Coexistence between highly localised wireless broadband stations and radio altimeters

3950 – 4000 MHz

JuLY 2024

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Executive summary

The purpose of this paper is to study coexistence between proposed highly localised wireless broadband (HL WBB) devices in the 3950-4000 MHz band and aircraft radio altimeters (RA) in the 4200-4400 MHz band.

The studies covered two potential interference mechanisms:

* RA receiver overload from HL WBB emissions within the 3950-4000 MHz band; and
* RA receiver desensitisation from HL WBB unwanted emissions falling within the 4200-4400 MHz band.

Based on the results of studies, this paper presents proposals on regulatory measures to enable coexistence between HL WBB and RA.

## RA receiver overload

Studies show that, due to existing obstacle restrictions around airports, HL WBB devices will not overload RA receivers when the in-band power spectral density (PSD) is limited to 17 dBm/MHz equivalent isotropically radiated power (EIRP). Consequently, if the in-band PSD is limited to 17 dBm/MHz EIRP, no additional mitigation measures are necessary to enable coexistence under this interference scenario.

## RA receiver desensitisation

Studies were conducted to assess the impact on RA receivers from unwanted emissions from HL WBB devices falling within the 4200-4400 MHz band.

For user terminals (which include any terminal communicating with a HL WBB base station), studies show the risk of interference is low. This is due to their low operating power, use of power control and typically low antenna gains. There is a risk of interference occurring at relatively small separation distances and/or for higher gain terminals. However, this is limited to areas where the deployment of obstacles is prohibited by legislation[[1]](#footnote-2). As access to these areas is controlled by airports, it is considered that site management arrangements could be put in place to manage the issue. This could include, for example, restricting the use of user terminals that can connect to HL WBB networks in these areas.

For base stations (BS), studies considered unwanted emissions, based on 3GPP standards, for the following three cases: Local Area BS, Medium Range BS and an assumption that spurious emission limits apply across the entire 4200-4400 MHz band. BS with active antenna systems (AAS) and non-AAS were considered.

The results of the BS studies show that Local Area BS and Medium Range BS transmissions could potentially interfere with Ras if the antenna gain directed towards an aircraft is sufficiently high.

The maximum antenna gain of HL WBB BSs within the 4200-4400 MHz band may vary based on a number of factors. This is further complicated for the AAS case, where assumptions on when to assume decorrelation of the antenna pattern within the 4200-4400 MHz band are uncertain. However, in practice, the size of an AAS array and maximum antenna gains for non-AAS BSs is likely to be limited by the proposed in-band spectral density limit of 17 dBm/MHz (maximum 34 dBm EIRP over 50 MHz). This may even make the use of AAS impractical within the 3950-4000 MHz band.

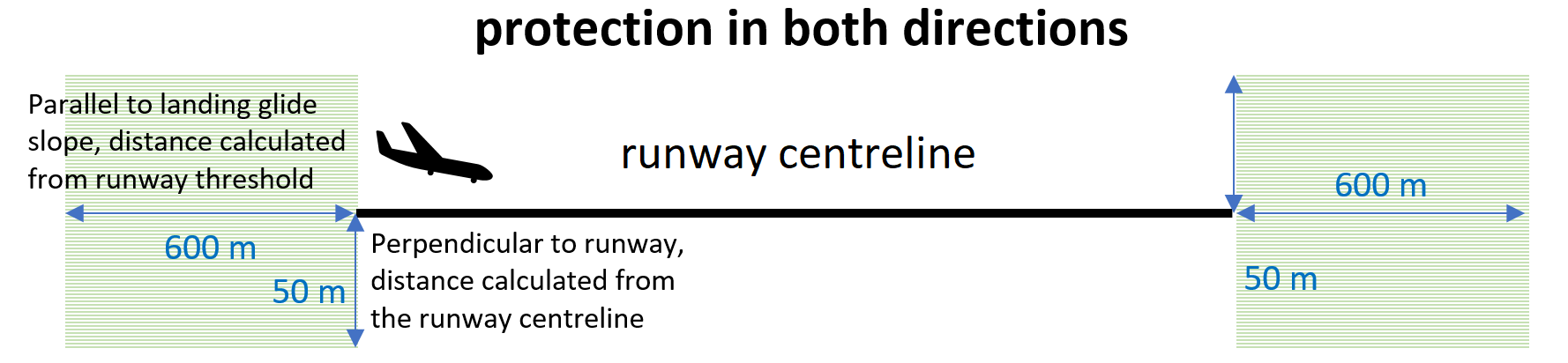
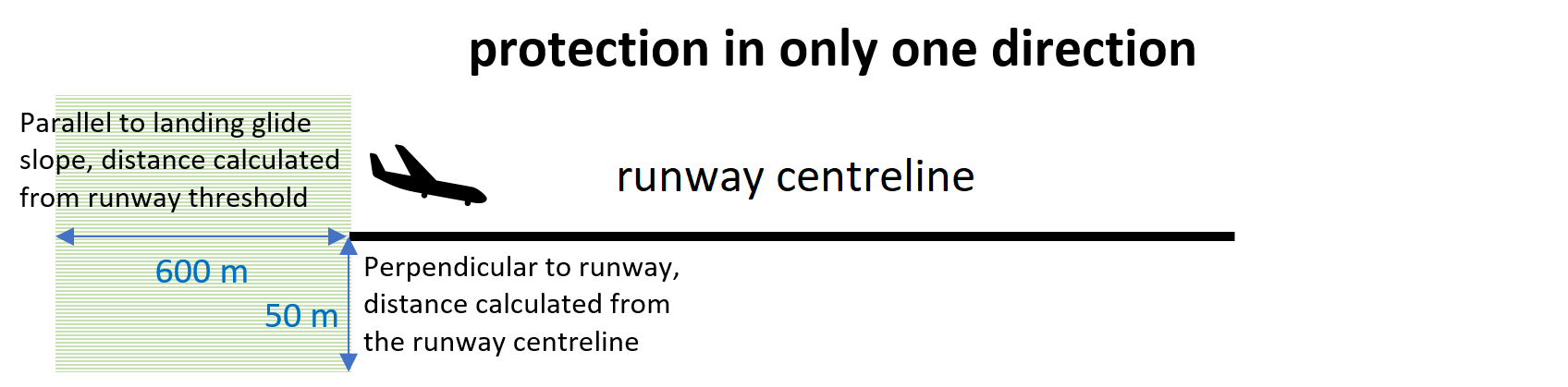
Taking this into account, additional studies were conducted focusing on radiated unwanted emissions (as EIRP) within the 4200-4400 MHz range. This resulted in the following measures being identified to facilitate coexistence with RAs:

* No additional mitigation measures are required for BS that meet category B spurious emissions limits (as defined by 3GPP) across the entire 4200-4400 MHz band.
* For BS that meet Local Area BS and Medium Range BS unwanted emissions within the 4200-4240 MHz band, a small restricted zone is proposed in the area parallel to the glide landing slope at airports[[2]](#footnote-3). This is detailed in Figure 1. No restricted zone is required perpendicular to the runway.

Within the restricted zone it is proposed to implement limits on the EIRP of unwanted emissions from HL WBB BS at different elevation angles (with respect to the horizon). An equation has been derived that defines these limits and is provided in the *Final proposed mitigation measures* section.

* When coordinating indoor HL WBB BS, licence applicants (or their accredited persons) may apply to the ACMA to have building penetration losses considered. Such a request would need to include suitable information detailing the level of building penetration loss and how this was determined. If the building penetration losses are greater than or equal to 5.6 dB then no additional mitigation measures are required.

Diagram of the proposed Restricted zone (not to scale)



## Feedback

The HL WBB Technical Liaison Group (TLG) is requested to provide feedback on:

* the studies conducted, including parameters used and assumptions made; and
* the measures proposed to enable coexistence between HL WBB and RAs.

# Obstacle restrictions around airports

The existing legislation for obstacles around airports is in chapter 7 of [Part 139 (Aerodromes) Manual of Standards 2019](https://www.legislation.gov.au/F2019L01146/latest/text). This legislation defines the Obstacle Limitation Surfaces (OLS) which are three dimensional volumes of airspace that restrict the installation of physical structures such as BS around airport runways – refer to Figure 2. The dimensions of the OLS differ depending on the runway type and code. For studies conducted in this paper a category I, code 1, 2, precision, instrument landing approach runway is used.

Example of OLS surfaces around a runway[[3]](#footnote-4)



The legislation defines the runway strip as an obstacle restriction area (ORA), where no physical objects or structures may be deployed. For an instrument landing approach runway, with code 1, 2, the runway strip extends 70 m either side of the runway centreline and 60 m beyond the runway threshold.

The OLS defines the maximum height of physical structures outside the runway strip. Extending from the runway strip the two OLS are the approach surface and the transitional surface. The approach surface is defined as a linear slope that begins 60 m from the threshold of the runway that trends upwards. The maximum height of an obstacle at the beginning of the slope is 0 m and progressively increases as the distance from the runway threshold increases. For a category I, code 1,2, precision, instrument landing approach runway, the OLS slopes upward at a rate of 2.5% (equivalent to an angle of 1.432°). The transitional surface starts at the side edges of the approach surface and the runway strip and slopes linearly upwards. For a category I, code 1,2, precision instrument landing runway the transitional surface slopes upwards at a rate of 14.3% (equivalent to an angle of 8.138°).

# RA receiver overload studies

Studies were conducted to assess the risk of interference from HL WBB transmitters into RA receiver front ends[[4]](#footnote-5). The intention of the studies was to assess when receiver overload may occur and use the results to determine what (if any) regulatory measures may be required to manage it.

Receiver front-end overload occurs when sufficient power from an interfering signal saturates the front-end of a RA receiver causing the inherent effects of non-linear behaviour; for example, harmonic distortion or intermodulation. This mechanism is often also called “blocking” as the unwanted signal affects the ability of the receiver to correctly demodulate it’s wanted signal and “blocks” it.

The RA receiver overload studies covered two scenarios:

Scenario 1: HL WBB located directly underneath an aircraft as it is landing

Scenario 2: HL WBB located perpendicular to the runway centreline.

It is noted that studies conducted:

take into account existing obstacle deployment restrictions around airports.

used the same methodology as in the [3.4 / 3.7 GHz spectrum licensing TLG package](https://www.acma.gov.au/spectrum-licence-technical-liaison-groups), *Coexistence between Radio Altimeters operating in 4200-4400 MHz and Wireless Broadband systems in 3400-4000 MHz* (the 2022 RA Coexistence Report);

generally assumed an in-band power spectral density (PSD) limit for HL WBB of 17 dBm/MHz EIRP as proposed within the HL WBB TLG.

## Rx overload calculations – Scenario 1

Calculations on the required separation distance between a HL WBB transmitter and an RA to avoid receiver overload are provided in Table 1.

The following assumptions were made for calculations performed:

The proposed in-band PSD limit of 17 dBm/MHz EIRP is a total value combining all polarisations. This is modelled as 14 dBm/MHz EIRP per polarisation in studies to account for a 3 dB polarisation mismatch/discrimination at the RA antenna. A sensitivity analysis was also conducted that considers lower and higher values per polarisation.

The maximum gain of the HL WBB antenna is pointed directly at the RA receiver (worst case assumption).

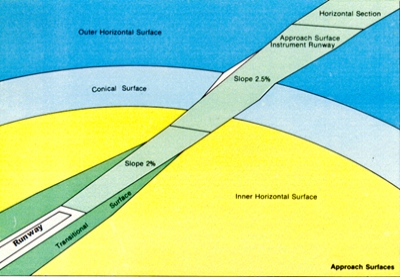
The Interference Tolerance Mask (ITM)[[5]](#footnote-6) threshold value was interpolated across the entire 3950–4000 MHz band and the resulting margins were calculated for different frequencies within that range. This allowed the frequency that gave the worst-case result to be identified and used in studies. In this case, the worst case was determined to be at 4000 MHz.

RA receiver overload calculation

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Variable | Value | Notes |
| EIRP |  | 14 dBm/MHz | ACMA-proposed EIRP limit (per polarisation) for metro and regional areas for HL WBB use in 3950–4000 MHz |
| Radio altimeter antenna gain |  | 0 dBi | French National Frequency Agency (ANFR) study[[6]](#footnote-7) refers to Radio Technical Commission for Aeronautics (RTCA) report[[7]](#footnote-8) which used 0 dBi |
| Margin |  | 6 dB | ANFR study used a 6 dB aviation safety factor |
| ITM threshold |  | -42.88 dBm/MHz | RTCA Fundamental emissions at 50‑200 feet, linearly interpolated to 4000 MHz. |
| Required Path Loss |  | 63 dB  (rounded up) | Calculation |
| Separation distance | distance to achieve required path loss assuming free space loss (FSL) | 9 m (rounded up) | Calculation: |

The geometry of an aircraft landing is shown in Figure 3. In a worst-case scenario, a potential interferer is located directly below the aircraft radio altimeter. As mentioned previously, the OLS restricts the height of objects below an aircraft.

Manual of Standards 2019 Figure 7.08 (6)-1 Approach surface for an instrument approach runway[[8]](#footnote-9)

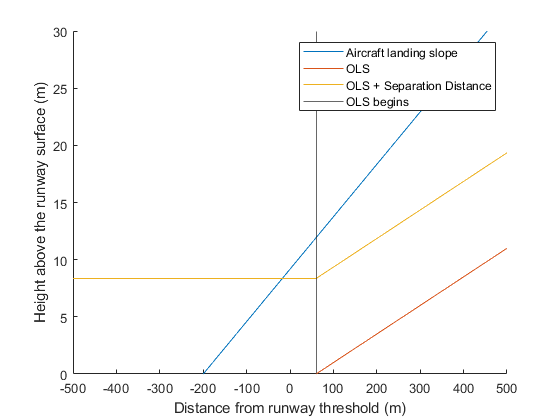


To interpret the results in Table 1, the required separation distance of 9 metres is added to the OLS slope and compared to the aircraft landing slope.[[9]](#footnote-10) This is shown in Figure 4. This figure shows the points at which an RA receiver can potentially be overloaded from an interferer directly below it when the maximum gain of the interferers’ antenna occurs vertically upward.

The geometry of the aircraft landing shows that the aircraft is always above the required separation distance at points where the OLS applies. Therefore, interference is not predicted to occur at those locations. The aircraft does dip below the required separation distance of 9 metres after the runway threshold. However, at this point the aircraft is on the ground or over the runway strip where no obstacles can be deployed.

Based on these results, HL WBB BSs with a maximum in-band EIRP limit of 17 dBm/MHz will not cause RA receivers to overload. Given user terminals will be subject to the same power restrictions (though will typically operate at lower EIRPs), the same conclusions can be drawn for those devices. While theoretically it may be possible for UEs to operate within the runway strip, they will generally operate at lower EIRPs. Also, access to the runway strip and obstacle restriction areas is controlled by Airports. This means site management arrangements can be put in place to restrict use and manage the issue.

Geometry of aircraft landing slope (axis not 1:1)



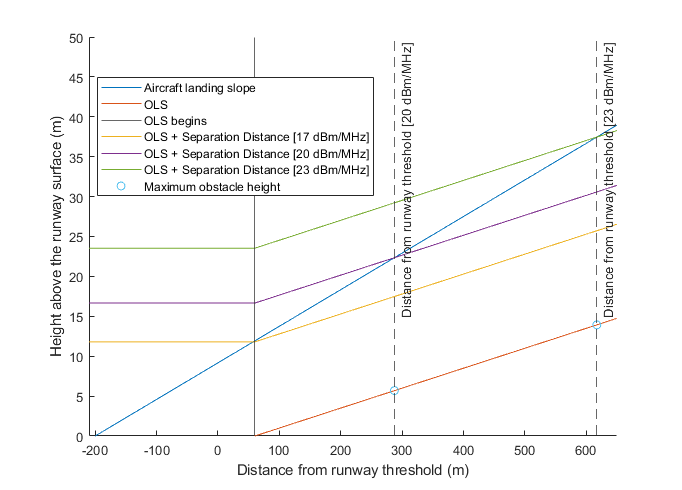
### Sensitivity Analysis – different EIRP limits

The RA receiver overload calculation in Table 1 was repeated using a range of different in-band PSDs for HL WBB transmitters. Figure 5 and Table 2 summarises the results. The results show that even for the case of 17 dBm/MHz EIRP per polarisation, the distance at which interference could occur is limited to within the runway strip – where no obstacles are allowed. As the proposed maximum in-band PSD limit for HL WBB transmitters is 17 dBm/MHz EIRP, the 20 and 23 dBm/MHz EIRP cases will not occur and are provided for information.

RA receiver overload calculations for different EIRP limits

|  |  |  |  |
| --- | --- | --- | --- |
| EIRP Limit per polarisation | Separation distance (free space path loss) | Distance from runway threshold within which interference could potentially occur[[10]](#footnote-11) | Maximum obstacle height |
| 11 dBm/MHz | 5.9 m | None | No obstacles allowed |
| 14 dBm/MHz | 8.4 m | None | No obstacles allowed |
| 17 dBm/MHz | 11.8 m | 57.3 m | No obstacles allowed |
| 20 dBm/MHz | 16.7 m | 287.4 m | 5.7 m |
| 23 dBm/MHz | 23.5 m | 617 m | 13.9 m |

Geometry of aircraft landing slope for sensitivity analysis cases 17, 20 and 23 dBm/MHz EIRP limits (axis not 1:1)



## Rx overload calculations – Scenario 2

Scenario 2 studies considered the potential for interference from base stations that are perpendicular to the runway centreline within the transitional surface (refer to Figure 2). For a category I, code 1, 2 precision, instrument landing approach runway (Manual of standards 2019) the transitional surface begins along the side of the approach surface or runway strip and extends at a slope of 14.3% (equivalent to 8.14°) upwards until it reaches the inner horizontal surface. The length of the inner edge of the approach surface is 140 m.

As the aircraft is landing, the RA can be at different heights along the runway centreline. Therefore, for a worst-case geometry the required separation distance is the shortest distance from the base station to the runway centreline when the RA is at the same height as the base station.

For an inner-edge length of 140 m the shortest distance from the runway centreline to the transitional surface is 70 m. BS cannot be deployed within the transitional surface. The required separation distances for a PSD of 14 dBm/MHz and 17 dBm/MHz EIRP, as detailed in Table 2, are less than 70 m. As no obstacles (including BS) can be deployed within this area, there is no risk of interference into RAs.

## RA receiver overload study conclusions

Studies conducted assessed the risk of RA receiver overload from HL WBB transmitters operating in the 3950-4000 MHz band. The results show that, due to existing obstacle restrictions around airports, HL WBB devices will not overload RA receivers when the in-band power spectral density is limited to 17 dBm/MHz EIRP. Therefore, other than the in-band power spectral density limit, no mitigation measures are necessary to enable coexistence for this interference scenario.

# Rx desensitisation studies

Studies were conducted to assess the risk of RA receiver desensitisation from HL WBB unwanted emissions falling within the 4200-4400 MHz band. The intention of the studies was to understand when receiver desensitisation may occur and use the results to determine what (if any) regulatory measures may be required to manage it.

The RA receiver overload studies covered two scenarios:

Scenario 1: HL WBB located directly underneath an aircraft as it is landing

Scenario 2: HL WBB located perpendicular to the runway centreline.

In conducting these studies, the ACMA:

took into account existing obstacle deployment restrictions around airports (refer to the *Obstacles restrictions and limitations around airports* section for details).

used a similar methodology as for the [3.4 / 3.7 GHz spectrum licensing TLG package](https://www.acma.gov.au/spectrum-licence-technical-liaison-groups), *Coexistence between Radio Altimeters operating in 4200-4400 MHz and Wireless Broadband systems in 3400-4000 MHz* (the 2022 RA Coexistence Report);

considered HL WBB UEs as well HL WBB BS with and without AAS. When modelling AAS antennas, 100% correlation was assumed for the antenna pattern within the 4200-4400 MHz frequency range (worst case assumption). For HL WBB BSs using AAS, the same parameters as used in the ACMAs 2022 RA Coexistence Report were initially assumed for studies in this paper. The antenna parameters in that report (and resulting grating lobes) were based on an 8x8 antenna array resulting in a maximum in-band gain of 23-25 dBi. It is unclear if such antennas would be used for HL WBB deployments in the 3950-4000 MHz band, where we have proposed a maximum in-band EIRP of 34 dBm/50 MHz (based on the PSD of 17 dBm/MHz EIRP proposed within the HL WBB TLG);

considered three cases for HL WBB unwanted emissions within the 4200-4400 MHz band. As follows:

* Local Area BS[[11]](#footnote-12) unwanted emissions within the 4200-4240 MHz frequency range (with spurious emissions applying above 4240 MHz)
* Medium Range BS[[12]](#footnote-13) unwanted emissions within the 4200-4240 MHz frequency range (with spurious emissions applying above 4240 MHz )
* Spurious emission limits apply across the entire 4200-4400 MHz band (this aligns with the limits adopted for AWLs and 3.4 GHz band spectrum licences).

## HL WBB transmitter unwanted emissions

Table 3 provides a summary of the unwanted emissions used in studies for the different HL WBB transmitters. These are based on the unwanted emission limits defined in 3GPP technical specifications (TSs) 38.101-1 and 38.104. As there is a 200 MHz frequency separation between the 3950-4000 MHz and 4200-4400 MHz bands, the unwanted emissions modelled are either those defined for category B spurious emission limits or the value for operating band unwanted emissions at frequency offsets greater than 10 MHz from the operating channel edge.

For HL WBB BS with AAS, 9 dB is added to the 3GPP basic (per port conducted power) limit to derive a TRP level. As this represents the total power for all polarisations combined, 3 dB has been subtracted to obtain the level of unwanted TRP per polarisation.

For HL WBB BS with non-AAS, 4 port MIMO operation is assumed. To account for this, 6 dB is first added to the 3GPP basic limits, then 3 dB is subtracted to obtain the total conducted power per polarisation.

3GPP TS 38-101-1 only specifies unwanted emissions limits for UEs without AAS. For this reason, studies do not consider UEs with AAS.

HL WBB transmitter unwanted emissions

|  |  |  |  |
| --- | --- | --- | --- |
| Transmitter | 3GPP basic limits per antenna port[[13]](#footnote-14) | Non-AAS  Conducted power per polarisation | AAS  TRP per polarisation |
| Medium Range BS[[14]](#footnote-15) | -19 dBm/MHz  (-29 dBm/100 kHz) | -16 dBm/MHz | -13 dBm/MHz |
| Local Area BS[[15]](#footnote-16) | -27 dBm/MHz  (-37 dBm/100 kHz) | -24 dBm/MHz | -21 dBm/MHz |
| BS Spurious Emissions[[16]](#footnote-17) | -30 dBm/MHz | -27 dBm/MHz | -24 dBm/MHz |
| UE Spurious Emissions[[17]](#footnote-18) | -30 dBm/MHz | -30 dBm/MHz | N/A |

## Calculation methodology

The required path loss between a HL WBB transmitter and an RA to avoid RA receiver desensitisation can be calculated using the equation below.

(dB) – propagation loss between the HL WBB transmitter and RA

(dBm/MHz) – power into the antenna of the HL WBB BS

(dBi) – gain of the HL WBB antenna in direction of the RA

(dBi) – RA antenna gain in direction of HL WBB transmitter

(dB) – none (0 dB)

(dBm/MHz) – Interference Threshold Mask (ITM) value for UC 1 spurious emissions (RTCA report Figure 9-10).

Free space propagation loss (worst case) is assumed between the HL WBB transmitter and RA. The required separation distance can then be calculated using the equation below and rearranging to solve for *d*.

= 4200 MHz

## Rx desensitisation calculations – HL WBB BS with AAS

### Scenario 1 – HL WBB located under an aircraft

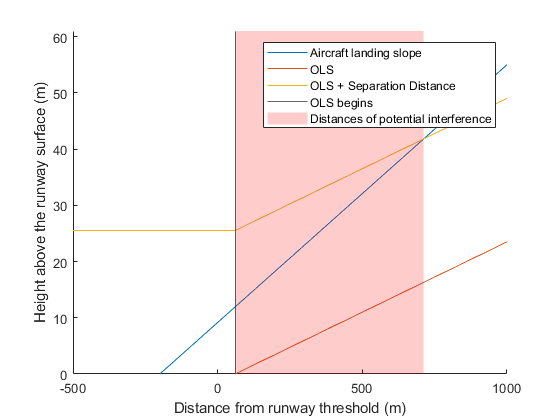
The calculated required separation distance between an RA and a HL WBB BS (using AAS), assuming WBB spurious emissions occurring at prescribed limits across the whole 4200–4400 MHz band, are provided in Table 4.

Calculation summary for HL WBB with AAS (RA Rx desensitisation case)

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Notes |
| Maximum Tx unwanted emissions – (total radiated power) per polarisation | -24 dBm/MHz | Refer to *HL WBB transmitter unwanted emissions* section (Table 3) |
| Maximum transmitter gain above the horizon, | 12 dBi | Assumes AAS with 12 dBi grating lobes (worst case level identified for use in studies associated with the [3.4/3.7 GHz bands public consultation](https://www.acma.gov.au/consultations/2023-02/draft-allocation-and-technical-instruments-3437-ghz-bands-auction)) |
| Radio altimeter net gain, | 5 dBi | RTCA Figure 6-12 of ~8 dBi less AVSI use of 3 dB cable loss |
| ITM Threshold (in 1MHz), | -80 dBm/MHz | RTCA Category 1 4.2–4.4 GHz band spurious limit at 50-200 ft |
| Required path loss | 73 dB | Calculation |
| Separation distance to achieve path loss | 25.5 m | Calculation using FSL with frequency 4200.5 MHz |

Figure 6 shows the geometry of an aircraft landing in a worst-case scenario when a potential HL WBB interferer is directly below it. Considering the OLS gradient in combination with the separation distance calculated, based on the HL WBB parameters used, the radio altimeter could potentially receive interference from unwanted emissions from a HL WBB base station at horizontal distances up to 712 metres from the runway threshold. The area highlighted in red shows the distances from the OLS threshold in which the aircraft landing slope is below the (OLS + 25.5 metre) separation distance boundary. This red zone occurs when an aircraft is at an altitude of 41.81 metres or less – which corresponds to a maximum object height of 16.3 metres or less.

Geometry of aircraft landing slope, HL WBB with AAS, RA Rx desensitisation case, OLS gradient and potential interference height (OLS + Separation Distance, axis not 1:1)



### Sensitivity analysis

The results in Table 4 (and shown in Figure 6) are based on the following parameters:

* HL WBB BS spurious emissions occur at the prescribed limit across the entire 4200-4400 MHz frequency range
* HL WBB BS have a 12 dBi grating lobe above the horizon that points directly at an RA.

A sensitivity analysis was conducted by varying these parameters to see what impact those variations would have on the required separation distance.

#### HL WBB BS unwanted emissions sensitivity analysis

The required separation distance calculation was repeated for a range of different unwanted emission levels. All other parameters remained the same. The results are summarised in Table 5.

Table 5 shows that the Local Area and Medium Range BS cases result in required separation distances of greater than 1130 metres. Beyond this distance, the aircraft altitude is above 200 ft (61 m) – at that point the ITM value used in the required separation distance calculations changes. Analysis for those cases has been included for comparison, but it needs to be noted that the ITM value that applies for RA operation below 200 ft has been used.

HL WBB BS – RA separation distance for different unwanted emissions

|  |  |  |  |
| --- | --- | --- | --- |
| Unwanted emissions TRP per polarisation | Separation distance (free space path loss) | Distance from runway threshold that interference can potentially occur | Maximum obstacle height |
| -30 dBm/MHz | 12.8 m | 101.6 m | 1.0 m |
| -27 dBm/MHz | 18.1 m | 354.6 m | 7.4 m |
| -24 dBm/MHz  (BS spurious emissions) | 25.5 m | 712 m | 16.3 m |
| *-21 dBm/MHz*  *(Local Area BS)* | *36 m* | *1216.9 m* | *28.9 m* |
| *-13 dBm/MHz*  *(Medium Range BS)* | *90.5 m* | *3830.4 m* | *94.3 m* |

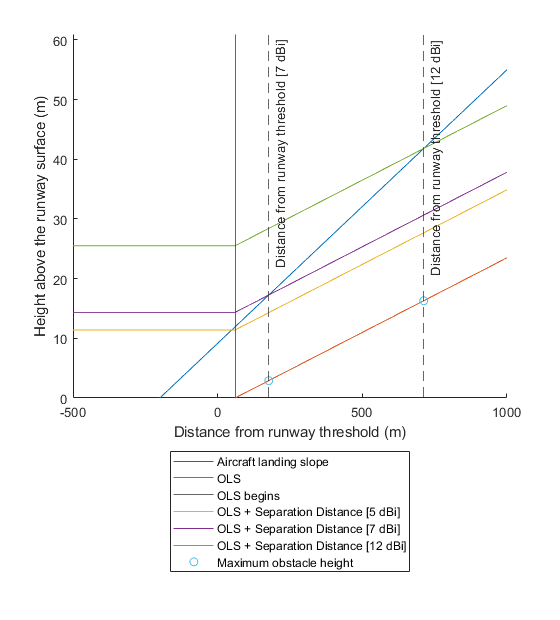
#### HL WBB BS antenna grating lobe sensitivity analysis

The required separation distance calculation was repeated for a range of different values of HL WBB antenna grating lobe gain above the horizon. All other parameters were unchanged. The results of that analysis are summarised in Figure 7 and Table 6. This includes results for the approach taken by the RTCA[[18]](#footnote-19) in paper No.274-20, which assumed a single element radiation pattern of 6.4 and 7.1 dBi.

HL WBB – RA separation distances for different grating lobe gains

|  |  |  |  |
| --- | --- | --- | --- |
| Grating lobe gain | Separation distance (free space path loss) | Distance from runway threshold within which interference could potentially occur | Maximum obstacle height |
| 3 dBi | 9.1 m | None | No obstacles allowed |
| 5 dBi | 11.4 m | 48.6 m | No obstacles allowed |
| 6 dBi | 12.8 m | 101.6 m | 1 m |
| 6.4 dBi (RTCA single element urban) | 13.4 m | 130.5 m | 1.8 m |
| 7 dBi | 14.3 m | 176.4 m | 2.9 m |
| 7.1 dBi (RTCA single element suburban/rural) | 14.5 m | 184.4 m | 3.1 m |
| 9 dBi | 18.1 m | 354.6 m | 7.4 m |
| 12 dBi | 25.5 m | 712.0 m | 16.3 m |

Geometry of aircraft landing slope for sensitivity analysis cases 5, 7 and 12 dBi grating lobe gains (axis not 1:1)



### Scenario 2 – HL WBB located perpendicular to the runway

Scenario 2 considered the potential for interference from a BS that is perpendicular to the runway centreline within the transitional surface (refer to Figure 2). In this case, the separation distances calculated for Rx desensitisation contained in Tables 5 and 6 also apply to this scenario.

As detailed in the *Obstacle restrictions around airports* section, the ORA runway strip for an instrument landing approach runway, with code 1, extends 70 m either side of the runway centreline and 60 m beyond the runway threshold. Results for the BS spurious emissions and Local Area BS do not exceed a separation distance of 70 m. Therefore, for those cases, there is no risk of interference as the ORA runway strip prevents BS from being deployed at the calculated separation distances.

In the case of a Medium Range BS, the required separation distance could extend beyond the ORA runway strip, so there could be potential for interference to occur. However, this would not be the case when the gain of the side lobes (or grating lobes) above the horizon is sufficiently low (in the order of a few dBi). This is investigated further in the *Potential mitigation measures* section of this paper.

## Rx desensitisation calculations – HL WBB BS with non-AAS

### Scenario 1 – HL WBB located under an aircraft

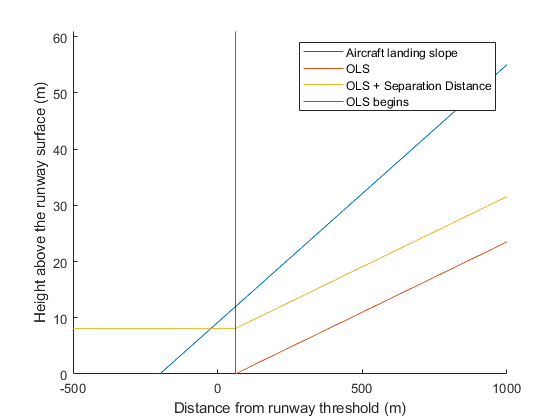
The results of calculations of the required separation distance between radio altimeters and HL WBB BS (non-AAS), assuming spurious emissions occurring at their limits across the whole 4200-4400 MHz band are provided in Table 7.

Calculation summary for HL WBB with non-AAS (RA Rx desensitisation case)

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Notes |
| Maximum Tx unwanted emissions – (total radiated power) per polarisation | -27 dBm/MHz | Refer to *HL WBB transmitter unwanted emissions* section |
| Maximum transmitter gain above the horizon, | 5 dBi | Example only. Maximum non-AAS BS antenna gain for a small cell (outdoor) in Annex 4.4 of WP5D/[716](https://www.itu.int/md/R19-WP5D-C-0716/en) |
| Radio altimeter net gain, | 5 dBi | RTCA Figure 6-12 of ~8 dBi less AVSI use of 3 dB cable loss |
| ITM Threshold (in 1MHz), | -80 dBm/MHz | RTCA Category 1 4.2–4.4 GHz band spurious limit at 50-200 ft |
| Required path loss | 63 dB | Calculation |
| Equivalent distance to achieve path loss | 8.1 m | Calculation using FSL with frequency 4200.5 MHz |

Figure 8 shows the geometry of the aircraft landing in a worst-case scenario where a potential HL WBB interferer is directly below it. An examination of the OLS gradient with the calculated separation distance added shows that a radio altimeter would not be at risk from unwanted emissions from a HL WBB base station (non-AAS) for the scenario considered. This is because the aircraft goes below the separation distance of 8.1 metres at 24 metres past the runway threshold, at which point the aircraft is over the runway (in the ORA runway strip) where no obstacles can be deployed.

Geometry of aircraft landing slope, HL WBB with non-AAS, RA Rx desensitisation case, OLS gradient and potential interference height (OLS + Separation Distance, axis not 1:1)



### Sensitivity analysis

The results in Table 7 (and shown in Figure 8) are based on the following parameters:

* HL WBB BS spurious emissions apply across the entire 4200-4400 MHz frequency range
* HL WBB BS have an antenna gain of 5 dBi above the horizon that is pointing directly at an RA.

A sensitivity analysis was conducted by varying the levels of unwanted emissions to see what impact those variations have on the required separation distance. An investigation of the effects of differing antenna gains (and associated EIRPs) are provided in the *Proposed mitigation measures* section.

#### HL WBB BS unwanted emissions sensitivity analysis

Calculation of required separation distance between a HL WBB BS and an RA receiver was repeated for a range of different unwanted emission levels. All other parameters were unchanged. The results are summarised in Figure 9 and Table 8.

Calculations for both the BS spurious emission and Local Area BS cases result in separation distances that are within the ORA runway strip where no obstacles can be deployed.

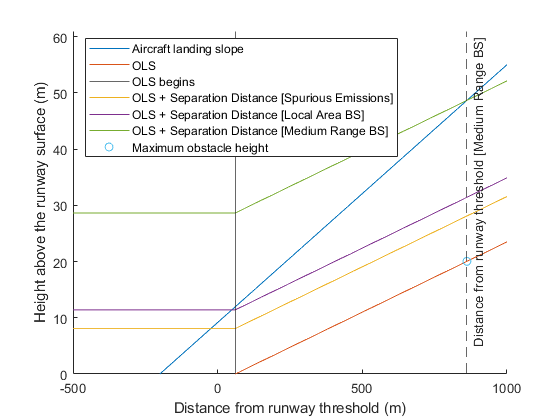
For the Medium Range BS case, for which a 5 dBi antenna gain above the horizon is assumed, interference can occur up to 861.3 m from the runway threshold. This correlates to an obstacle limitation height of 20 metres.

In the RTCA report, a 3 dB reduction in unwanted emission levels (termed a “frequency-dependant rejection” in the report) has been included to account for the lower relative base station antenna gain in the 4200-4400 MHz frequency range. Taking this 3 dB reduction in interference into account results in the calculated separation distance from a Medium Range BS coming down to 460.3m from the runway threshold, which correlates to an obstacle limitation height of 10 metres. Conversely, this means that, for the BS spurious emission and Local Area BS cases, the above-the-horizon antenna gain could be increased without exceeding the interference threshold. Further investigation of this scenario is provided in the *Potential mitigation to manage Rx desensitisation* section.

Example analysis for different non-AAS unwanted emissions limits

|  |  |  |  |
| --- | --- | --- | --- |
| Unwanted emissions limit conducted power per polarisation | Separation distance (free space path loss) | Distance from runway threshold that interference can potentially occur | Maximum obstacle height |
| -27 dBm/MHz  (Spurious Emissions) | 8.1 m | None | No obstacles allowed |
| -24 dBm/MHz (Local Area BS) | 11.4 m | 48.6 m | No obstacles allowed |
| -21 dBm/MHz | 16.1 m | 260.4 m | 5 m |
| -19 dBm/MHz (RTCA equivalent Medium Range BS calculation) | 20.2 m | 460.3 m | 10 m |
| -16 dBm/MHz (Medium Range BS) | 28.6 m | 861.3 m | 20 m |

Geometry of aircraft landing slope for sensitivity analysis spurious emissions, Local Area BS and Medium Range BS unwanted emissions limits (axis not 1:1)



### Scenario 2 – HL WBB located perpendicular to the runway

Scenario 2 studies considered the potential for interference from base stations that are perpendicular to the runway centreline within the transitional surface (refer to Figure 2). In this case, the separation distances calculated for Rx desensitisation contained in Table 8 also apply to this scenario.

As detailed in the *Obstacle restrictions around airports* section, the ORA runway strip for an instrument landing approach runway with code 1,2 extends 70m either side of the runway centreline, and 60 m beyond the runway threshold. As shown in Table 8, none of the separation distances calculated for the BS spurious emissions, Local Area BS and Medium Range BS scenarios exceed 70 m. It follows that when HL WBB BS above-the-horizon antenna gain does not exceed 5 dBi, there is no risk of interference occurring, since the ORA runway strip prevents BS from being deployed within the calculated separation distances.

An investigation of the effects of different antenna gains (and associated EIRPs) on separation distances is provided in the *Proposed mitigation measures* section.

## Rx desensitisation calculations – HL WBB UEs

### Scenario 1 – HL WBB UEs located under an aircraft

A calculation of the required separation distance between RAs and HL WBB UEs (which includes all devices that communicate with a HL WBB BS) is provided in Table 9. A typical WBB UE antenna gain has been assumed to represent common use cases, however a sensitivity analysis was also conducted (see below) to assess the risk of interference where higher antenna gains towards an RA might occur.

Calculation summary for HL WBB UEs (unwanted emissions case)

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Notes |
| Maximum Tx unwanted emissions – (total radiated power) per polarisation | -30 dBm/MHz | 3GPP spurious emission limits for user equipment |
| Transmitter gain above the horizon, | -4 dBi | Typical antenna gain for user equipment in Annex 4.4 of WP5D/[716](https://www.itu.int/md/R19-WP5D-C-0716/en) |
| Radio altimeter net gain, | 5 dBi | RTCA Figure 6-12 of ~8 dBi less AVSI use of 3 dB cable loss |
| ITM Threshold (in 1MHz), | -80 dBm/MHz | RTCA Category 1 4.2–4.4 GHz band spurious limit at 50-200 ft |
| Required path loss | 51 dB | Calculation |
| Equivalent distance to achieve path loss | 2.03 m | Calculation using FSL at 4200.5 MHz |

The calculated separation distance in Table 9 is sufficiently small that, for the case considered, the risk of interference from user equipment can be considered is negligible. These results equally apply to Scenario 2 where the WBB UE is located perpendicular to the runway centre.

### Sensitivity analysis

The calculations in Table 9 were repeated to assess the impact on separation distances from increasing antenna gains. As the restrictions within the OLS do not apply to UEs, it was assumed UEs are operating at a height of 2 metres above the ground. This height was applied in combination with the calculated separation distance to determine the distance from the runway threshold that interference could occur to an RA from a UE. The results of this sensitivity analysis are provided in Table 10.

The results show that a UE with an antenna gain towards an RA greater than 6 dBi could potentially cause interference to an RA. However, this would only occur if the UE was operating within the ORA runway strip with direct line of sight to the RA. As this is a controlled space at airports, it is considered that site management arrangements would mitigate the issue.

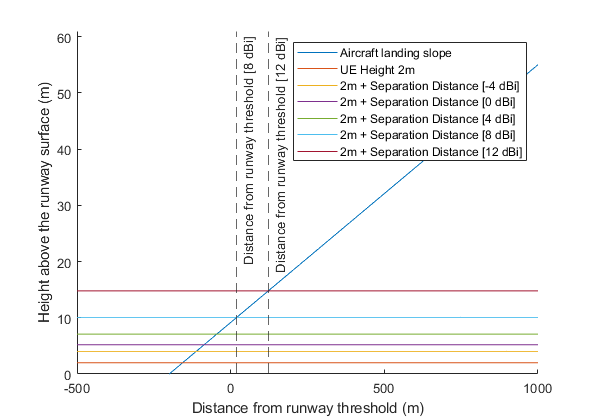
The minimum UE gain for which interference could occur within the OLS area (greater than 60 m distance from the runway threshold) is 10 dBi, as shown in Figure 10. This is also based on an assumption that the UE is operating at maximum power. However, in practice, due to power control, UEs will typically operate at lower power levels, which further reduces the risk. Furthermore, as indicated in the RTCA report and as discussed when considering the HL WBB (non-AAS) potential interference scenario, an additional 3 dB of margin could be considered to account for the lower effective antenna gain within the 4200-4400 MHz frequency range.

Additionally, the maximum in-band emission limit proposed for HL WBB systems places a practical limit on the maximum UE antenna gain. 3GPP TS 101-1 specifies a maximum power of 23 dBm per occupied bandwidth for power class 3 terminals in the 3400-4200 MHz band. The maximum in-band EIRP proposed for a HL WBB transmitter is 34 dBm/50 MHz (17 dBm/MHz EIRP) within 3950-4000 MHz band. This results in a maximum antenna gain of 11 dBi for a HL WBB UE operating at maximum power. When the 3 dB RTCA margin is taken into account, it can be concluded that a HL WBB UE operating outside the ORA runway strip will not cause interference to an RA.

Calculations of separation distances for different UE antenna gains

|  |  |  |
| --- | --- | --- |
| UE Antenna gain towards RA | Separation distance (free space path loss) | Distance from runway threshold that interference can potentially occur |
| -4 dBi | 2.0 m | None |
| 0 dBi | 3.2 m | None |
| 3 dBi | 4.5 m | None |
| 6 dBi | 6.4 m | None |
| 7 dBi | 7.2 m | 0.5 m |
| 8 dBi | 8.1 m | 19.6 m |
| 9 dBi | 9.1 m | 41.1 m |
| 12 dBi | 12.8 m | 122.5 m |

Geometry of aircraft landing slope, HL UE with different antenna gains, potential interference height (2m + Separation Distance, axis not 1:1)



## Rx desensitisation study conclusions

The studies presented in this paper include an assessment of the risk of RA receiver desensitisation from HL WBB transmitters operating in the 3950-4000 MHz band. The results show that:

* Interference from HL WBB BS with and without AAS will not occur when the BS antenna gain above the horizon is sufficiently low. The level of antenna gain towards the RA for which interference may occur depends on the level of unwanted emissions within the 4200-4400 MHz band from the BS. A Medium Range BS using AAS represents the highest interference risk, where a relatively low BS antenna gain towards the RA (in the order of a few dBi) could cause interference. BS spurious emissions and BS with non-AAS represent a lower risk case. They can support higher antenna gains, in the order of 10 dBi, before there is a chance of interference occurring. The relative effect of changing unwanted emissions and antenna gains (in the form of EIRP) is considered further in the next section, which contains a description of possible mitigation measures.
* The risk of interference to RAs from HL WBB UEs is considered low due to their low operating power, use of power control and typically low antenna gains. There is some risk of interference occurring at small separation distances and/or for higher gain terminals. However, this is limited to operation from locations where the deployment of obstacles is prohibited by legislation. Access to these areas is controlled by airports, so site management arrangements could be put in place to manage the issue. This could include, for example, restricting the access of user terminals that can connect to HL WBB networks in these areas.

# Proposed mitigation measures

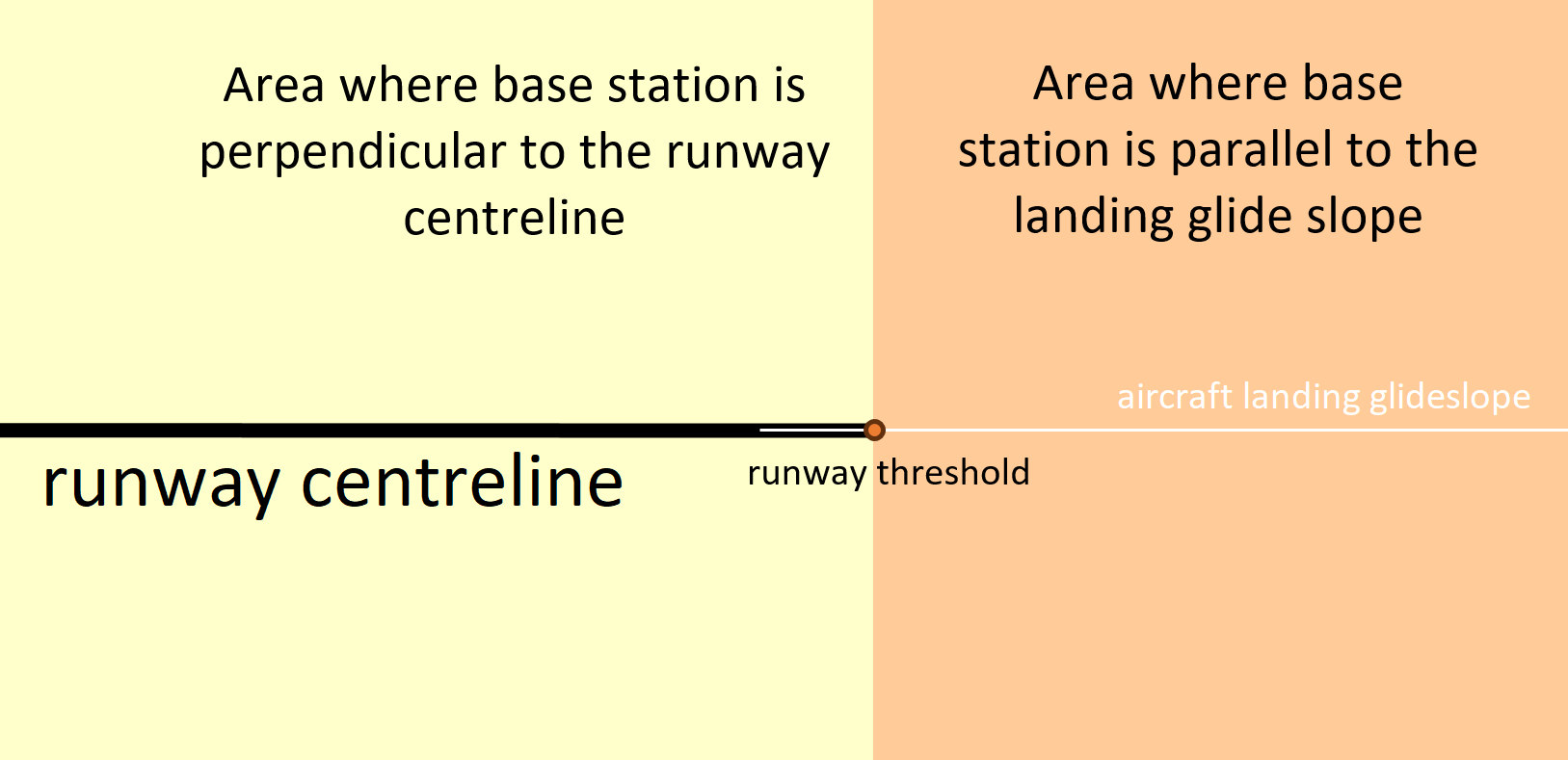
Results of the Rx desensitisation studies detailed in the previous section show that the risk of interference to RAs from HL WBB is dependent upon the combination of unwanted emissions and antenna gains towards an aircraft assumed in the 4200-4400 MHz range. Consequently, in this section, we focus on translating HL WBB BS unwanted emissions to EIRP values within the 4200-4400 MHz range to inform the development of possible mitigation measures to enable coexistence with RAs.

In line with this, it is proposed that a HL WBB BS must meet an in-band EIRP limit[[19]](#footnote-20) and a prescribed unwanted emissions EIRP limit (EIRPlim) within a defined area (referred to as a restricted zone). Operators then have flexibility as to how they meet these conditions. This approach avoids restricting the operation of HL WBB BS to certain base station types or locations.

In developing the proposed mitigation measures, two cases are considered (as shown in Figure 11):

* the area a HL WBB BS is parallel to the landing glideslope (including under the glide slope); and
* the area a HL WBB BS is not parallel to the aircraft landing glideslope but is perpendicular to the runway centreline.

Diagram of the two cases around the runway



Equations for EIRPlim for the two cases detailed in Figure 11 are provided below. These are based on the runway scenario Category I code 1, 2. = 2.5% slope, which is the worst-case scenario. Details on the derivation of these equations is provided at Appendix A.

*Unwanted emissions EIRP limit – for BS located parallel to the landing glide slope*

(dBm/MHz) – unwanted emissions EIRP limit at angle (degrees) with respect to the horizon

(metres) – maximum height of the base station at height allowed by the OLS

*Unwanted emissions EIRP limit – for BS located perpendicular to the runway centreline*

(dBm/MHz) – unwanted emissions (EIRP) limit at angle (degrees) with respect to the horizon

(metres) – maximum height of the base station at height allowed by the OLS

(degrees) – OLS slope which rises at a rate of 14.3%.

The following sections contain further work to simplify these equations and define an area (referred to as a restricted zone) that they are proposed to apply within.

### Defining the area EIRPlim applies

The proposed maximum in-band EIRP for HL WBB in the 3950-4000 MHz band is a radiated power spectral density limit of 17 dBm/MHz. When this is applied to the largest possible bandwidth of a device (50 MHz) it results in a maximum in-band EIRP of 34 dBm/50 MHz. In practice, this will place a limit on the antenna gain that can be applied to a HL WBB BS. This information can then be used to define the area around airports where RA desensitisation may occur and EIRPlim should apply, referred to as the ‘restricted zone’.

The unwanted emissions limits within the operating band modelled for Medium Range BSs are those that relate to a BS with a transmitter power of 31 dBm or lower per occupied bandwidth, as defined in 3GPP Technical Specification 38.104. If we assume that a Medium Range BS is operating at its maximum transmitter power, then the maximum antenna gain will be 3 dBi (including losses). Similarly, for Local Area BS, the output power limit is 24 dBm per occupied bandwidth, which translates to a maximum antenna gain of 10 dBi (including losses) when operating at peak power.

These antenna gain values can be combined with the unwanted emission limits detailed in the *HL WBB transmitter unwanted emissions* section to determine the highest likely unwanted emissions radiated (EIRP) per polarisation for the different BS types for both AAS and non-AAS cases. These EIRP values are presented in Table 11.

As discussed in the sensitivity analysis part of *Rx overload calculations – Scenario 1* section, the RTCA report also assumed an additional frequency dependent rejection of 3 dB. This accounts for the lower effective BS antenna gain within the 4200-4400 MHz frequency range that results from the antenna systems not being optimised for that frequency range. This factor is included in calculations to determine the highest likely unwanted EIRP, as it is the antenna gain within the 4200-4400 MHz band that contributes to the amount of interference. .

1. Highest likely radiated unwanted emissions expressed as EIRP per polarisation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Base station unwanted emission case | Unwanted emissions limit TRP per polarisation | Maximum allowable antenna gain | Frequency dependent rejection[[20]](#footnote-21) | EIRP per polarisation |
| Medium Range  AAS[[21]](#footnote-22) | -13 dBm/MHz | 3 dBi | 3 dB | -13 dBm/MHz |
| Medium Range  non-AAS | -16 dBm/MHz | 3 dBi | 3 dB | -16 dBm/MHz |
| Local Area AAS | -21 dBm/MHz | 10 dBi | 3 dB | -14 dBm/MHz |
| Local Area non-AAS | -27 dBm/MHz | 10 dBi | 3 dB | -20 dBm/MHz |
| Spurious emissions AAS Medium Range | -24 dBm/MHz | 3 dBi | 3 dB | -24 dBm/MHz |
| Spurious emissions non-AAS Medium Range | -27 dBm/MHz | 3 dBi | 3 dB | -27 dBm/MHz |
| Spurious emissions AAS Local Area | -24 dBm/MHz | 10 dBi | 3 dB | -17 dBm/MHz |
| Spurious emissions non-AAS Local Area | -27 dBm/MHz | 10 dBi | 3 dB | -20 dBm/MHz |

Table 11 shows that the highest likely unwanted emissions radiated are ‑13 dBm/MHz EIRP per polarisation. This corresponds to the Medium Range BS with AAS case. It is questionable whether a practical AAS system could produce such a low antenna gain. Due to the restriction on maximum antenna gain, it is possible AAS may not be used for HL WBB systems. However, in the absence of any alternative information, it is assumed HL WBB BS with AAS will be deployed in this report as it represents the worst case interference scenario.

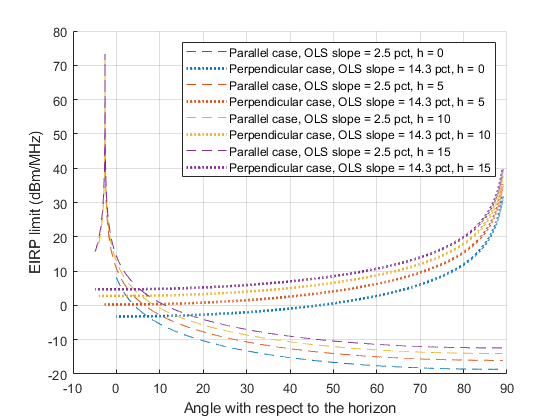
Figure 12 plots EIRPlim for both the perpendicular to the runway and parallel to landing glide scope cases. This figure shows that for the perpendicular case, EIRPlim does not go below ‑3.3 dBm/MHz EIRP. This is nearly 10 dB higher than the highest likely EIRP for the Medium Range BS using AAS, so emissions from this equipment will never reach that limit. Consequently, no restriction zone is required to manage interference in the area perpendicular the runway centreline.

This is not the case for the area parallel to the landing glide slope – so a restricted zone is required. The dimensions of the restricted zone, are defined as follows:

* the distance from the runway threshold (when BS is directly under the RA) -parallel case; and
* the width either side of the glide slope (when the BS is parallel to the glide slope but not directly under the RA) – perpendicular case.

Figure 13 depicts how the dimensions of the restricted zone are defined with respect to a runway. Calculations to determine the size of the required restricted zone are based on the Medium Range BS case.

Example EIRP limit at angles with both parallel and perpendicular cases



Dimensions of the restricted zone

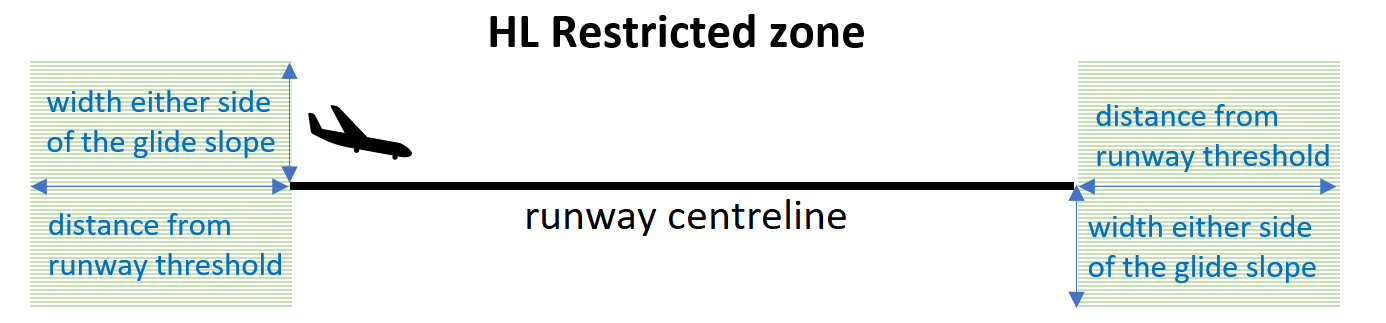
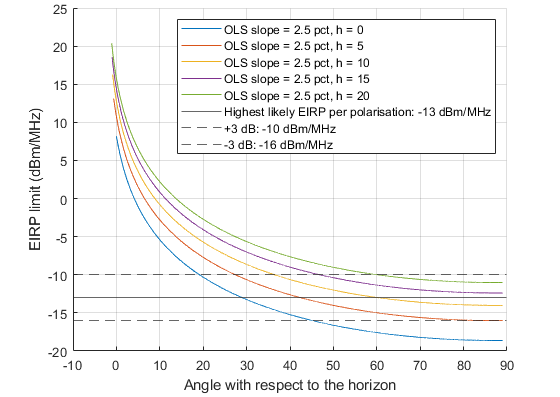
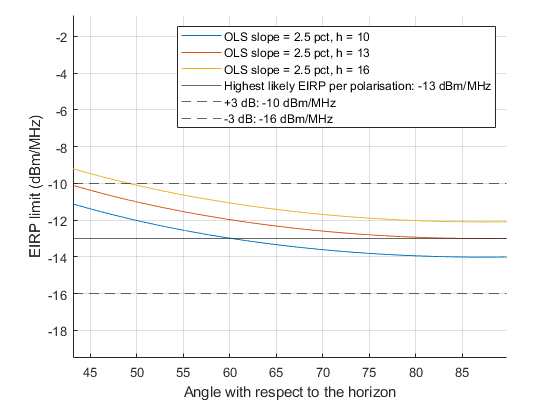


Figure 14 contains a plot of the EIRPlim (parallel to the landing glide slope) of a BS with unwanted emissions of -13 dBm/MHz EIRP at multiple heights above ground level. The results show that interference into an RA could occur for BS heights lower than or equal to 13 metres. For BS that are higher than 13 metres, the OLS restrictions will ensure they will not exceed the ITM PSD at the RA.

A BS height of 13 metres and unwanted emission of -13 dBm/MHz EIRP are assumed in the following sections in determining the extents of the proposed restricted zone.

Plots of EIRPlim against angles (parallel to the landing glideslope) for different BS heights





*Restricted zone –horizontal distance from the runway*

The horizontal distance from the runway that the restricted zone should cover is determined by the first point along the OLS where an obstacle of 13 metres is permitted. This corresponds to a distance of 576 m from the runway threshold. It is proposed to round this up to 600 m when defining the restricted zone to provide for a small margin of error when calculating locations with respect to the runway threshold.

As a sensitivity analysis, Table 12 shows the required horizontal distance from the runway threshold for a range of different EIRPs per polarisation. This table shows that no restricted zone is required for the BS spurious emission case (both AAS and non-AAS) and Local Area BS non-AAS case. This is because the highest likely unwanted emissions (EIRP) for these cases, as shown in Table 11, are less than -18.6 dBm/MHz EIRP. The ORA runway strip area, where no obstacles can be deployed, is sufficiently large to enable co-existence in these cases.

Table 12 also shows what the dimensions of a restricted zone would be if the proposed maximum in-band EIRP limit for HL WBB in the 3950-4000 MHz band were to make AAS impractical. In that case, the maximum unwanted emissions (EIRP) would apply the Medium Range BS with non-AAS case – which equates to -16 dBm/MHz EIRP per polarisation.

*Restricted zone –width either side of landing glide slope*

The width either side of the glide scope is calculated based on the required separation distance between a BS operating at -13 dBm/MHz EIRP and an RA. Applying the same methodology used in producing the figures in Table 1, with the RA gain and ITM threshold values from the desensitisation study, results in a calculated separation distance of 45.4 metres. In practice, the horizontal distance between a BS and RA would be smaller than this – as the aircraft is always higher than the BS in the OLS zone. However, as the distance is relatively small, it is used as the basis to define the width either side of landing glide slope for the restricted zone. It is proposed to round this up to 50 m in defining the restricted zone.

1. Dimensions of restricted zone based on the likely highest operating unwanted emissions (EIRP) of a BS

|  |  |  |  |
| --- | --- | --- | --- |
| Highest EIRP per polarisation | Base station height | Length from the runway threshold | Width either side of landing glide slope |
| -7 dBm/MHz | 40.2 m | 1668 m | 90.5 m |
| -10 dBm/MHz | 24.3 m | 1032 m | 64.1 m |
| -13 dBm/MHz | 12.9 m | 576 m | 45.4 m |
| -16 dBm/MHz | 5.1 m | 264 m | 32.1 m |
| -18.6 dBm/MHz | None | None | None |

*Restricted zone – elevation angles EIRPlim applies*

Figure 14 shows that the minimum angle that a BS with unwanted emissions of ‑13 dBm/MHz EIRP in the 4200-4400 MHz band can operate before causing interference to an RA is 28.5° (note: the minimum angle is 45° if AAS is not considered practical). While this corresponds to a BS height of 0 metres, which is impractical, it is used to provide a lower bound for EIRPlim calculations.

*Restricted zone – HL WBB BS located indoors*

As shown in Table 12, for BS limited to unwanted emissions of -13 dBm/MHz EIRP in the 4200-4400 MHz band, an additional 5.6 dB of losses would remove any need for a restricted zone (note: only 2.6 dB of additional loss would be required if AAS is not considered practical). Consequently, additional consideration is provided for HL WBB BS located indoors.

Recommendation ITU-R[[22]](#footnote-23) P.2109 *Prediction of building entry loss* (P.2109) provides guidance on methods for estimating building entry loss at frequencies between 80 MHz and 100 GHz. From reciprocity, the numerical value of building exit loss is the same as building entry loss. The model in P.2109 is based on data collated in Report ITU-R P.2346 for the frequency range 80 MHz to 73 GHz and is validated for probabilities between 1-99%. While it is a generic model, it provides useful insight into the level of building penetration loss that may apply.

At 4 GHz, the median building penetration loss for a 28.5° elevation from a HL WBB transmitter to an RA is approximately 19 dB and 33.5 dB for traditional and thermally efficient buildings, respectively. The probability of building loss being less than 5.6 dB at a 28.5° elevation is 4.0% and 0.42% for traditional and thermally efficient buildings, respectively (for 2.6 dB loss it is 0.55% and 0.1% respectively which applies to the 45 degree elevation case). These probabilities decrease as the elevation angle from a HL WBB transmitter to an RA increases.

Given that building penetration losses of 5.6 dB or more cannot be guaranteed for a low enough percentage of cases, it is proposed that they only be considered on a case-by-case basis. When assigning indoor HL WBB BS, licence applicants (or accredited persons) may apply to the ACMA to have building penetration losses considered. Such a request should include information detailing the level of building penetration loss and how this was determined. If the building penetration losses are greater than or equal to 5.6 dB then no additional mitigation measures will be required.

### Simplifying EIRPlim equations

It is proposed to base the equation (parallel to the landing glide scope) on the distance from the runway threshold/centreline, rather than the OLS height. Note that while there are definitions for OLS surfaces, the sizes, slope angles and applicability of these can vary for different runway types. To simplify calculations, the equations consider the worst-case slope (2.5% for Category I Code 1, 2).

For a BS of a given height (h) parallel to the aircraft landing glide slope, the minimum horizontal distance from the runway threshold that the BS can be located is calculated by re-arranging the equation below to solve for x:

(metres) – maximum height of the base station at height allowed by the OLS

(metres) – parallel distance from the runway threshold (parallel to the runway centreline)

For a BS of a given height (h) perpendicular to the runway centreline (along the runway but not parallel to the aircraft landing glide slope), the minimum horizontal distance from the runway centreline where the BS can be located is calculated by re-arranging the equation below to solve for x:

(metres) – maximum height of the base station at height allowed by the OLS

(metres) – distance from the runway centreline

These terms are incorporated into the final EIRPlim (parallel to the landing glide scope) equation presented in the next section.

### Summary of proposed mitigation measures

Mitigation measures proposed for different HL WBB transmitters to facilitate coexistence with RAs are as follows:

* HL WBB UEs: Interference potential from UEs can be mitigated using site management arrangements implemented by airports.
* HL WBB BS:
* When assigning indoor HL WBB BS, licence applicants (or their accredited persons) may apply to the ACMA to have building penetration losses considered. Such a request should include suitable information detailing the level of building penetration loss and how this was determined. If the building penetration losses are greater than or equal to 5.6 dB, then no additional mitigation measures will be required;
* No additional mitigation measures are required for BS that meet category B spurious emission limits (as defined by 3GPP) across the entire 4200-4400 MHz band;
* For BS that meet Local Area and Medium Range BS unwanted emission limits (as defined by 3GPP), a small restricted zone is proposed around airports[[23]](#footnote-24). The restricted zone extends no more than 600m from the runway threshold and 50m from the runway centreline – refer to Figure 15. Within the ‘HL restricted zone’, HL WBB BS unwanted emissions falling within the 4200-4400 MHz band must not exceed the relevant (dBm/MHz) value determined by the equation below.

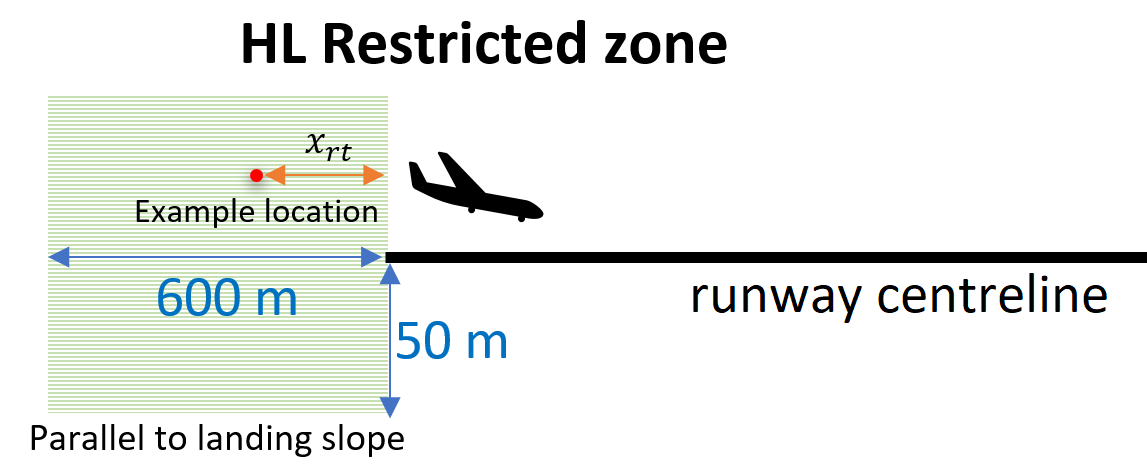
*Unwanted emissions EIRP limit – for BS located parallel to the landing glide slope*

(dBm/MHz)

(dBm/MHz) – unwanted emissions EIRP limit within the 4200-4400 MHz frequency band at angle (degrees) with respect to the horizon

(metres) –distance from the runway threshold (parallel to the runway centreline)

Diagram of the HL Restricted zone with example distance (xrt) for calculating EIRPlim

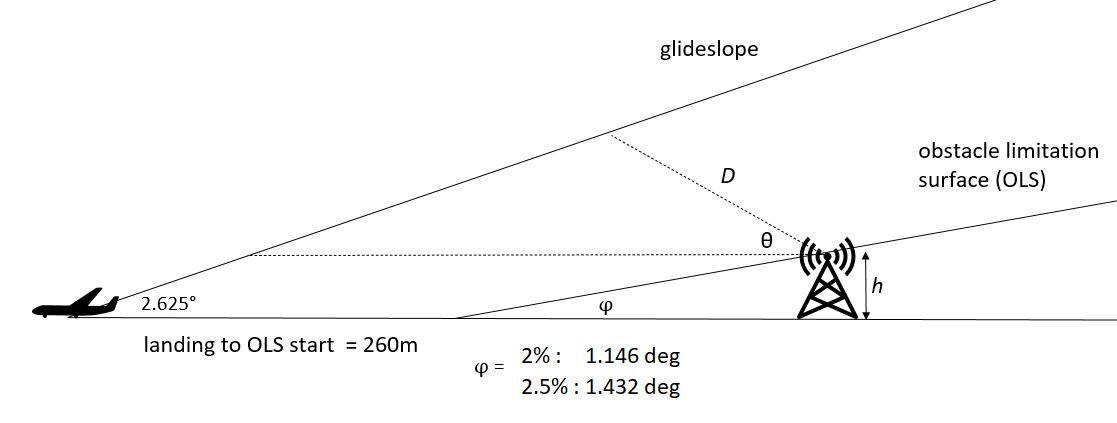


# Appendix A: EIRP limit derivation

## Derivation of proposed unwanted emissions EIRP limit equation – parallel to the landing glide scope

This section provides details of how the equation for the unwanted emissions EIRP limit was derived for the case of HL WBB BS located parallel to the landing glide scope. Figure 16 provides the geometry of this case.

Geometry of aircraft landing glideslope (not to scale)



A formula for the distance *D* from a base station of height *h* to the aircraft landing slope at θ degrees with respect to the horizon can be derived:

(metres) – distance from the base station to aircraft landing slope at angle (degrees) with respect to the horizon

(metres) – maximum height of the base station allowed by the OLS

(degrees) – OLS slope which can be 2% or 2.5%, depending on the category runway

The derivation of the above equation is provided in Appendix B. Note that, while the formula incorporates the maximum permitted base station height, the distance between the BS and the runway can also be used with some substitution.

The method for calculating of the required separation distance in for the HL WBB BS studies in the *RA receiver overload studies* section is used here, with the path loss calculated from the formula for *D*, to determine the resulting unwanted emissions EIRP () equation:

(dBm/MHz) – unwanted emissions (EIRP) limit at angle (degrees) with respect to the horizon

(metres) – maximum height of the base station at height allowed by the OLS

(degrees) – OLS slope which can be 2% or 2.5% depending on the category runway

This can be simplified to:

Category I, II & III code 3, 4. = 2% slope

Category I code 1, 2. = 2.5% slope

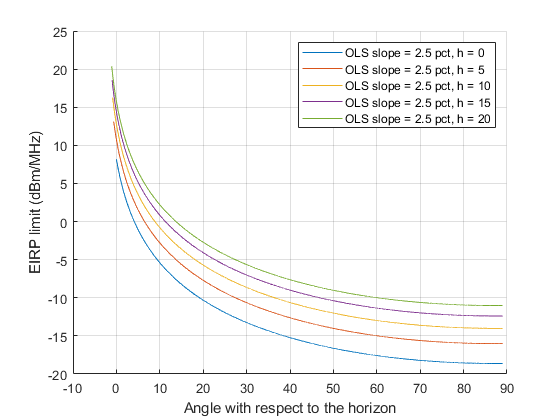
The above formulae have been used to produce unwanted emission EIRP limits for angles with respect to the horizon for a base station of height *h*. It has been assumed that a base station with height *h* is in the worst-case position allowed by the OLS. Therefore, if such a base station meets the limit derived above, it will also meet it anywhere else around the runway (parallel to the landing glideslope).

Note that a negative value of can exist and implies a limit below the horizon is also required. The starting angle below the horizon is the calculated angle of depression from the base station height to the touchdown point of the aircraft.

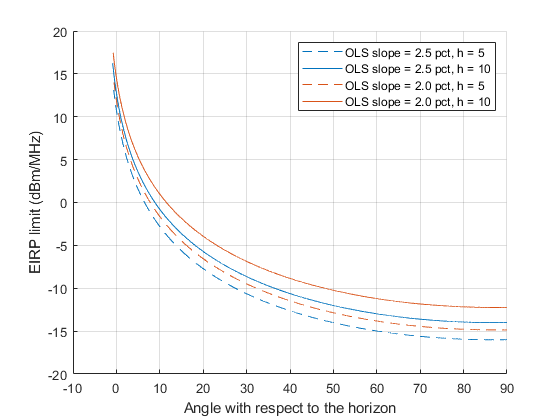
Figure 17 displays the unwanted emissions EIRP limit for the Category 1 code 1, 2.  = 2.5% slope. This figure shows that the strictest EIRP curve corresponds to a 0 m height reference base station with an unwanted emission EIRP limit approaching -18.6 dBm/MHz at high angles with respect to the horizon. The limit decreases as the base station height increases, due to the OLS restrictions moving the base station further away from the runway threshold and landing glideslope.

A comparison of unwanted emissions EIRP limit curves for the 2% slope and 2.5% slope is provided in Figure 18. This figure shows a stricter curve for the 2.5% slope, as the higher slope allows base stations of the same height to be positioned closer to the runway. Therefore, it is proposed that mitigations be based on the 2.5% slope.

Example unwanted emissions EIRP limit at angles (parallel to the landing glideslope) 2.5% OLS slope



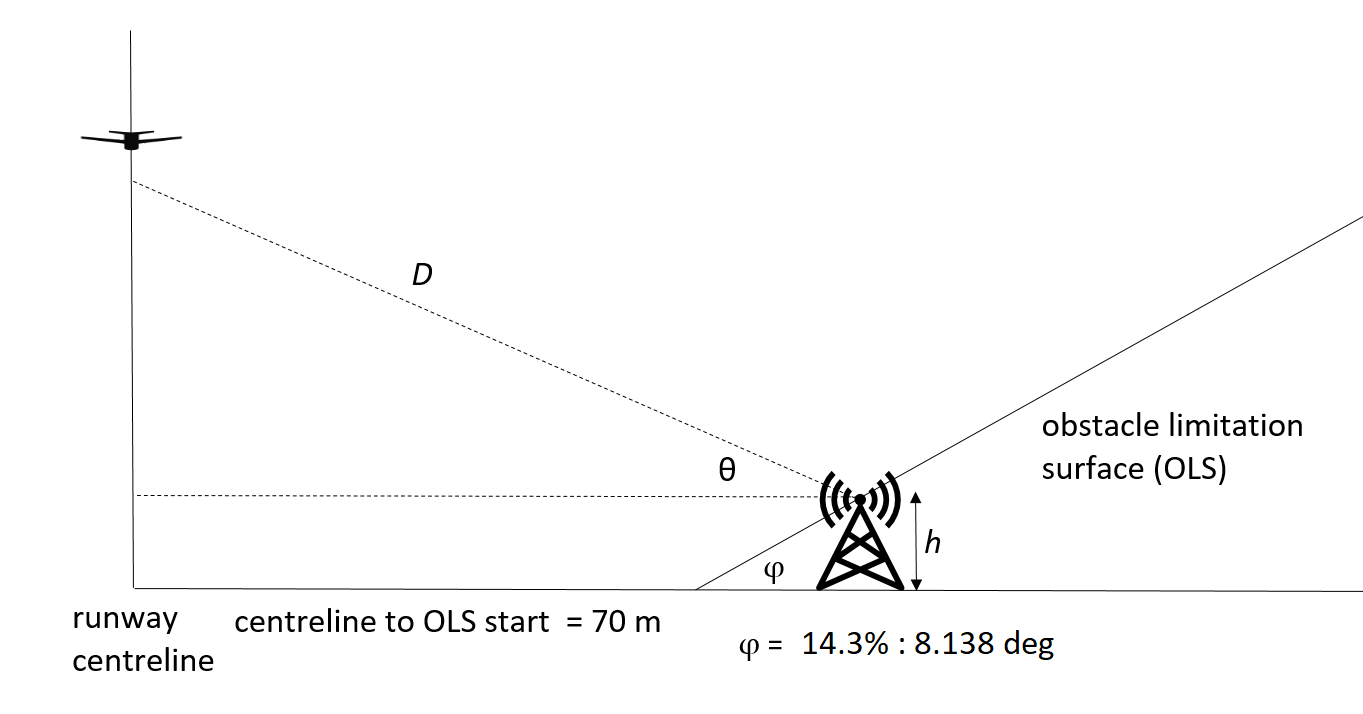
Example unwanted emissions EIRP limit at angles θ (parallel to the landing glideslope) 2% and 2.5% slope comparison



## Derivation of proposed unwanted emissions EIRP limit equation – perpendicular to the runway centreline

This section provides details of how the equation for the unwanted emissions EIRP limit was derived for the case of HL WBB BS located perpendicular to the runway centreline. Figure 19 provides the geometry of this case.

Geometry of aircraft landing perpendicular to runway centreline (not to scale)



The calculations in the *Rx desensitisation calculations – HL WBB BS with AAS* section showed that there is a risk of interference from HL WBB with AAS perpendicular to the runway within the transitional surface (beyond 70m form the runway centreline). This applied to the Medium Range BS with reasonably high antenna gains (including 12 dBi grating lobes gains).

As the aircraft is landing the height of the radio altimeter can be at any altitude on the runway centreline. Therefore, for a worst-case geometry, the required separation distance is the shortest horizontal distance from the base station to the runway centreline when the RA is the same height as the base station.

For an inner edge length of 140 m the shortest distance from the runway centreline to the transitional surface is 70 m, noting that this would occur at 0 m above ground level where a base station could not be realistically deployed. The transitional surface begins at the side of the approach surface and slopes upward at a rate of 14.3%.

A formula for the distance *D* from a base station of height *h* to the runway centreline (at any altitude) at θ degrees with respect to the horizon can be derived:

(metres) – distance from the base station to runway centreline (at any altitude) at angle (degrees) with respect to the horizon

(metres) – maximum height of the base station at height allowed by the OLS

(degrees) – OLS slope which is 14.3%

The method for calculating the required separation distance in for the HL WBB BS studies in the *RA receiver overload studies* section has been used here, with the path loss calculated using the formula for *D*, to determine the resulting unwanted emissions EIRP () equation:

(dBm/MHz) – unwanted emissions EIRP limit at angle (degrees) with respect to the horizon

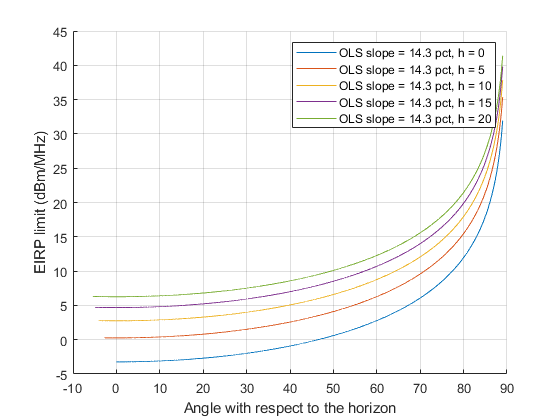
(metres) – maximum height of the base station at height allowed by the OLS

(degrees) – OLS slope which is 14.3%

The above formula is used to calculate the unwanted emissions EIRP limit for angles with respect to the horizon for a base station of height *h*. It has been assumed that a base station with height *h* is in the worst-case position allowed by the OLS. Therefore, if such a base station meets the EIRP limit derived above, it will also meet it anywhere else perpendicular to the runway centreline.

Note that that a negative value of can exist and implies a limit below the horizon is required. The starting angle below the horizon is the calculated angle of depression from the base station height to runway centreline on the ground.

Example unwanted emissions EIRP limit at angles (perpendicular to the runway centreline)



The EIRP curves provided in Figure 20 show that as the height of the base station increases, the EIRP limit relaxes, as the OLS requirement moves the base station further away from the runway centreline.

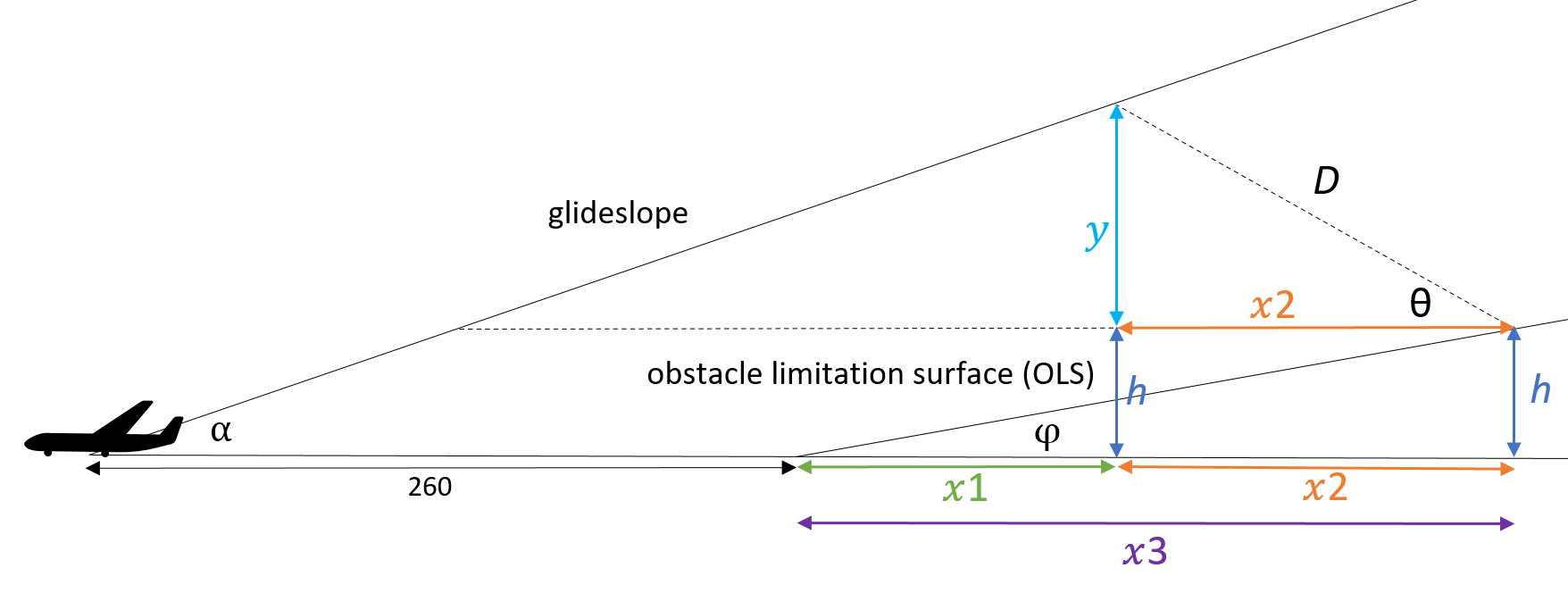
Unlike the parallel case, there is no aircraft landing slope over the base station, therefore as the angle with respect to the horizon increases the distance to the runway centreline increases, resulting in higher EIRP levels.

# Appendix B: Additional derivations

## Derivation of distance from base station to aircraft landing glideslope

The geometry of an aircraft landing with respect to the OLS is provided in Figure 21. This is used to derive the distance between a base station (located on the OLS) and an aircraft following the glideslope.

Dimensions of aircraft landing slope and OLS



(1)

(2)

(3)

(4)

(5)

Substitute equations (4) and (5) into (3):

(6)

Substitute equations (2) and (6) into (1):

## Converting distance to EIRP limit

(7

(dB) – free space path loss between the WBB base station and the radio altimeter

(dBm/MHz) – power into the antenna of the WBB base station

(dBi) – gain of the WBB antenna in direction of the radio altimeter

(dBi) – radio altimeter antenna gain in direction of WBB base station

(dB) – none (0 dB)

(dBm/MHz) – Interference Threshold Mask (ITM) value for UC 1 spurious emissions (RTCA report Figure 9-10).

The path loss distance is calculated using the below formula rearranged to solve for the distance:

(8)

= 4200 MHz

Let equation (7) == (8):

= 5 dBi, = -80 dBm/MHz

Distance *d* defined in km units to convert to m units subtract 60 dB:

1. Refer to Chapter 7 of [Part 139 (Aerodromes) Manual of Standards 2019](https://www.legislation.gov.au/F2019L01146/latest/text) [↑](#footnote-ref-2)
2. The list of airports to which the restricted zone applies is intended to be the same as those defined for 3.4 GHz spectrum licences and area-wide licences. [↑](#footnote-ref-3)
3. [Federal Register of Legislation - Part 139 (Aerodromes) Manual of Standards 2019](https://www.legislation.gov.au/F2019L01146/latest/text) [↑](#footnote-ref-4)
4. A receiver front end is a generic term for the circuitry between a receiver’s antenna input up to and including the mixer stage. Band pass filters (if any), low noise amplifiers and local oscillators also form part of the front end. The receiver front end processes a signal from an antenna into an intermediate frequency that is more easily handled by the rest of the receiver. [↑](#footnote-ref-5)
5. A performance mask derived by the Aerospace Vehicle Systems Institute (AVSI) taking the worst-case interference tolerance threshold measured across several altimeter models. [↑](#footnote-ref-6)
6. [Actions taken in France to mitigate interference into the radio altimeters systems from 5G/MFCN in the band 3.4-3.8 GHz](https://www.icao.int/safety/FSMP/MeetingDocs/Forms/AllItems.aspx?RootFolder=%2fsafety%2fFSMP%2fMeetingDocs%2fFSMP%20WG11%2fIP&FolderCTID=0x012000556AC038F4589F4281B27ABB7E901CAE), FSMP-WG11-IP03 [↑](#footnote-ref-7)
7. [Assessment of C-Band Mobile Telecommunications Interference Impact on Low Range Radar Altimeter Operations](https://www.rtca.org/wp-content/uploads/2020/10/SC-239-5G-Interference-Assessment-Report_274-20-PMC-2073_accepted_changes.pdf), No. 274-20/PMC-2073 [↑](#footnote-ref-8)
8. Note that, as per the text, initial slope is dependent on ILS class [↑](#footnote-ref-9)
9. From the ANFR study, an aircraft approach angle of 3 degrees with 0.375 degrees margin resulting in 2.625 degrees as the worst case, including a touchdown distance of 200 metres from the runway threshold. [↑](#footnote-ref-10)
10. This is the point the Aircraft landing slope crosses the OLS + separation distance slope. [↑](#footnote-ref-11)
11. Table 6.6.4.2.4-1, 3GPP Specification: 38.104 [↑](#footnote-ref-12)
12. Table 6.6.4.2.3-2, 3GPP Specification: 38.104 [↑](#footnote-ref-13)
13. Conducted power per antenna port for BS and total power for UEs [↑](#footnote-ref-14)
14. Table 6.6.4.2.3-2, 3GPP Specification: 38.104 [↑](#footnote-ref-15)
15. Table 6.6.4.2.4-1, 3GPP Specification: 38.104 [↑](#footnote-ref-16)
16. Table 6.6.5.2.1-2, 3GPP Specification: 38.104 [↑](#footnote-ref-17)
17. Table 6.5.3.1-2, 3GPP Specification: 38.101-1 [↑](#footnote-ref-18)
18. RTCA Paper No. 274-20/PMC-2073) [↑](#footnote-ref-19)
19. The HL WBB TLG proposes limiting HL WBB stations to an in-band power spectral density of 17 dBm/MHz EIRP. [↑](#footnote-ref-20)
20. In this case the frequency dependant rejection is the assumed change in antenna gain of the base station from 3.9 GHz (in-band operation) to 4.2-4.4 GHz (out-of-band operation). It is noted that the antenna frequency dependent rejection may not apply to the AAS case. [↑](#footnote-ref-21)
21. The general EIRP restriction and resulting low maximum allowable antenna gain may make AAS operation impractical for both Medium Range and Local Area cases [↑](#footnote-ref-22)
22. International Telecommunications Union – Radiocommunications Sector [↑](#footnote-ref-23)
23. The list of airports that the restricted zone applies is intended to be the same as those defined for 3.4 GHz spectrum licences and area-wide licences. [↑](#footnote-ref-24)