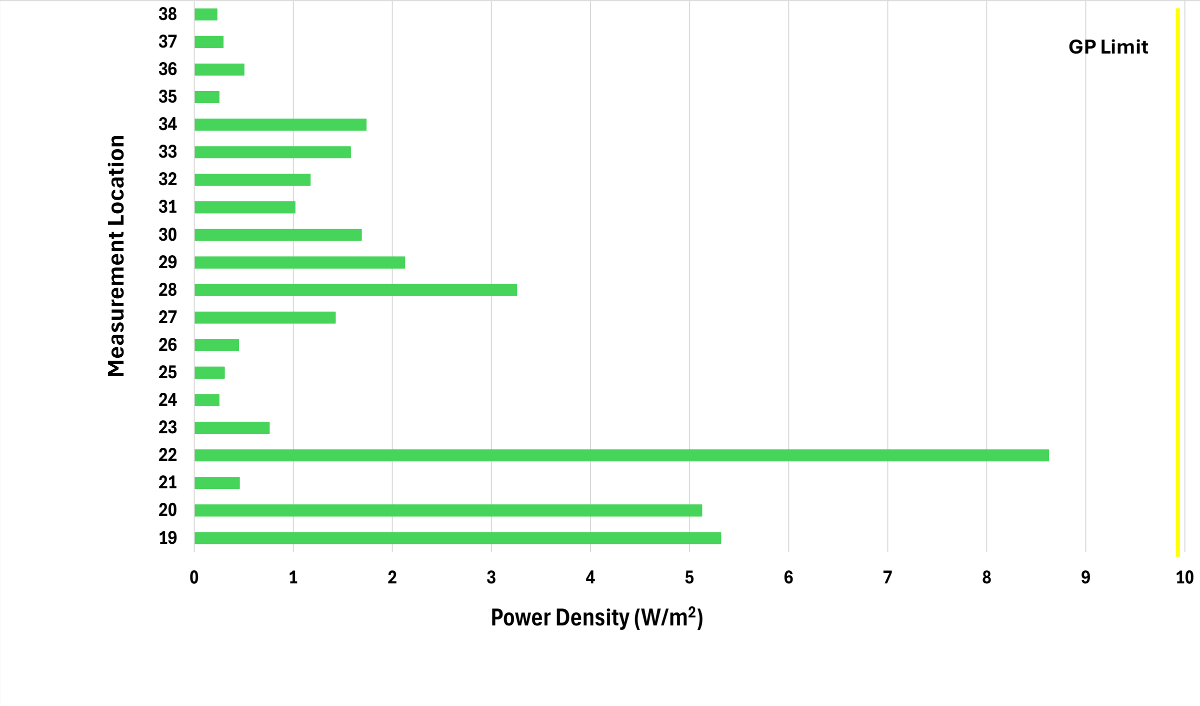


Figure 4 Plot of Fenceline Max Average Levels



7. Summary

The highest time-averaged RF EME level was 67.60 W/m^2. This was measured at 0m from the dish along the centre line, at a height of 4m.

All other levels were below the occupational whole body, time averaged (30 minutes) reference exposure limits (Table 1) specified by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Standard for Limiting Exposure to Radiofrequency Fields – 100 kHz to 300 GHz, (RPS S-1).

All fence line measurements levels were below the general public whole body, time averaged (30 minutes) reference exposure limits (Table 1) specified by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Standard for Limiting Exposure to Radiofrequency Fields – 100 kHz to 300 GHz, (RPS S-1).

APPENDIX A –Photos

Photo 1 - Measurement 1, 0m from Dish, 2m High

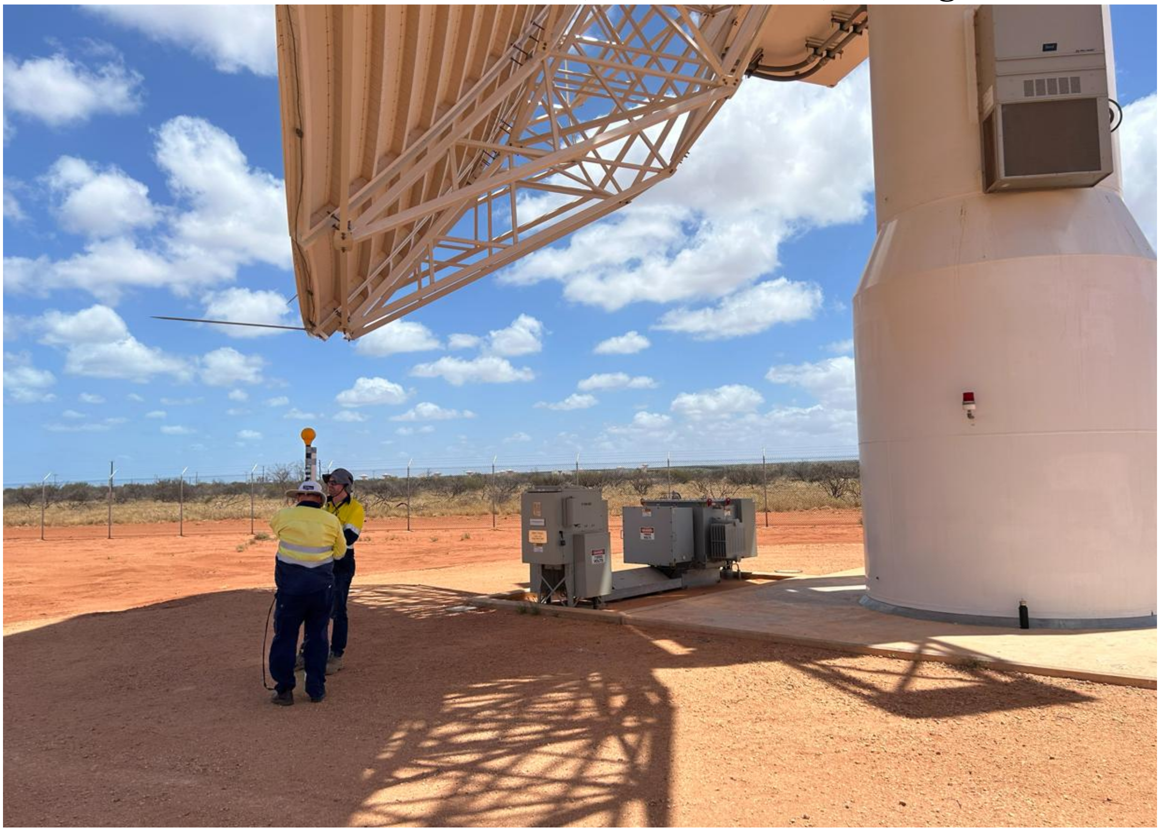


Photo 2 - Measurement 2, 5m from Dish, 2m High

Photo 3 – Measurement 9, 40m from Dish, 2m High

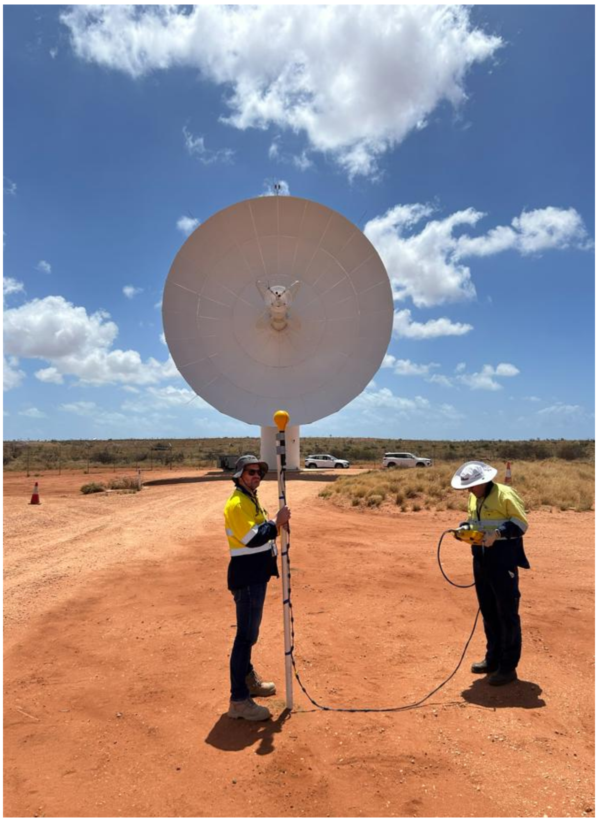


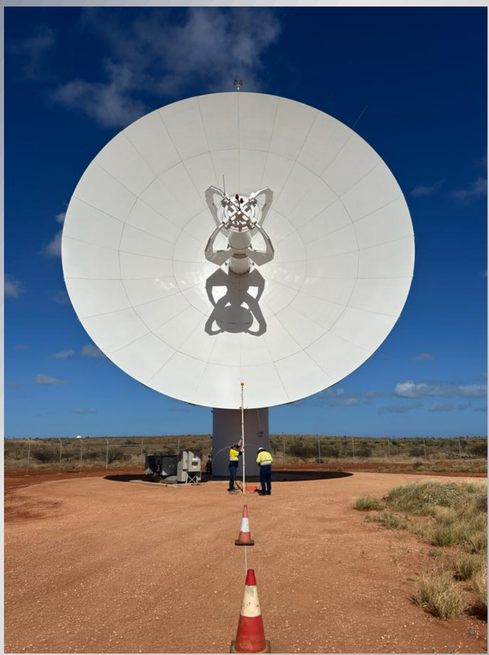
Photo 4a – Measurement 10, 0m from Dish, 4m High – Side Profile

Photo 4b – Measurement 10, 0m from Dish, 4m High – Front Profile

Photo 5 - Measurement 19, 1m from Fence, Centre line of Dish, 4m High

APPENDIX B – Locations 24 to 38 Photo

RF EME SURVEY REPORT
DARC S1 AUGUSTA TX SITE
DISH COMPREHENSIVE



MURAT ROAD
NORTH WEST CAPE WA 6707

November 2025

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RF EME SURVEY REPORT

For

Northrop Grumman Australia Pty Limited
Level 5, 197 Coward Street
Mascot NSW 2020

At

DARC S1 Agusta TX Site
Murat Road
North West Cape WA 6707

Measurement Date: 6th and 7th November 2025

Reference No: 5144 – 8585

Approved Signatory

Name: Dr Phillip Knipe
Title: Consultant Physicist
Date: 18/11/2025
Total Radiation Solutions

NATA Accredited Laboratory Number: 15096

This document is issued in accordance with requirements for compliance with ISO/IEC 17025 - Testing.

The results of the measurements included in this document are traceable to Australian / National Standards.

NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration, inspection, proficiency testing scheme providers and reference materials producers reports and certificates.

Contents

1. Introduction

Northrop Grumman Australia Pty Limited (NGA) is commissioning a radar system at the Naval Communications Station, Harold E. Holt (NCSHEH), located on Murat Road, North West Cape, WA, 6707.

Consequently, NGA requested that Total Radiation Solutions (TRS) conduct a radiofrequency frequency (RF) electromagnetic energy (EME) survey.

The purpose of this survey is to determine the RF EME levels at specified locations of interest.

2. Regulatory Exposure Limits

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), an agency of the Commonwealth Department of Health has established a Radiation Protection Standard (RPS S-1) specifying limits for continuous exposure to RF EME transmissions (Tables 1). Further information can be gained from the ARPANSA web site at http://www.arpansa.gov.au.

The Australian Communications and Media Authority (ACMA) mandates exposure limits for continuous exposure of the general public to RF EME. Further information can be found at the ACMA website at http://www.acma.gov.au.

Table 1 Reference levels for whole body exposure, averaged over 30 minutes, to RF electromagnetic fields from 100 kHz to 300 GHz (unperturbed rms values)

Exposure Scenario	Frequency Range	Incident E-Field Strength E_{inc} (V/m)	Incident H-Field Strength (A/m)	Incident Power Density S_{inc} (W/m^2)
Occupational	0.1 – 6.943 MHz	ES	$4.9 / f_M$	NA
	>6.943 – 30 MHz	$660 / f_M^{0.7}$	$4.9 / f_M$	NA
	30 – 400 MHz	61	0.16	10
	400 – 2000 MHz	$3 f_M^{0.5}$	$0.008 f_M^{0.5}$	$f_M / 40$
	>2 – 300 GHz	NA	NA	50
General Public	0.1 – 6.27 MHz	ES	$2.2 / f_M$	NA
	>6.27 – 30 MHz	$300 / f_M^{0.7}$	$2.2 / f_M$	NA
	>30 – 400 MHz	27.7	0.073	2
	>400 – 2000 MHz	$1.375 f_M^{0.5}$	$0.0037 f_M^{0.5}$	$f_M / 200$
	>2 – 300 GHz	NA	NA	10

Notes:

1. 'NA' signifies 'not applicable' and does not need to be taken into account when determining compliance.
2. 'ES' signifies that no reference level is available, as it would be greater than the reference level for spatial peak and temporal peak field strengths based on electrostimulation effects shown in Table 7 of ARPANSA RPS S-1.
3. f_M is frequency in MHz; f_G is frequency in GHz.
4. S_{inc}, E_{inc} and H_{inc} are to be averaged over 30 minutes, over the whole-body space. Temporal and spatial averaging of each of E_{inc} and H_{inc} must be conducted by averaging over the relevant square values (see ICNIRP 2020a for details).
5. For frequencies of 100 kHz to 30 MHz, regardless of the far-field/near-field zone distinctions, compliance is demonstrated if neither E_{inc} nor H_{inc} exceeds the above reference level values.
6. For frequencies of >30 MHz to 2 GHz: a) within the far-field and radiating near-field zones: compliance is demonstrated if either S_{inc}, E_{inc} or H_{inc}, does not exceed the above reference level values (only one is required); S_{eq} derived from either E_{inc} or H_{inc} may be substituted for S_{inc}; b) within the reactive near-field zone: compliance is demonstrated if both E_{inc} and H_{inc} do not exceed the above reference level values; S_{inc} cannot be used to demonstrate compliance, and so basic restrictions must be assessed.
7. For frequencies of >2 GHz to 300 GHz: a) within the far-field and radiating near-field zones: compliance is demonstrated if S_{inc} does not exceed the above reference level values; S_{eq} derived from either E_{inc} or H_{inc} may be substituted for S_{inc}; b) within the reactive near-field zone, reference levels cannot be used to determine compliance, and so basic restrictions must be assessed.
8. There are additional applicable limits for exposure to RMS electric and magnetic fields (unperturbed fields). These limits are less restrictive than the limits specified in Table 1 or do not apply and as a result are not referenced in this measurement report.

3. Equipment Under Test

Antennas	Transmit Dish 2, 4 and 6
Power (Peak)	350 kW
Dish Diameter	15.6m
Centre Frequency	3.4 GHz
Pulse Width	1ms
PRI	6.25 ms
PRF	160 pulses per second
Duty Cycle	16%
Transmit Band Width	5 MHz
Elevation	5°
Azimuth – Locations 1 – 18	97°
Azimuth – Locations 19 – 38	220°

4. Measurement Methodology

Measurements were conducted from 8.00 to 10.00am on the 6th of November and 7.00 to 11.00am on the 7th of November.

Using a NARDA SRM-3006 Selective Radiation Meter with an E-Field probe (200 MHz to 6 GHz) and 5m RF-Cable (9 kHz – 6 GHz) the RF EME levels due to the transmitting equipment was measured.

- The spectrum analyser was set to be used in level recorder mode.
- The meter was set to measure the x, y and z-axis manually and then provide the isotropic value.
- To ensure that the maximum level was generated for each of the axes, the meter readout was observed until the maximum level stabilised.
- The isotropic maximum level was then recorded.
- The probe was mounted vertically on a non-conductive pole.
- The probe height was 4 metres above the top of the concrete base for the dish foundations.
- The measurement locations (Table 2) were selected in consultation with a NGA representative.
- These measurements determined the representative RF EME level present at the time of measurement at the selected locations.
- All measurements determined the representative RF EME signals present at the time of measurement, for the selected locations.

Diagram 1 – Measurement Equipment Setup

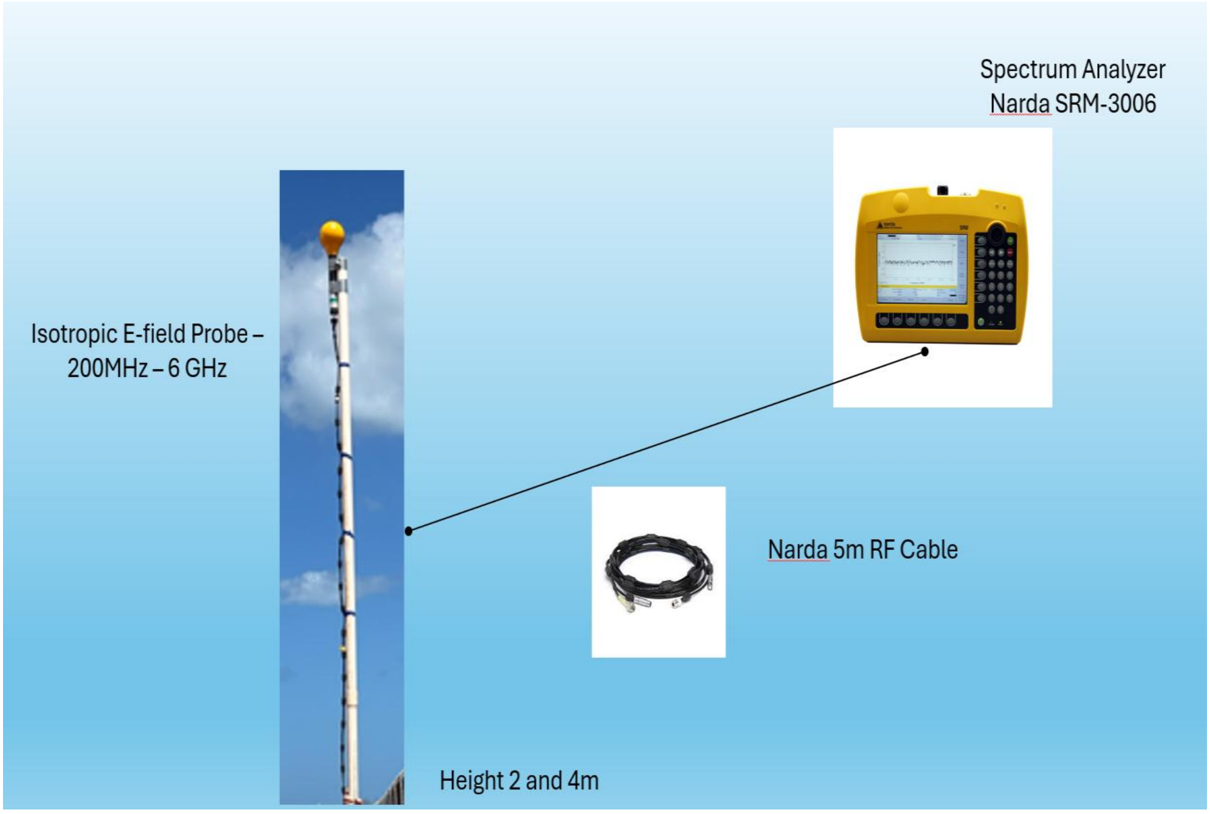

Table 2 Measurement Location Description

Measurement Location	Measurement Location Description	Photo Reference
Tx 2		
1	Centreline of dish, 1m out from dish, 4m height	1, 2
2	Centreline of dish, 2m out from dish, 4m height	-
3	Centreline of dish, 4m out from dish, 4m height	-
4	Centreline of dish, 6m out from dish, 4m height	-
5	Centreline of dish, 8m out from dish, 4m height	-
6	Centreline of dish, 10m out from dish, 4m height	3
7	Centreline of dish, 12m out from dish, 4m height	-
8	Centreline of dish, 14m out from dish, 4m height	-
9	Centreline of dish, 16m out from dish, 4m height	-
10	Centreline of dish, 18m out from dish, 4m height	-
11	Centreline of dish, 20m out from dish, 4m height	4
12	RHS edge of dish, 1m out from dish, 4m height	5, 6
13	RHS edge of dish, 2m out from dish, 4m height	-
14	RHS edge of dish, 4m out from dish, 4m height	-
15	RHS edge of dish, 6m out from dish, 4m height	7
16	RHS edge of dish, 8m out from dish, 4m height	-
17	RHS edge of dish, 10m out from dish, 4m height	-
18	RHS edge of dish, 12m out from dish, 4m height	-

19	RHS edge of dish, 14m out from dish, 4m height	-
20	RHS edge of dish, 16m out from dish, 4m height	8
2	RHS edge of dish, 18m out from dish, 4m height	-
22	RHS edge of dish, 20m out from dish, 4m height	-
23	LHS edge of dish, 1m out from dish, 4m height	9
24	LHS edge of dish, 2m out from dish, 4m height	-
25	LHS edge of dish, 4m out from dish, 4m height	10
26	LHS edge of dish, 6m out from dish, 4m height	-
27	LHS edge of dish, 8m out from dish, 4m height	-
28	LHS edge of dish, 10m out from dish, 4m height	11
29	LHS edge of dish, 12m out from dish, 4m height	-
30	LHS edge of dish, 14m out from dish, 4m height	-
31	LHS edge of dish, 16m out from dish, 4m height	-
32	LHS edge of dish, 18m out from dish, 4m height	-
33	LHS edge of dish, 20m out from dish, 4m height	-
34	Behind centreline of dish, 2.4m out from dish support, 4m height	-
Tx 4		
1	Centreline of dish, 1m out from dish, 4m height	-
2	Centreline of dish, 2m out from dish, 4m height	-
3	Centreline of dish, 4m out from dish, 4m height	-
4	Centreline of dish, 6m out from dish, 4m height	-
5	Centreline of dish, 8m out from dish, 4m height	-

6	Centreline of dish, 10m out from dish, 4m height	-
7	Centreline of dish, 12m out from dish, 4m height	-
8	Centreline of dish, 14m out from dish, 4m height	-
9	Centreline of dish, 16m out from dish, 4m height	-
10	Centreline of dish, 18m out from dish, 4m height	-
11	Centreline of dish, 20m out from dish, 4m height	-
12	RHS edge of dish, 1m out from dish, 4m height	-
13	RHS edge of dish, 2m out from dish, 4m height	-
14	RHS edge of dish, 4m out from dish, 4m height	-
15	RHS edge of dish, 6m out from dish, 4m height	-
16	RHS edge of dish, 8m out from dish, 4m height	-
17	RHS edge of dish, 10m out from dish, 4m height	-
18	RHS edge of dish, 12m out from dish, 4m height	-
19	RHS edge of dish, 14m out from dish, 4m height	-
20	RHS edge of dish, 16m out from dish, 4m height	-
2	RHS edge of dish, 18m out from dish, 4m height	-
22	RHS edge of dish, 20m out from dish, 4m height	-
23	LHS edge of dish, 1m out from dish, 4m height	-
24	LHS edge of dish, 2m out from dish, 4m height	-
25	LHS edge of dish, 4m out from dish, 4m height	-
26	LHS edge of dish, 6m out from dish, 4m height	-
27	LHS edge of dish, 8m out from dish, 4m height	-

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Handle as AUS OFFICIAL and/or UK OFFICIAL

28	LHS edge of dish, 10m out from dish, 4m height	-
29	LHS edge of dish, 12m out from dish, 4m height	-
30	LHS edge of dish, 14m out from dish, 4m height	-
31	LHS edge of dish, 16m out from dish, 4m height	-
32	LHS edge of dish, 18m out from dish, 4m height	-
33	LHS edge of dish, 20m out from dish, 4m height	-
34	Behind centreline of dish, 2.4m out from dish support, 4m height	12
Tx 6		
1	Centreline of dish, 1m out from dish, 4m height	13, 14
2	Centreline of dish, 2m out from dish, 4m height	-
3	Centreline of dish, 4m out from dish, 4m height	-
4	Centreline of dish, 6m out from dish, 4m height	-
5	Centreline of dish, 8m out from dish, 4m height	-
6	Centreline of dish, 10m out from dish, 4m height	-
7	Centreline of dish, 12m out from dish, 4m height	-
8	Centreline of dish, 14m out from dish, 4m height	-
9	Centreline of dish, 16m out from dish, 4m height	-
10	Centreline of dish, 18m out from dish, 4m height	-
11	Centreline of dish, 20m out from dish, 4m height	-
12	RHS edge of dish, 1m out from dish, 4m height	-
13	RHS edge of dish, 2m out from dish, 4m height	-
14	RHS edge of dish, 4m out from dish, 4m height	-

15	RHS edge of dish, 6m out from dish, 4m height	-
16	RHS edge of dish, 8m out from dish, 4m height	-
17	RHS edge of dish, 10m out from dish, 4m height	-
18	RHS edge of dish, 12m out from dish, 4m height	-
19	RHS edge of dish, 14m out from dish, 4m height	-
20	RHS edge of dish, 16m out from dish, 4m height	15
2	RHS edge of dish, 18m out from dish, 4m height	-
22	RHS edge of dish, 20m out from dish, 4m height	-
23	LHS edge of dish, 1m out from dish, 4m height	16, 17
24	LHS edge of dish, 2m out from dish, 4m height	-
25	LHS edge of dish, 4m out from dish, 4m height	-
26	LHS edge of dish, 6m out from dish, 4m height	-
27	LHS edge of dish, 8m out from dish, 4m height	-
28	LHS edge of dish, 10m out from dish, 4m height	-
29	LHS edge of dish, 12m out from dish, 4m height	-
30	LHS edge of dish, 14m out from dish, 4m height	-
31	LHS edge of dish, 16m out from dish, 4m height	-
32	LHS edge of dish, 18m out from dish, 4m height	-
33	LHS edge of dish, 20m out from dish, 4m height	18
34	Behind centreline of dish, 2.4m out from dish support, 4m height	19

5. Measurement Equipment

- NARDA SRM-3006 Selective Radiation Meter
  Frequency Range 9 kHz – 6 GHz
  Model Number 3006-01
  Serial Number K-0092
  Calibration 11-10-2024

- NARDA 3-Axis Antenna
  Frequency Range 200 MHz – 6 GHz
  Model Number 3502-01
  Serial Number G-0299
  Calibration 11-10-2024

- NARDA RF-Cable SRM, Length 5m, 50 Ohms
  Frequency Range 9 kHz – 6 GHz
  Model Number 3602-02
  Serial Number AC-0385
  Calibration 11-10-2024

6. Measurement Results

The measured RF EME levels are shown in Table 3 below.

Table 3 Measurement Results – Power Density (W/m^2)

Measurement ID	Transmitter Power (kW)	Measured Max Level	Time Average Level	Level for 350kW Power
Tx 2				
1	277	208.69	33.39	42.19
2	277	112.70	18.03	22.78
3	277	122.51	19.60	24.77
4	277	74.83	11.97	15.13
5	277	21.49	3.44	4.34
6	277	37.82	6.05	7.65
7	277	6.29	1.01	1.27
8	277	7.98	1.28	1.61
9	277	6.02	0.96	1.22

10	277	10.09	1.61	2.04
11	277	6.60	1.06	1.33
12	270	4.36	0.70	0.90
13	270	1.48	0.24	0.31
14	270	2.84	0.45	0.59
15	270	3.42	0.55	0.71
16	270	2.15	0.34	0.45
17	270	1.72	0.27	0.36
18	270	1.73	0.28	0.36
19	270	1.28	0.21	0.27
20	270	4.20	0.67	0.87
21	270	10.34	1.65	2.15
22	270	5.22	0.83	1.08
23	270	5.11	0.82	1.06
24	270	3.49	0.56	0.72
25	270	8.68	1.39	1.80
26	270	16.96	2.71	3.52
27	270	14.48	2.32	3.00
28	270	12.30	1.97	2.55
29	270	7.50	1.20	1.56
30	270	6.49	1.04	1.35
31	270	7.64	1.22	1.58
32	270	7.52	1.20	1.56
33	270	9.67	1.55	2.00
34	270	1.69	0.27	0.35

Tx 4				
1	328	161.04	25.77	27.49
2	328	190.08	30.41	32.45
3	328	104.46	16.71	17.84
4	328	26.14	4.18	4.46
5	328	33.95	5.43	5.80
6	328	22.56	3.61	3.85
7	328	19.47	3.12	3.32
8	328	12.13	1.94	2.07
9	328	9.32	1.49	1.59
10	328	5.20	0.83	0.89
11	328	4.85	0.78	0.83
12	328	9.43	1.51	1.61
13	328	5.26	0.84	0.90
14	328	2.05	0.33	0.35
15	328	3.44	0.55	0.59
16	328	4.70	0.75	0.80
17	328	2.25	0.36	0.38
18	328	2.51	0.40	0.43
19	328	2.09	0.33	0.36
20	328	4.85	0.78	0.83
21	328	2.45	0.39	0.42
22	328	7.17	1.15	1.22
23	328	13.97	2.23	2.38
24	328	3.99	0.64	0.68

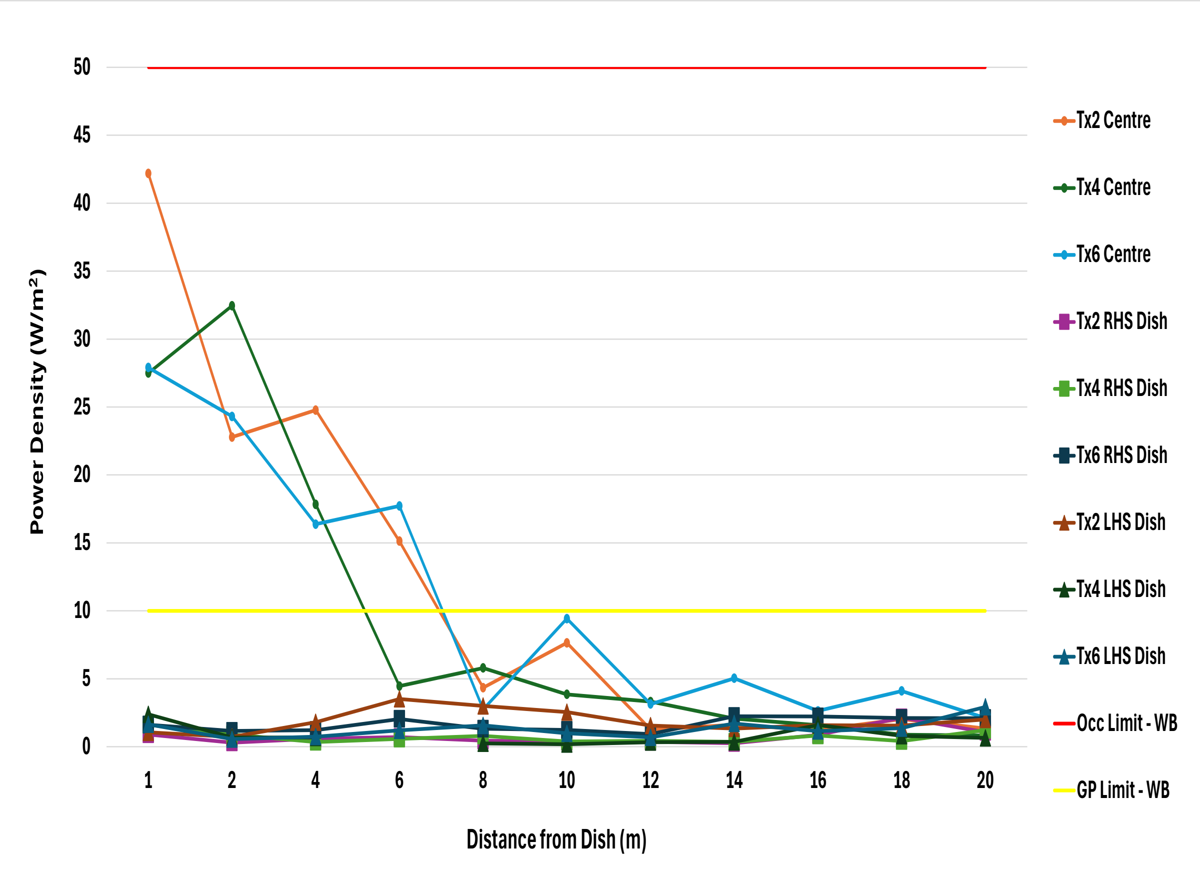
25	328	3.99	0.64	0.68
26	328	NM	-	-
27	328	1.45	0.23	0.25
28	328	1.09	0.17	0.19
29	328	1.95	0.31	0.33
30	328	2.09	0.33	0.36
31	328	9.39	1.50	1.60
32	328	4.70	0.75	0.80
33	328	3.80	0.61	0.65
34	328	0.80	0.13	0.14
Tx 6				
1	72	35.88	5.74	27.90
2	72	31.24	5.00	24.30
3	72	21.05	3.37	16.38
4	72	22.78	3.65	17.72
5	72	3.55	0.57	2.76
6	72	12.11	1.94	9.42
7	72	4.04	0.65	3.14
8	72	6.47	1.04	5.03
9	72	3.38	0.54	2.63
10	72	5.27	0.84	4.10
11	72	2.72	0.44	2.12
12	72	2.08	0.33	1.62
13	72	1.50	0.24	1.16
14	72	1.58	0.25	1.23

15	72	2.63	0.42	2.04
16	72	1.70	0.27	1.32
17	72	1.59	0.25	1.24
18	77	1.28	0.20	0.93
19	77	3.09	0.50	2.25
20	77	3.06	0.49	2.23
21	77	2.90	0.46	2.11
22	77	2.89	0.46	2.10
23	77	2.27	0.36	1.65
24	77	0.77	0.12	0.56
25	77	1.02	0.16	0.74
26	77	1.66	0.27	1.21
27	77	2.16	0.35	1.57
28	77	1.36	0.22	0.99
29	77	0.95	0.15	0.69
30	77	2.34	0.38	1.70
31	77	1.58	0.25	1.15
32	77	1.87	0.30	1.36
33	77	4.04	0.65	2.94
34	77	0.28	0.04	0.20

NOTES:

1. The recorded measurements were taken from the SRM-3006 for the 5 MHz transmit channel centred at 3.4 GHz.
2. The measurements were taken as per Australian/New Zealand Standard AS/NZS 2772.2 Radiofrequency fields Part 2: Principles and methods of measurement and computation–3 kHz to 300 GHz.
3. The measurements conducted with the SRM-3006 instrument with a non-conductive pole mounted probe and 5m cable have an expanded uncertainty of + 3 dB. See uncertainty excel spreadsheets in the specific job folder for the calculations.
4. The coverage factor (k) value used to give an upper one-sided expanded uncertainty with a 95% confidence interval was 1.64.
5. A duty cycle of 16% was used to determine the time averaged level.
6. The recorded measurements taken from the SRM-3006 were power density (W/m^2).
7. NM – Measurement result was incorrectly stored.
8. The ARPANSA RPS S-1 reference level for whole body exposure limit, averaged over 30 minutes for the general public (10 W/m^2) and occupational persons (50 W/m^2) were used for comparison.
9. TRS permanently stores all measurement equipment calibration details, site maps and recorded measurement scans.

Figure 1 Plot of Max-Average Levels Vs Distance from Dish



7. Summary

The highest time-averaged RF EME level was 42.19 W/m^2. This was measured at 1m from the Tx2 dish along the centre line, at a height of 4m.

All time-averaged RF EME levels were below the occupational whole body, time averaged (30 minutes) reference exposure limits (Table 1) specified by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Standard for Limiting Exposure to Radiofrequency Fields – 100 kHz to 300 GHz, (RPS S-1).

RF EME levels beyond 8 m from the dishes were below the general public whole body, time averaged (30 minutes) reference exposure limits (Table 1) specified by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) Standard for Limiting Exposure to Radiofrequency Fields – 100 kHz to 300 GHz, (RPS S-1).

APPENDIX A –Photos

Photo 1 – TX2, 1m from Centre of Dish, 4m High – Front-on

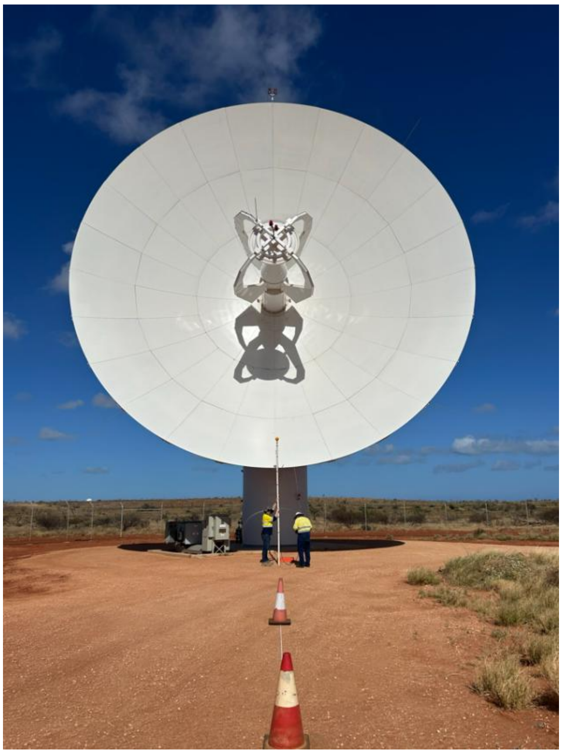


Photo 2 - TX2, 1m from Centre of Dish, 4m High – Side-on

Photo 3 – TX2, 10m from Centre of Dish, 4m High

Photo 4 – TX2, 20m from Centre of Dish, 4m High

Photo 5 – TX2, 1m from RHS of Dish, 4m High, Front-on

Photo 6 – TX2, 1m from RHS of Dish, 4m High, Side-on

Photo 7 – TX2, 6m from RHS of Dish, 4m High

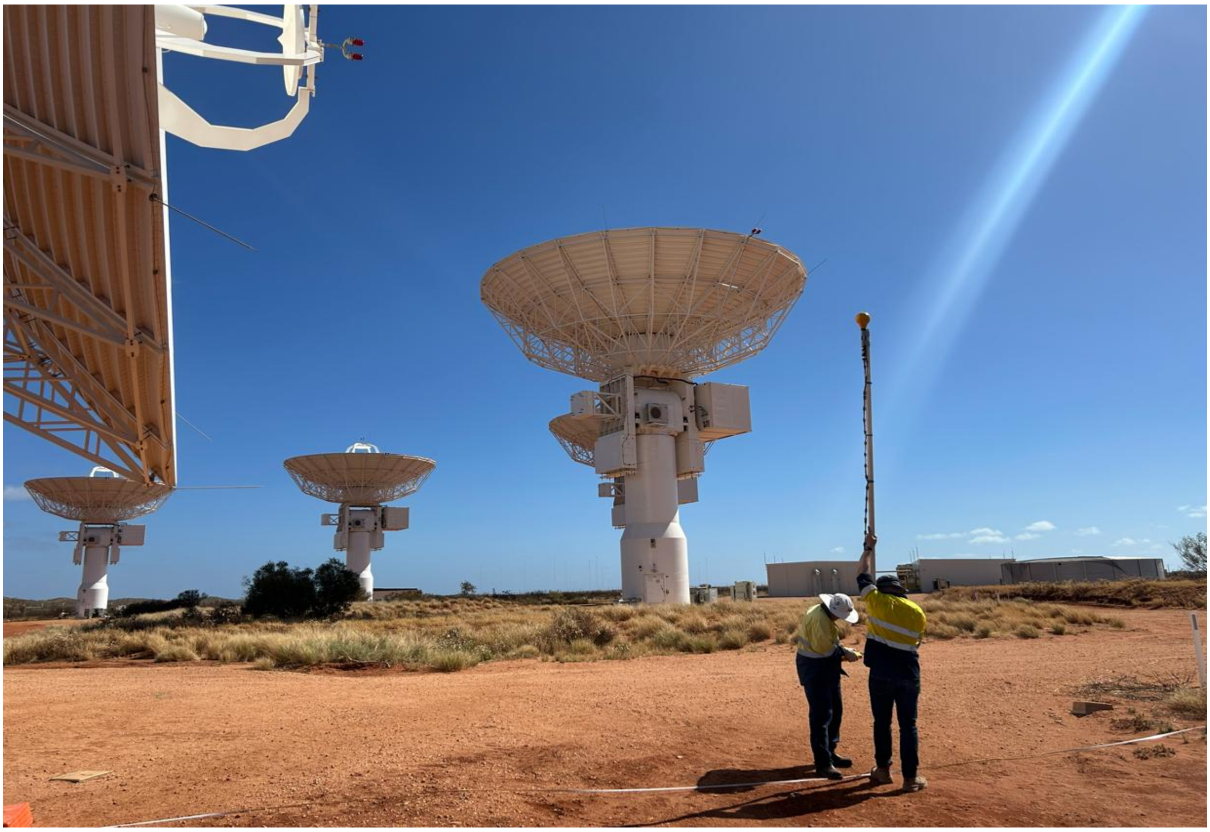


Photo 8 – TX2, 16m from RHS of Dish, 4m High

Photo 9 – TX2, 1m from LHS of Dish, 4m High

Photo 10 – TX2, 4m from LHS of Dish, 4m High

Photo 11 – TX2, 10m from LHS of Dish, 4m High

Photo 12 – TX4, Behind Dish, 4m High

Photo 13 – TX6, 1m from Centre of Dish, 4m High, Front-on

Photo 14 - TX6, 1m from Centre of Dish, 4m High, Side-on

Photo 15 – TX6, 16m from RHS of Dish, 4m High

Photo 16 – TX6, 1m from LHS of Dish, 4m High, Front-on

Photo 17 – TX6, 1m from LHS of Dish, 4m High, Side-on

Photo 18 – TX6, 20m from LHS of Dish, 4m High, Side-on

Photo 19 – TX6, Behind Dish, 4m High