Appendix D: Updated wireless broadband and radio altimeter study

DECEMBER 2021

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Executive Summary

Radio altimeters are an essential component of aeronautical safety-of-life systems[[1]](#footnote-2). There is a potential risk that Wireless Broadband (WBB) services in nearby frequency ranges cause interference to radio altimeters operating in the 4200–4400 MHz band. The ACMA conducted a study in July 2021 which looked at aggregate interference from multiple base stations deployed at existing WBB sites around example metropolitan airports. This study focuses on the worst-case airport runway identified in the previous study, transitions the base station frequencies to be adjacent to the radio altimeter band, considers statistical beamforming for active antenna systems (AAS) and the effect of base station unwanted emissions.

The study indicates that there is some potential for receiver overload and interference from out of band emissions for the worst performing radio altimeter model from M.2059, from non-AAS base stations, but AAS base stations have much less potential. It then examines how different mitigation methods may reduce the potential to an acceptable level.

It is noted that the results of the study are still highly dependent on the assumed parameters, both for radio altimeters and base stations.

# Background

This revised study follows from previous studies conducted by the ACMA to investigate compatibility of WBB services in the 3400-4000 MHz frequency range with radio altimeters in the 4200-4400 MHz range. These previous studies were:

A [study](https://www.acma.gov.au/sites/default/files/2020-07/Wireless%20broadband%20and%20radio%20altimeter%20compatibility%20study.docx) released along with the Replanning of the 3700-4200 MHz band – [Options paper](https://www.acma.gov.au/consultations/2020-07/planning-options-3700-4200-mhz-band-consultation-222020)

A study released earlier in the TLG process, included as Appendix B of the TLG document package.

This study version now includes:

Revised WBB base station parameters after feedback from the TLG

A revised radio altimeter antenna pattern used in the overload interference mechanism.

A variable sensitivity analysis of results based on the various radio altimeter models included in ITU-R M.2059-0

A revised methodology that more accurately models beamforming active antenna systems for the WBB services and provides a basis for statistical analysis of results

Study cases restricted to those around Sydney Airport as this was found to be the worst case in the previous (Appendix B) study

Cases that cover base station unwanted emissions into the radio altimeter wanted bandwidth, and

Analysis of possible safe operating distances from the aircraft flight path and a longer flight path.

# Study Methodology

### Interference Mechanisms

The following interference mechanisms were considered in this study:

Receiver front-end overload: Caused by emissions from a WBB transmitter saturating the front-end of a radio altimeter receiver. A front-end filter is assumed to provide some rejection of signals out of band to the altimeter.

Unwanted emissions: Caused by out of band emissions from a WBB transmitter falling directly into the wanted bandwidth of the altimeter.

### Cases

To investigate the potential of interference from WBB base stations the methods were modelled for each interference mechanism and antenna systems. Cases are divided into AAS and non-AAS base stations:

Case 1: Overload: AAS base stations with various mechanical tilts

Case 2: Overload: AAS base stations with various reduced TRP

Case 3: Overload: AAS base stations with various antenna height limits

Case 4: Overload: Non-AAS base stations with various mechanical tilts

Case 5: Overload: Non-AAS base stations with various reduced TRP

Case 6: Overload: Non-AAS base stations with various antenna height limits

Case 7: Unwanted emissions of non-AAS base stations

Case 8: Unwanted emissions of AAS base stations with uncorrelated antenna elements

Case 9: Unwanted emissions of AAS base stations with correlated antenna elements

Cases 1 to 6 investigate receiver front-end overload and the effect of changing the technical specifications of the base stations.

Cases 7, 8 and 9 consider the effect of base station unwanted emissions upon radio altimeters, with case 8 employing a single M.2102 element antenna and case 9 modelled like the AAS base stations. The preliminary method of calculating the radiated power levels in the band are from the worst case out of band unwanted emission limits stated in the draft AWL LCD. This can be scaled to account for different base station frequencies, the IF of different altimeters and to account for whether out of band or spurious domain emissions are dominant. For these cases, unlike M.2059, radio altimeters are protected to defined receive threshold level (rather than an I/N value). Also, a practical value of ground reflectivity, based on ED-30 has been used to determine a worst-case RA receiver wanted level, used conservatively for the entire landing.

### Base Station modelling

For all cases, the locations of the base stations are taken from RRL data for spectrum licenced base stations for a single operator utilising the range of 3575–3635 MHz in the 3.6 GHz (3575–3700 MHz) band. The full parameters for the base stations are described in tables 1 and 2. The operating frequency of the stations have then been transposed to the 3900–4000 MHz range.

Non-AAS base stations use azimuth and antenna down tilt values as recorded in the RRL.

For the AAS base stations, beamforming of a single beam is modelled. Each site is modelled with three sectors of common orientations of 30, 150 and 270 degrees azimuth and 6 degrees baseline mechanical tilt. The beams are steered towards dummy user equipment (UE) terminals, simulated at random locations across the base station network area. The tracking strategy of the beams is to track the closest dummy UE that meets the “restricted range” requirements. All antennas will attempt to track a UE in their range at every timestep of the simulation.

The “restricted range” is set by AAS vertical and horizontal coverage range parameters recommended in attachment 4.5 of the ITU-R Working Party 5D Chair report of 36th meeting ([5D/360](https://www.itu.int/md/R19-WP5D-C-0360/en)[[2]](#footnote-3)). For the horizontal range this is ±60 degrees of the antenna pointing azimuth. Vertically the coverage range antenna for beamforming is independent of the mechanical down tilt of the antenna and is between 90-100 degrees (beams do not steer above the horizon or more than 10 degrees below the horizon). This is consistent with the vertical coverage range defined in Annex 4.4 of the June 2021 WP 5D Chair report.

Note that only interference from base station antennas is assessed, this study does not consider aggregate interference from the UEs.

### Recording results

In these studies, the carrier to interference ratio (C/I) of a radio altimeter in the landing aircraft is recorded over 151 timesteps of 0.5 ms for a single modelled landing. The aggregate interference from all operating base stations is calculated to determine the level of interference to the radio altimeter receiver. The term ‘C’ represents the altimeter receiver overload threshold or sensitivity. Consequently, a positive C/I means the receiver threshold is not exceeded and interference is not expected.

For the AAS cases, the C/I is considered statistically for 100 simulated aircraft landings of 151 timesteps each. The percentage of test points which fail the C/I threshold is calculated. Different AAS cases are run with the same random seed, which will model the same beamforming sequence for each case.

### Simulation Implementation

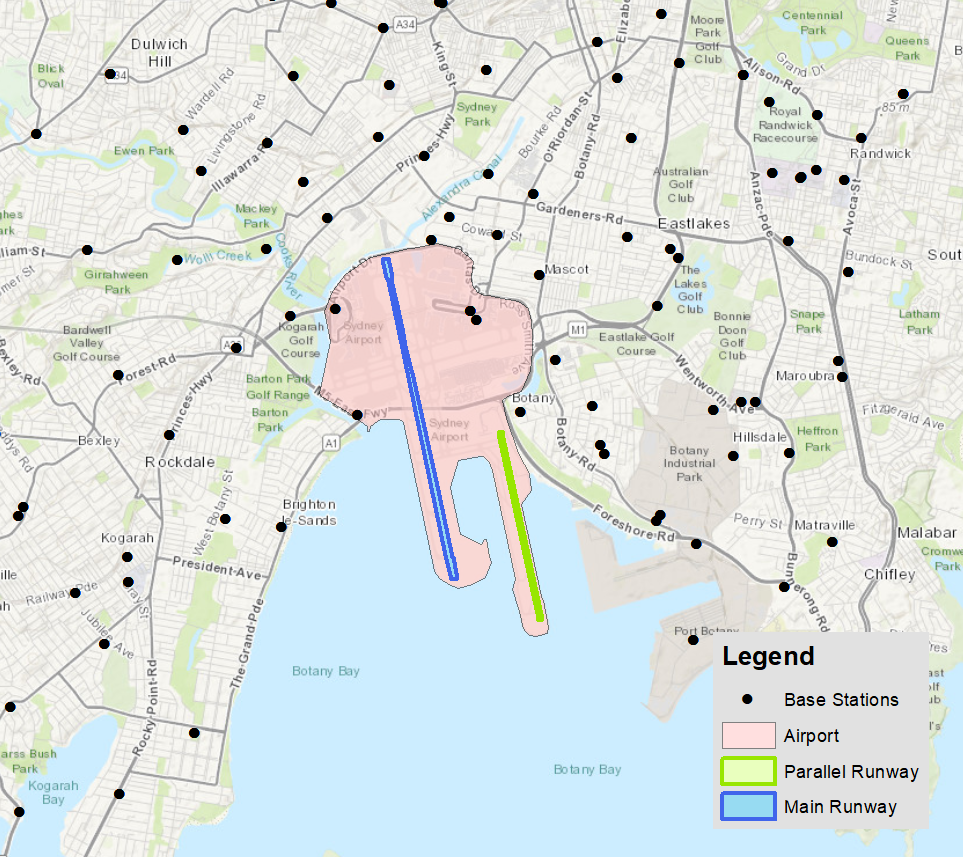
The simulation was implemented using *Visualyse Professional v7.979*.

The landing aircraft is modelled for a typical Category C aircraft landing[[3]](#footnote-4) using a speed of ~62 m/s (120 knots) and a climb/descent rate of 3.2 m/s (to match the ILS glide slope in the static model of 3 degrees.

## Flight Path

Flight path parallel runway from north at Sydney Airport is modelled. The flight path landing positions and bearings have been approximated from flight records published [online](https://webtrak.emsbk.com/). The figures below indicate Sydney Airport’s runways and flight paths.

Sydney Airport runways and surrounding BS[[4]](#footnote-5)



1. Sydney Airport landing flight path and modelled base stations

Diagram

Description automatically generated

## Base Station parameters

The WBB base station parameters are a combination of information from the RRL, relevant ITU recommendations and recent work in ITU-R SG5 WP5D. Parameters used in studies are summarised in tables 1 and 2.

The base station locations used in the study are from registered stations operating under a spectrum licence in the 3.6 GHz (3575–3700 MHz) range, culled to areas 5 km around the selected airport. The base station RRL data used in this study is detailed in the embedded file below.

Base station parameters used in this updated study are based on those defined in Annex 4.4 of the June 2021 WP 5D Chair report (this relates to IMT parameters for use in sharing studies). It is expected that this represents the most accurate way to model these systems at this point.



Non-AAS base station parameters

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Note |
| BS frequency | From RRL data | The frequency values have been transposed to the 3900–4000 MHz range. |
| Bandwidth | 60 MHz | From RRL data |
| Antenna Height | From RRL data |  |
| Average base station activity[[5]](#footnote-6) (Network loading factor) | 50% | Table 3-1, Attachment 4.5 WP 5D Chair report of 36th meeting (5D/360). |
| Base station TDD activity factor[[6]](#footnote-7) | 75% | Table 3-1, Attachment 4.5 WP 5D Chair report of 36th meeting (5D/360). |
| Non-AAS sectorisation | From RRL data |  |
| Non-AAS antenna down tilt | From RRL data |  |
| Non-AAS antenna vertical pattern | Recommendation ITU-R F.1336[[7]](#footnote-8) peak sidelobe  (recommends 3.1)  kp = 0.7  kv = 0.3  Horizontal 3 dB beamwidth:  65 degrees  Vertical 3 dB beamwidth:  determined from the horizontal  beamwidth by equations in  Recommendation ITU-R F.1336. | From M.2292-0. |
| Non-AAS antenna polarisation | Co-polar with radio altimeter | Worst case assumption |
| Non-AAS transmitter power (overload) | From RRL data |  |
| Non-AAS total power into antenna (unwanted emissions) | -15 dBm/MHz + 6 dB (‑9dBm/MHz) | Draft AWL LCD unwanted emission limit for Schedule 4 table 3[[8]](#footnote-9), > 10 MHz offset.  6 dB is added to account for multiple ports, two per polarisation. (4 ports total) |
| Non-AAS max antenna gain | 18 dBi | From M.2292-0. |
| Non-AAS resultant peak EIRP used in study (overload) | 71 dBm/60 MHz | Calculated |
| Non-AAS peak EIRP used in study (unwanted emissions) | 9 dBm/MHz | Calculated, scaled to applicable RA model IF bandwidth |

AAS base station parameters

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Note |
| AAS sectorisation | 30, 150, 270 degrees | Most common base station sector azimuths in RRL, approximately 30% of base stations around Sydney Airport. |
| AAS antenna base mechanical down tilt | 6 degrees | Table 6, Attachment 4.5 WP 5D Chair report of 36th meeting (5D/360). |
| AAS vertical coverage range | 90-100 degrees[[9]](#footnote-10) | Table 6, Attachment 4.5 WP 5D Chair report of 36th meeting (5D/360). |
| AAS horizontal coverage range | ±60 degrees | Table 6, Attachment 4.5 WP 5D Chair report of 36th meeting (5D/360). |
| AAS antenna vertical pattern | ITU-R  M.2101-0 8x8 element beamforming overall array | Single beam modelled. The software is not capable of modelling multiple beams using sub-arrays. |
| AAS antenna polarisation | Co-polar with radio altimeter | Worst case |
| AAS TRP (overload) | 200W /60 MHz | From RRL data |
| AAS TRP (unwanted emissions) | -6 dBm/MHz | Draft AWL LCD unwanted emission limit for Schedule 4 table 4.[[10]](#footnote-11), >10 MHz offset |
| AAS max antenna gain (correlated cases) | 23 dBi | From M.2101-0 |
| AAS resultant peak EIRP used in study (overload) | 76 dBm /60 MHz | Calculated using peak antenna gain |
| Single element gain (for uncorrelated cases) | 5 dBi | Software uses M.2101-0 single element pattern, not possible to use new WP5D figure. |
| Correlated resultant unwanted emissions peak EIRP used in study | 17 dBm/MHz | Calculated using peak antenna gain, to be scaled to applicable RA model IF bandwidth |
| Uncorrelated resultant unwanted emissions peak EIRP used in study | -1 dBm/MHz | To be scaled to applicable RA model IF bandwidth |

## 

## Radio altimeter parameters

Table 2 details the radio altimeter parameters used in the study. These use radio altimeter type A3 from ITU-R M.2059-0, as it represents the worst overload case and has been used in studies by some other administrations and ICAO. For the studies the C/I ratio is determined. For overload cases, the term C/I represents the altimeter rx overload threshold. Consequently, a positive C/I means the rx overload threshold is not exceeded.

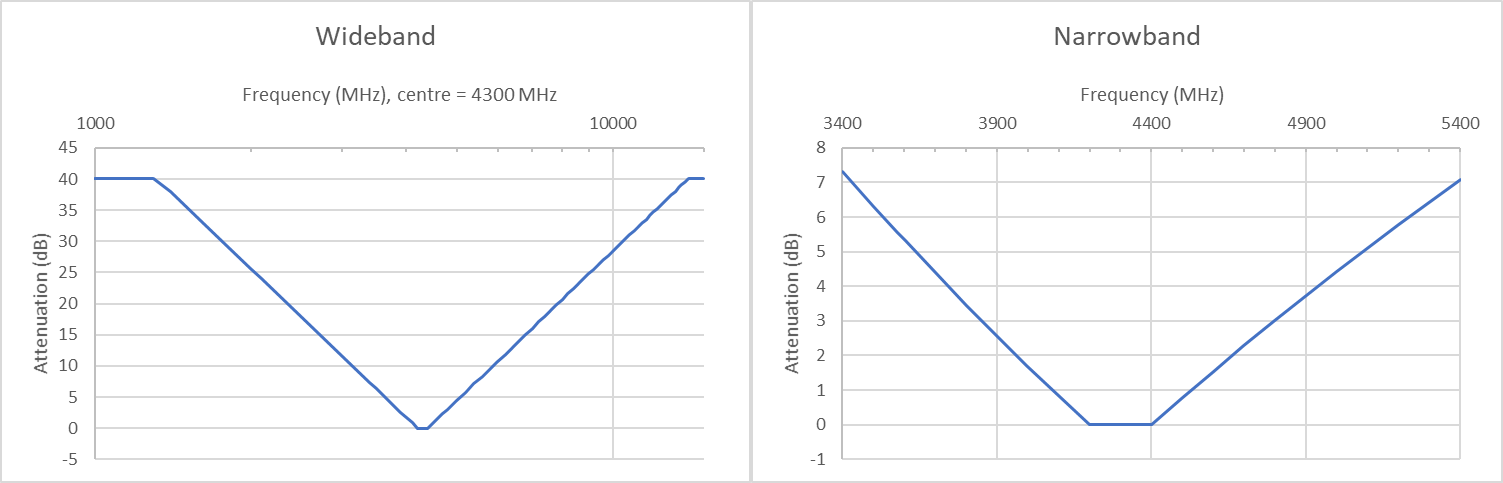
For unwanted emissions cases, the radio altimeter receiver protection level has been calculated using the following calculation, with a backscatter coefficient of 0.01 used from ED-30 (also used in the RTCA report). This value represents the expected RA receiver level a height of 250m of modelled landing, and will then be conservative when used for the entire landing. The protection level compares well with the laboratory value, measured in the RTCA report for commercial aircraft (“usage category 1”) for their “medium height” (1000 ft) case, of -85 dBm[[11]](#footnote-12).



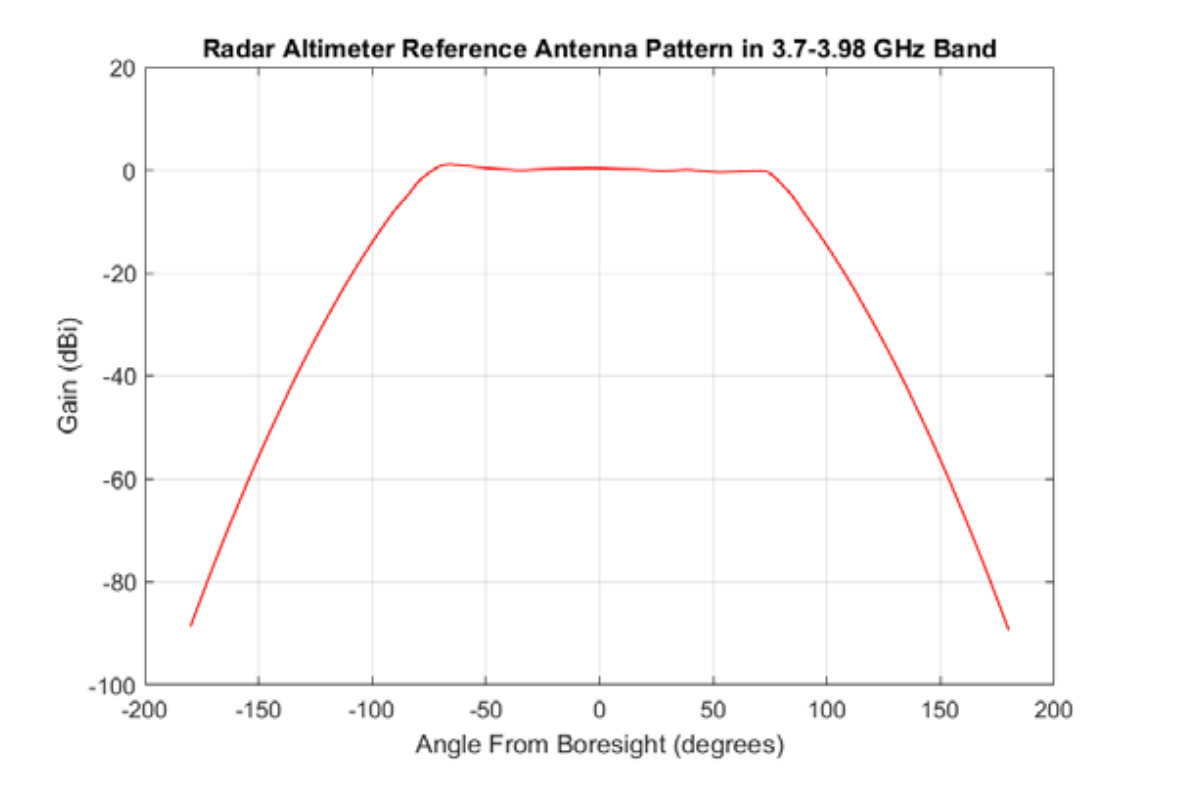
1. Radio altimeter parameters

|  |  |  |
| --- | --- | --- |
| Parameter | Value | Notes |
| Frequency | 4300 MHz | Nominal centre under ITU-R M.2059-0[[12]](#footnote-13) |
| Rx wanted Level (unwanted emissions) | -88.2 dBm | Radio altimeter received level estimation |
| Noise figure[[13]](#footnote-14) | 6 dB | From radio altimeter A3 under ITU-R M.2059-0 |
| Threshold rx (overload) | -56 dBm | From radio altimeter A3 under ITU-R M.2059-0 |
| Largest IF bandwidth | 2 MHz | From radio altimeter A3 under ITU-R M.2059-0 |
| Antenna gain (unwanted emissions) | 13 dBi | P4, ICAO[[14]](#footnote-15) study[[15]](#footnote-16) |
| Antenna vertical pattern (unwanted emissions) | As per P9 in ICAO study | Annex A, P9, ICAO study |
| Antenna gain out of band (overload) | 0.3 dBi | Figure 6-11, RTCA 274-20. |
| Antenna vertical pattern (overload) | [RTCA 274-20](https://www.rtca.org/wp-content/uploads/2020/10/SC-239-5G-Interference-Assessment-Report_274-20-PMC-2073_accepted_changes.pdf) out of band | Figure 6-11, RTCA 274-20. |
| Cable loss | 6 dB | P4, ICAO study[[16]](#footnote-17) |
| -3dB beamwidth | 60 degrees | P4, ICAO study |
| Front end filter  (overload) | As per Figure 3 | From ITU-R M.2059-0 |

1. Radio altimeter selectivity (overload)



Antenna Pattern (RTCA Paper No. 274-20/PMC-2073)



## Radio altimeter parameter sensitivity analysis (overload)

To compare the overload performance between different radio altimeter models in ITU-R M.2059-0, the overload threshold of the altimeters is normalised with their largest IF bandwidth. While ITU-R M.2059-0 provides different antenna gains for each altimeter in this analysis the ICAO antenna gain of 13 dBi is applied for all altimeters.

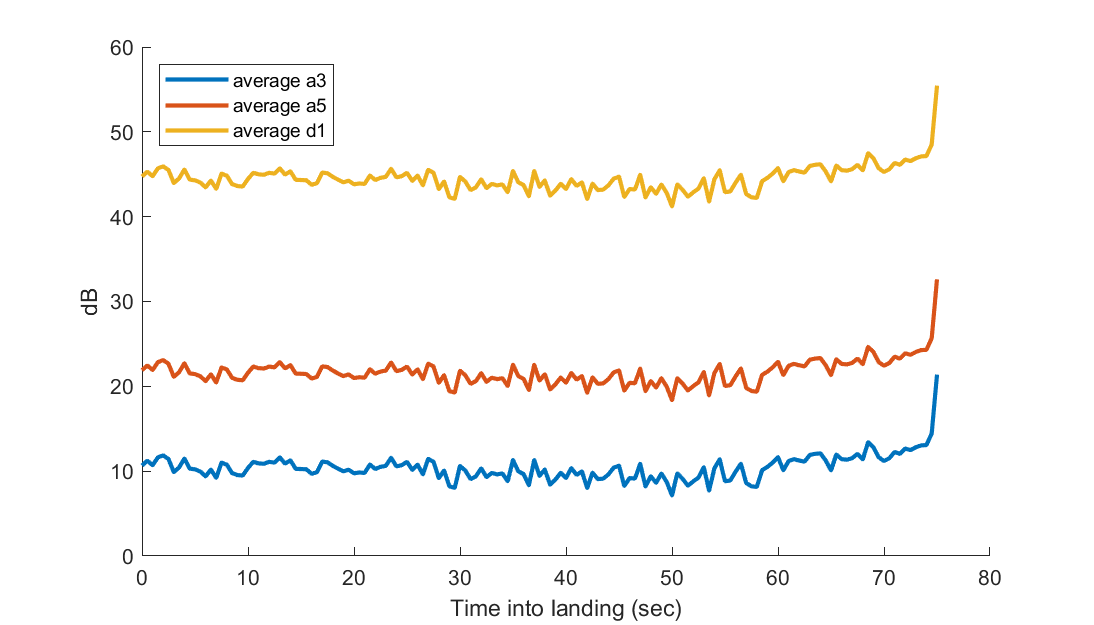
Summary of the altimeter values in ITU-R M.2059-0, in order of threshold

|  |  |  |  |
| --- | --- | --- | --- |
| Radio altimeter | Threshold receiver overload (dBm) | Largest IF bandwidth (MHz) | Threshold receiver overload/MHz |
| D1 | -30 | 0.312[[17]](#footnote-18) | -24.94 |
| A1 | -30 | 2 | -33.01 |
| D2 | -43 | 1.95 | -45.90 |
| A2 | -53 | 0.25 | -46.98 |
| A5 | -40 | 6 | -47.78 |
| A4 | -40 | 9.2 | -49.64 |
| A6 | -40 | 16 | -52.04 |
| D4 | -40 | 30 | -54.77 |
| D3 | -53 | 2 | -56.01 |
| A3 | -56 | 2 | -59.01 |

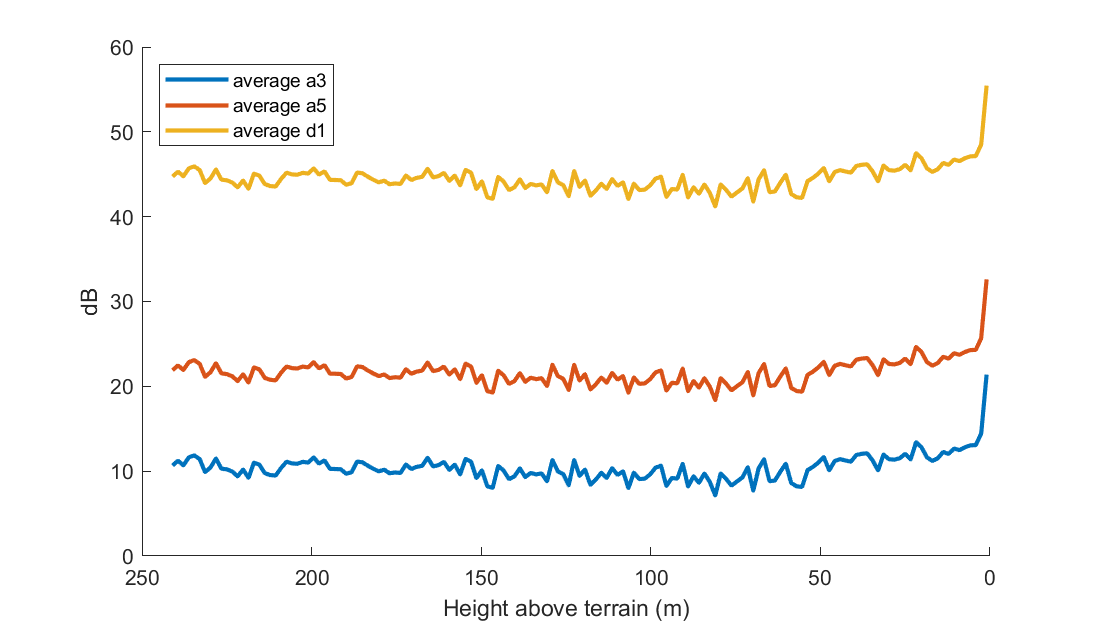
Results show a 34 dB difference between the best and worst performing altimeters. Altimeters D1, A5 and A3 were modelled to verify their effects on study results. They were chosen to examine the best, worst and median cases.

Note that the results in figures 5 and 6 used preliminary parameter values which may not be the same as those in tables 2 and 3. The conclusions of the results of figures 5 and 6 are independent of the exact parameters.

1. Average C/I of altimeters A3, A5 and D1 (time into landing)



1. Average C/I of altimeters A3, A5 and D1 (height above terrain)



Running AAS studies with the same (pseudo-random) seed results in average graphs of the same shape, with only a translation in C/I dB separating the altimeters. The separation in dB is the same as the difference in Threshold receiver overload/MHz in table 4. It is therefore possible to approximate the performance of different altimeters by applying a flat dB adjustment dependent on the altimeter’s receiver threshold and IF bandwidth.

## Distance analysis (overload)

The modelling results of the non-AAS case show a worst performance level 12 dB below the C/I threshold. The distance a base station would have to be from the aircraft flight path to improve the performance by that amount is approximated.

A non-AAS base station under the flight path in previous cases is modelled in free space. Distances are noted where the maximum interference power of the station to the radio altimeter is reduced by 9, 12 and 15 dB. The radio altimeter is modelled at a height of 50 m across various distances from the base station.

1. Distance away from non-AAS base station for interference power to reduce in dB

|  |  |
| --- | --- |
| Reduction in base station interference power (dB) | Max distance from base station to achieve reduction (m) |
| 9 | 570 |
| 12 | 790 |
| 15 | 1110 |

The worst performance in the non-AAS studies is -12 dB, which corresponds to 790 m distance from a base station underneath the flight path. A non-AAS case is run with stations that are within 800 m of the flight path removed.

## Extended flight path non-AAS (overload)

The landing flight path is extended further back in the time of the flight in this non-AAS case, in order to compare the magnitude of interference from earlier base stations. The flight path is extended from 151 to 600 time steps with the same endpoint, speed and descent rate. The base station RRL data used in this study is detailed in the embedded file below.



1. Parallel runway extended landing flight path and modelled non-AAS base stations

A map of a city

Description automatically generated with low confidence

## AAS Base Stations with increased TRP (overload)

The power of the base stations in an AAS case is increased, and the percentage of test points failed recorded. The power increase is applied after the simulation, which is equivalent to running the same study multiple times with the same seed.

## Non-AAS unwanted emission limit LCD frequency boundary

The TRP level for the non-AAS unwanted emissions used is a worst case scenario because the power level used in the study is based on the draft AWL LCD unwanted emission limit within the 3360–4240 MHz range. However, the radio altimeter band extends an additional 160 MHz outside this range where lower limits apply.

It is difficult to model the disjointed set of emission limits because radio altimeters shift operating frequencies between the full 4200–4400 MHz frequency range. The range of values can be determined by considering best and worst case scenarios and an average based on the potential distribution across the frequency range. The average assumes that the radio altimeter’s operation is evenly distributed across the entire radio altimeter frequency band. The power difference between cases is applied after the simulation, which is equivalent to running the same study multiple times with the same seed.

1. Different scenarios in which a radio altimeter could be operating at an instant of time

|  |  |  |  |
| --- | --- | --- | --- |
| Radio altimeter operation range | Base station power in frequency range | | Notes |
| Worst case  4200–4240 MHz | -15 dBm/MHz | +6 dB to account for multiple ports, two per polarisation (4 ports total) | Draft AWL LCD unwanted emission limit Schedule 4 table 3. |
| Best case  4240–4400 MHz | -30 dBm/MHz | +6 dB to account for multiple ports, two per polarisation (4 ports total) | Draft AWL LCD unwanted emission limit Schedule 4 table 6. |
| Average of partial operation across 4240 MHz boundary | -21.5 dBm/MHz | +6 dB to account for multiple ports, two per polarisation (4 ports total) | Calculated based on frequency range proportions of best and worst case. |

Additionally, a non-AAS unwanted emissions case is run and by reducing base station power relative to the worst case power limit, the threshold which there is 0.1% or less failure time across the landing time can be determined.

# Results

Results are presented in this section but no conclusions are drawn. The discussion section uses the results to make some observations.

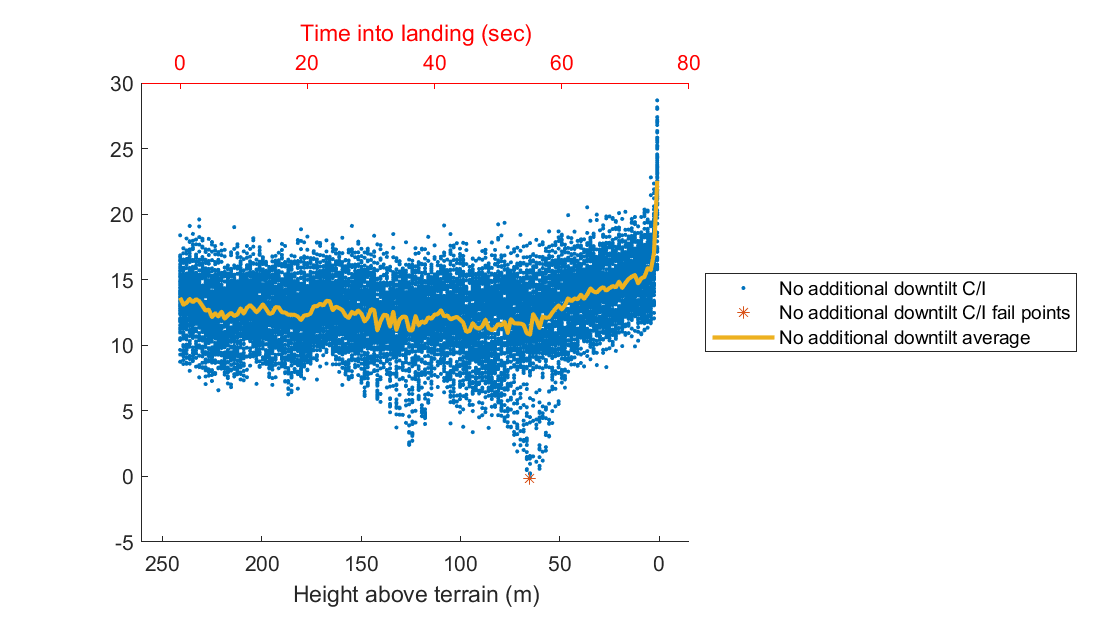
## AAS Base Stations

Percentage of test points that fail the C/I threshold

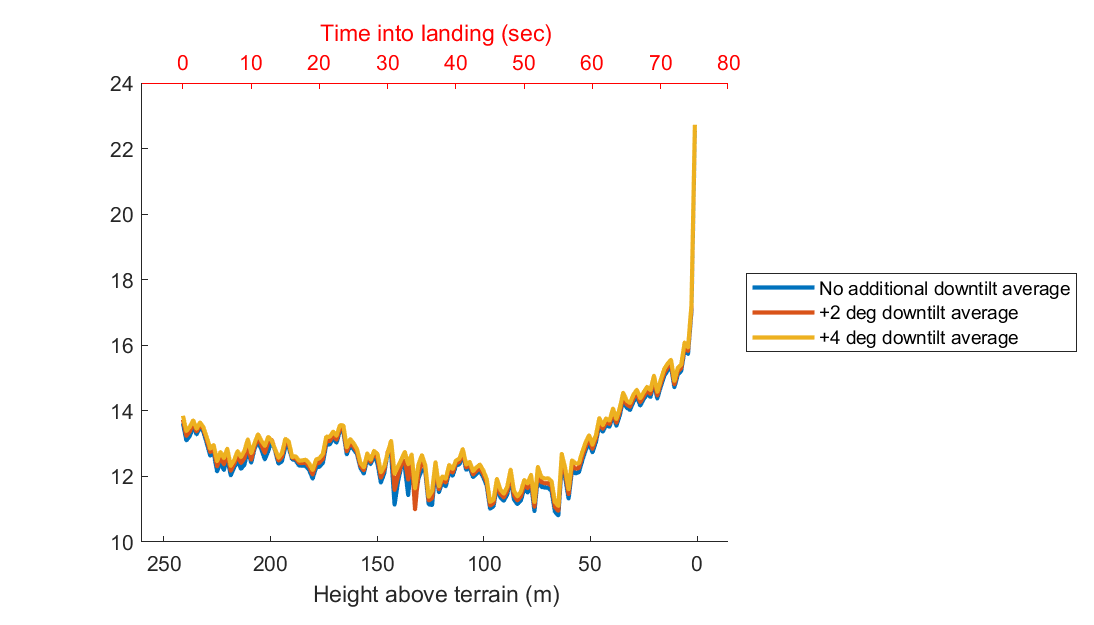
|  |  |  |
| --- | --- | --- |
| Case | | Percentage |
| Case 1 | No additional mechanical down tilt (6 degree down tilt) | 0.0066 |
| +2 deg mechanical down tilt (8 degrees down tilt) | 0.0066 |
| +4 deg mechanical down tilt (10 degrees down tilt) | 0 |
| Case 2 | No TRP reduction | 0.0066 |
| 3 dB TRP reduction | 0 |
| 6 dB TRP reduction | 0 |
| 9 dB TRP reduction | 0 |
| 12 dB TRP reduction | 0 |
| Case 3 | No antenna height limit | 0.0066 |
| Antenna height limited to 20m | 0.0066 |
| Antenna height limited to 10m | 0 |
| Antenna height limited to 5m | 0 |
| Antenna height limited to 2m | 0 |

### Case 1

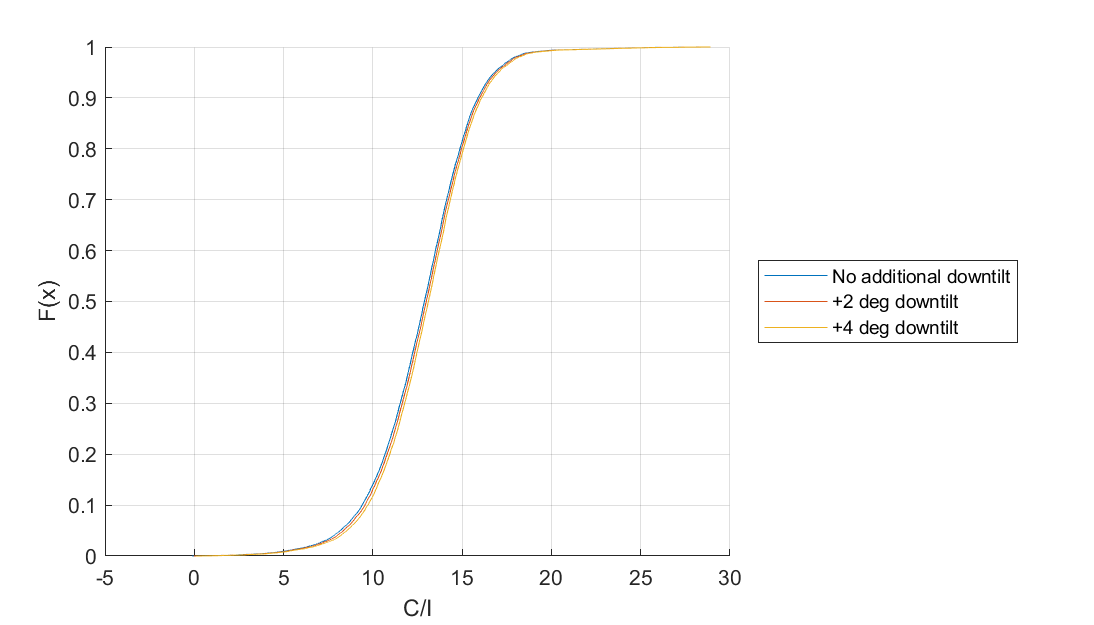
AAS overload C/I scatter plot with no additional mechanical down tilt



AAS overload comparison of average C/I of increasing mechanical down tilts



AAS overload comparison of CDF of increasing mechanical down tilts



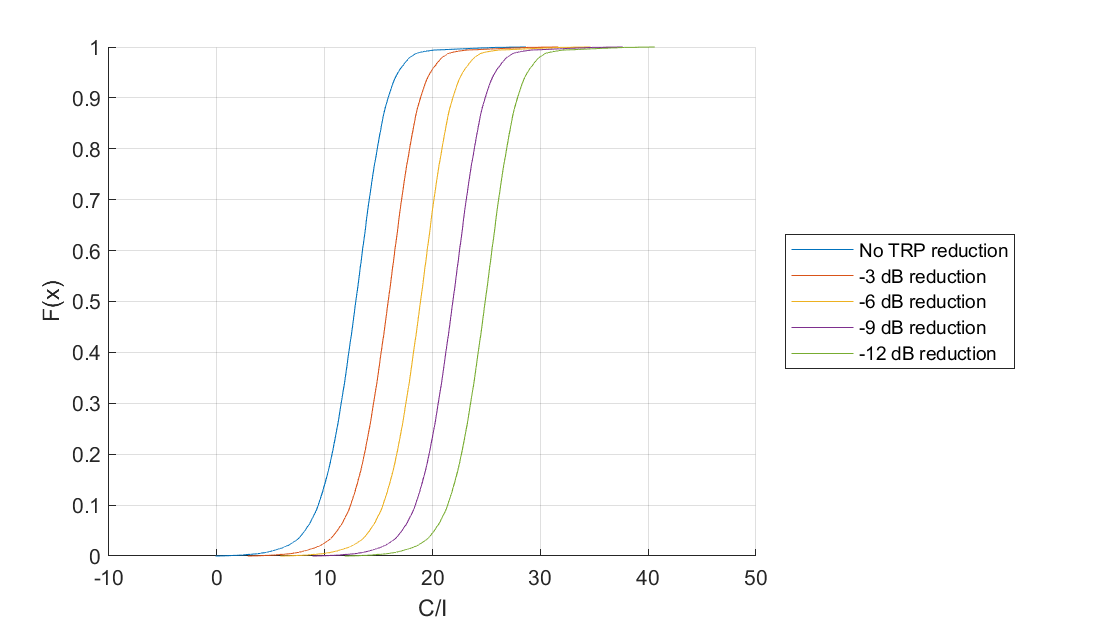
### Case 2

1. AAS overload comparison of average C/I of reducing TRP

Chart

Description automatically generated

1. AAS overload comparison of CDF of reducing TRP



### Case 3

1. AAS overload comparison of average C/I of different antenna height limits

Chart, histogram

Description automatically generated

1. Comparison of CDF of different antenna height limits

Chart

Description automatically generated

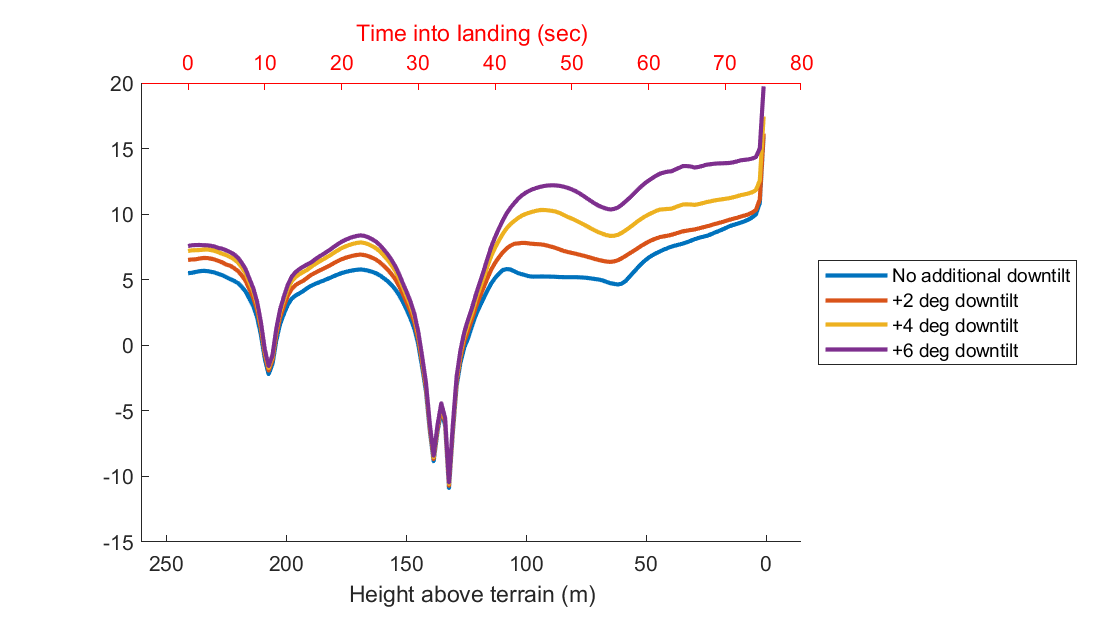
## Non-AAS base stations

Percentage of time that fails the C/I threshold

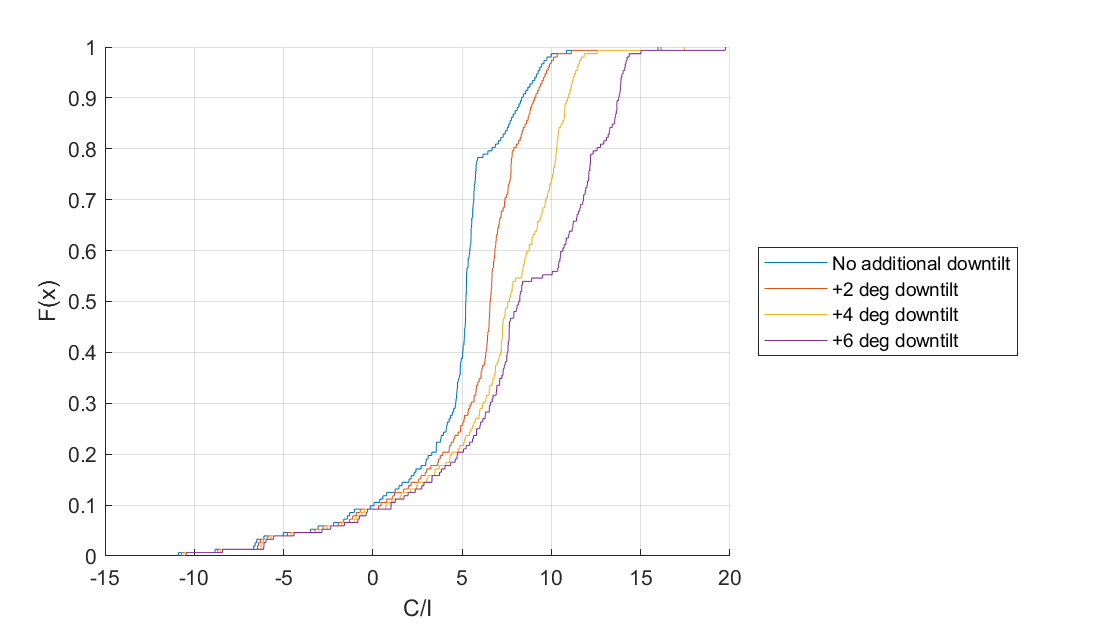
|  |  |  |
| --- | --- | --- |
| Case | | Percentage |
| Case 4 | No additional mechanical down tilt (6 degree down tilt) | 9.8684 |
| +2 deg mechanical down tilt (8 degrees down tilt) | 9.2105 |
| +4 deg mechanical down tilt (10 degrees down tilt) | 9.2105 |
| +6 deg mechanical down tilt (12 degrees down tilt) | 9.2105 |
| Case 5 | No TRP reduction | 9.8684 |
| 3 dB TRP reduction | 5.9211 |
| 6 dB TRP reduction | 3.9474 |
| 9 dB TRP reduction | 0.6579 |
| 12 dB TRP reduction | 0 |
| Case 6 | No antenna height limit | 9.8684 |
| Antenna height limited to 20m | 9.2105 |
| Antenna height limited to 10m | 9.2105 |
| Antenna height limited to 5m | 9.2105 |
| Antenna height limited to 2m | 9.2105 |

### Case 4

Non-AAS overload comparison of C/I of increasing mechanical down tilts

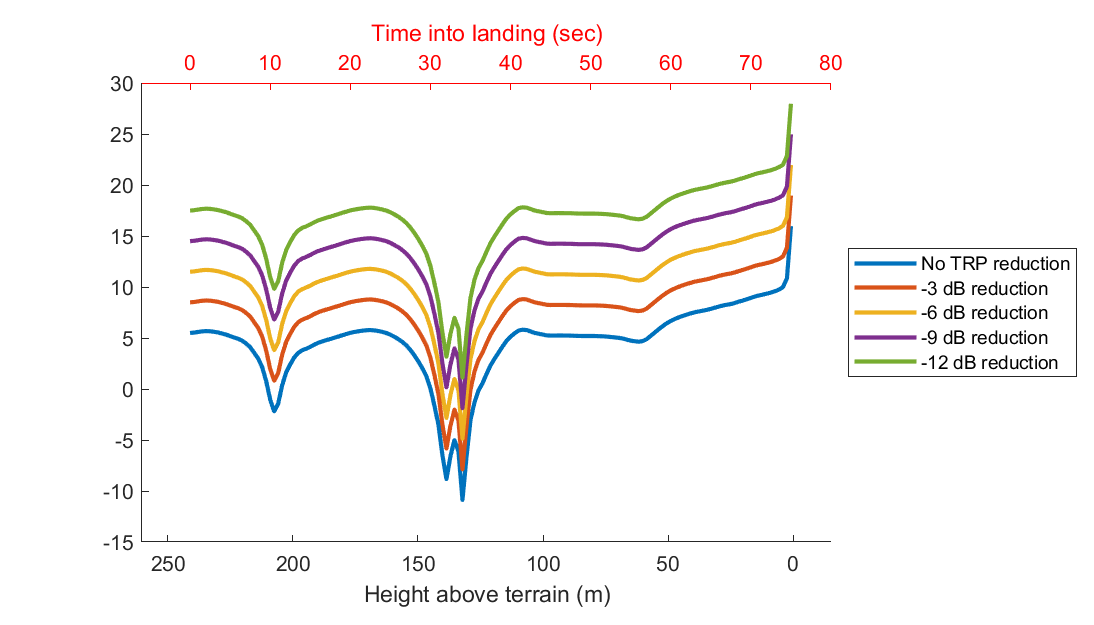


1. Non-AAS overload comparison of CDF of increasing mechanical down tilts

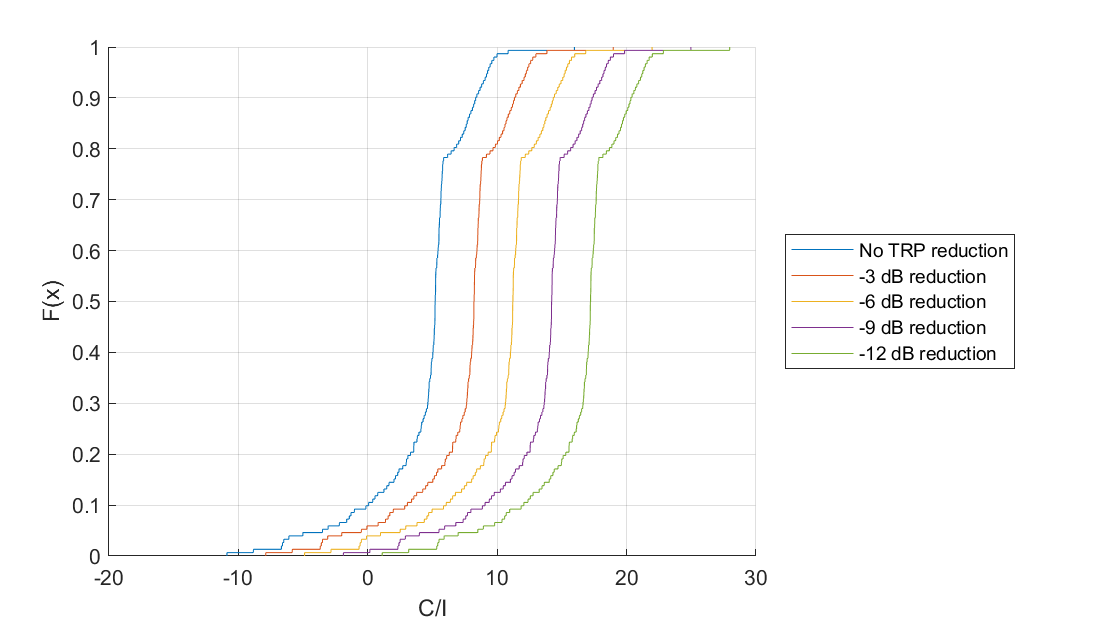


### Case 5

Non-AAS overload comparison of C/I of reducing TRP



Non-AAS overload comparison of CDF of reducing TRP



### Case 6

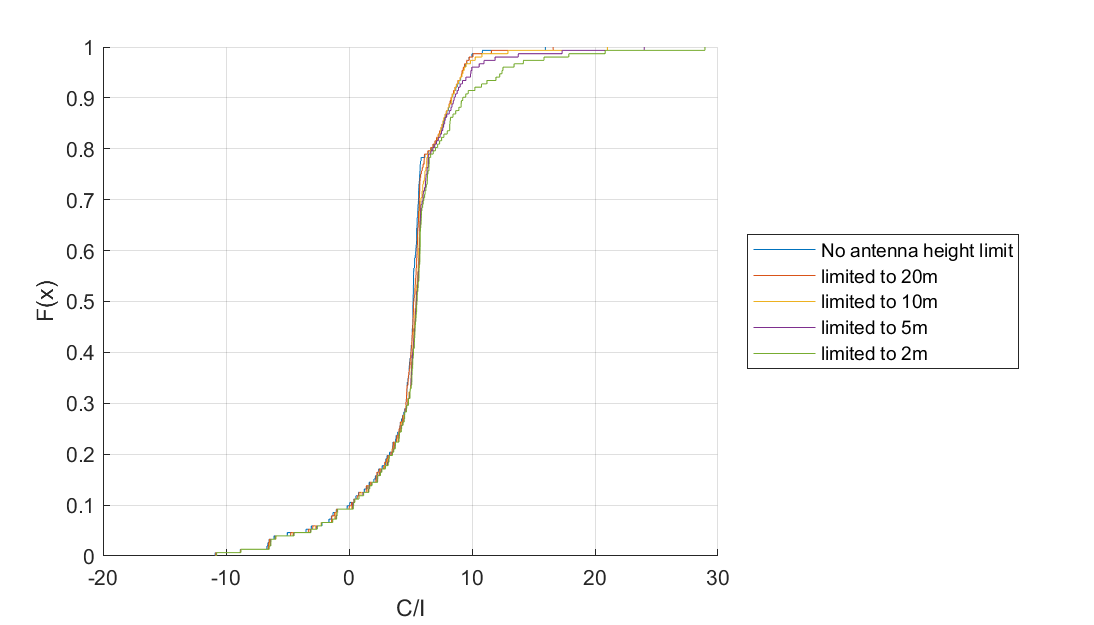
If the base station antenna height exceeds the height limit then the height is reduced to the height limit level. Antennas that are below the height limit do not have their heights changed.

1. Non-AAS overload comparison of C/I of different antenna height limits

Chart

Description automatically generated

1. Non-AAS overload comparison of CDF of different antenna height limits



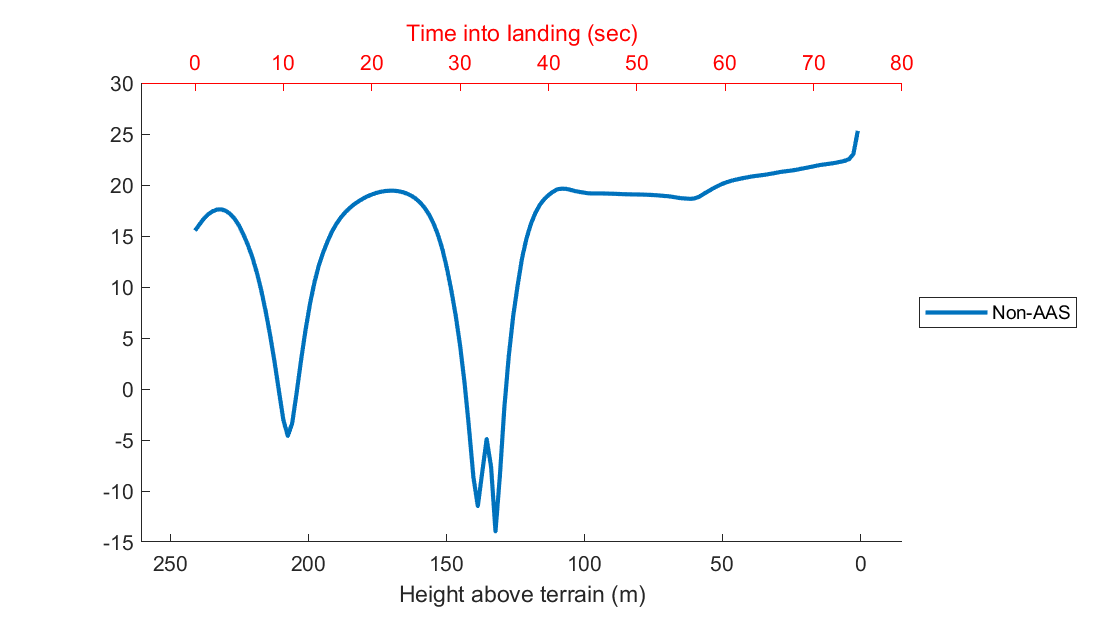
## Unwanted emissions cases

Percentage of test points/time that fail/s the C/I threshold

|  |  |  |
| --- | --- | --- |
| Case | | Percentage |
| Case 7 | Non-AAS unwanted emissions | 9.2105 |
| Case 8 | AAS unwanted emissions (uncorrelated) | 0.6622 |
| Case 9 | AAS unwanted emissions (correlated) | 0 |

### Case 7

Non-AAS unwanted emissions C/I



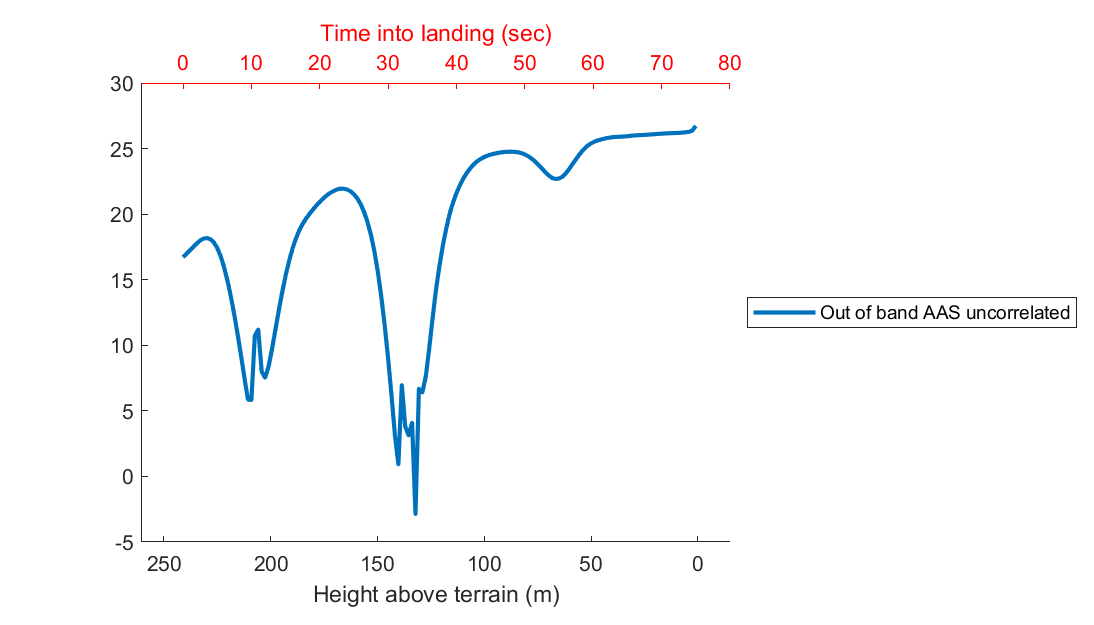
Non-AAS unwanted emissions CDF

Chart, line chart

Description automatically generated

### Case 8

AAS unwanted emissions C/I uncorrelated elements



AAS unwanted emissions CDF uncorrelated elements

Chart, line chart

Description automatically generated

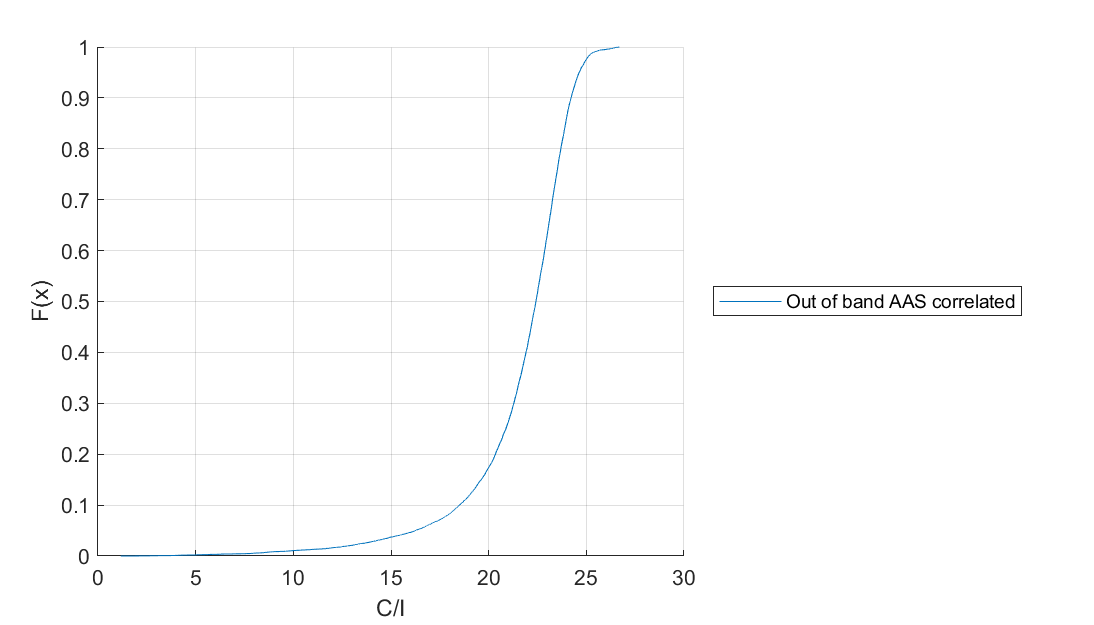
### Case 9

AAS unwanted emissions C/I correlated elements

Chart

Description automatically generated

AAS unwanted emissions CDF correlated elements



## Non-AAS Distance analysis

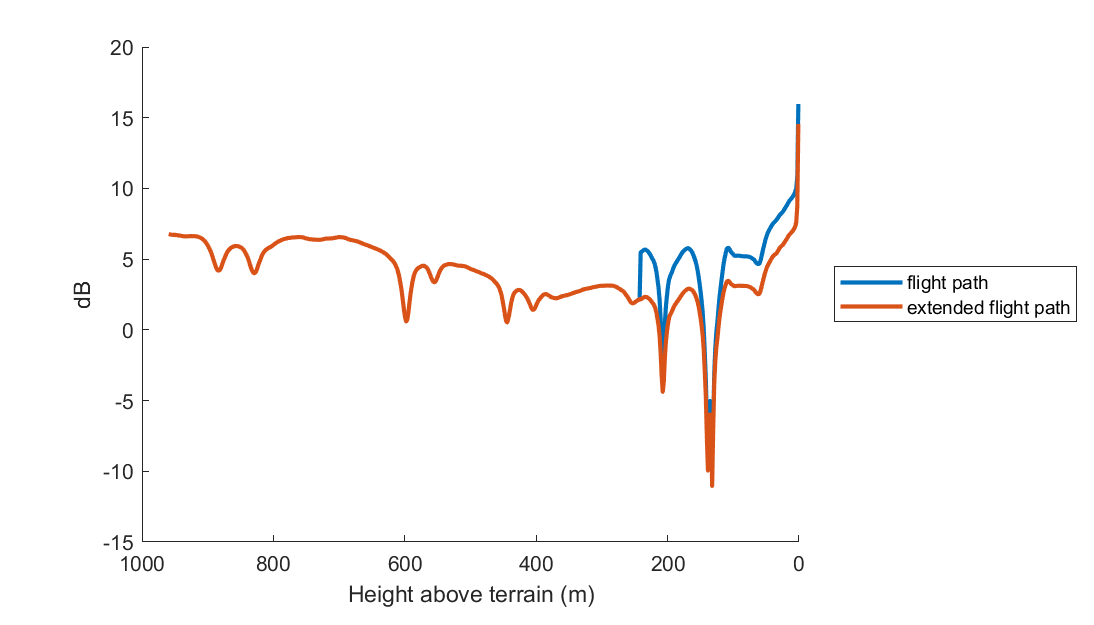
1. Non-AAS overload comparison of C/I with stations within 800m of the flight path removed

Chart, line chart

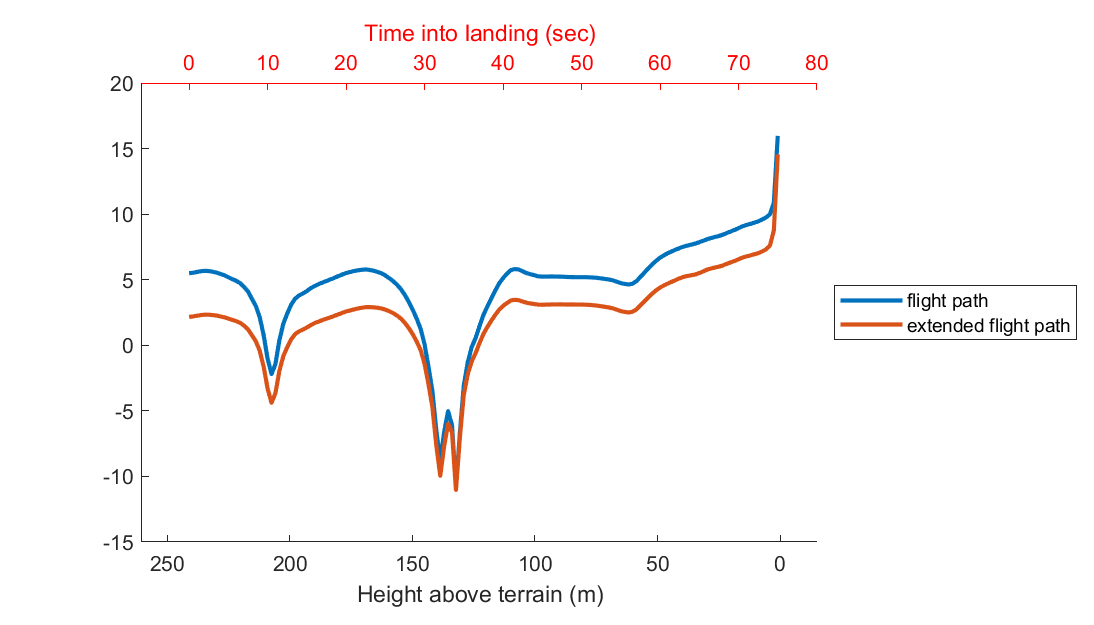
Description automatically generated

## Non-AAS extended flight path

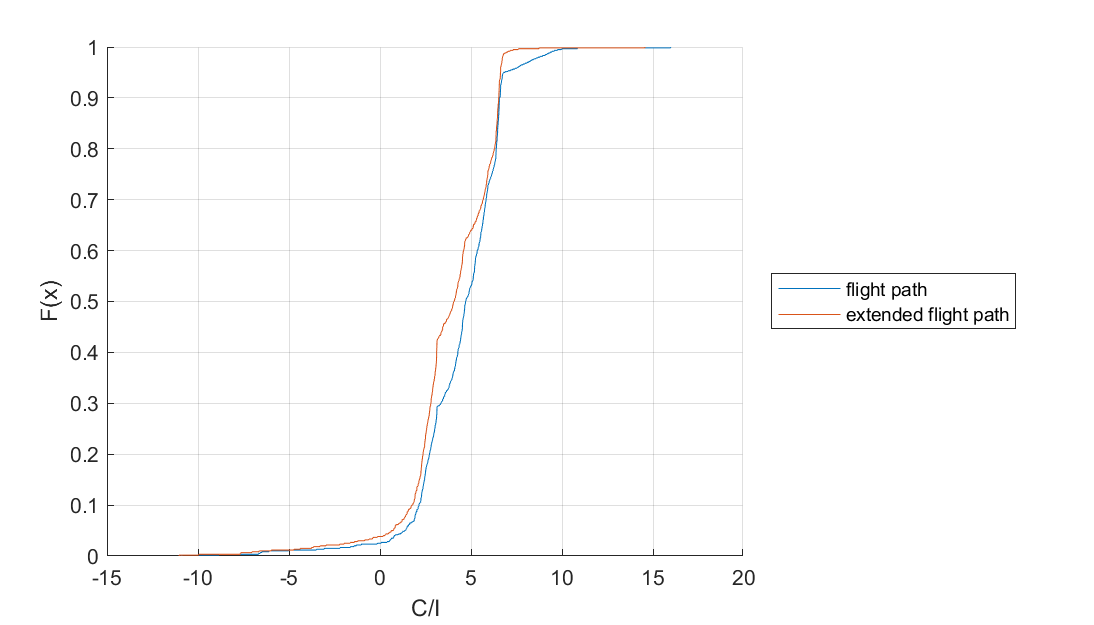
1. Non-AAS overload C/I with longer flight path



1. Non-AAS overload C/I with longer flight path at timeframe of flight path



1. Non-AAS overload CDF with longer flight path

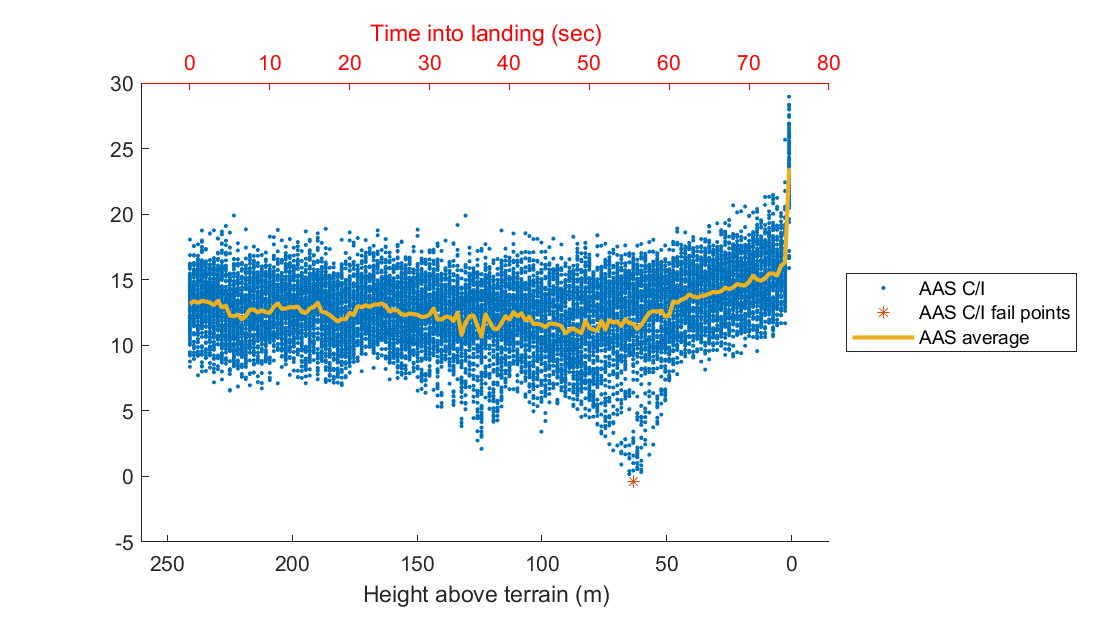


## AAS Base Stations with increased TRP

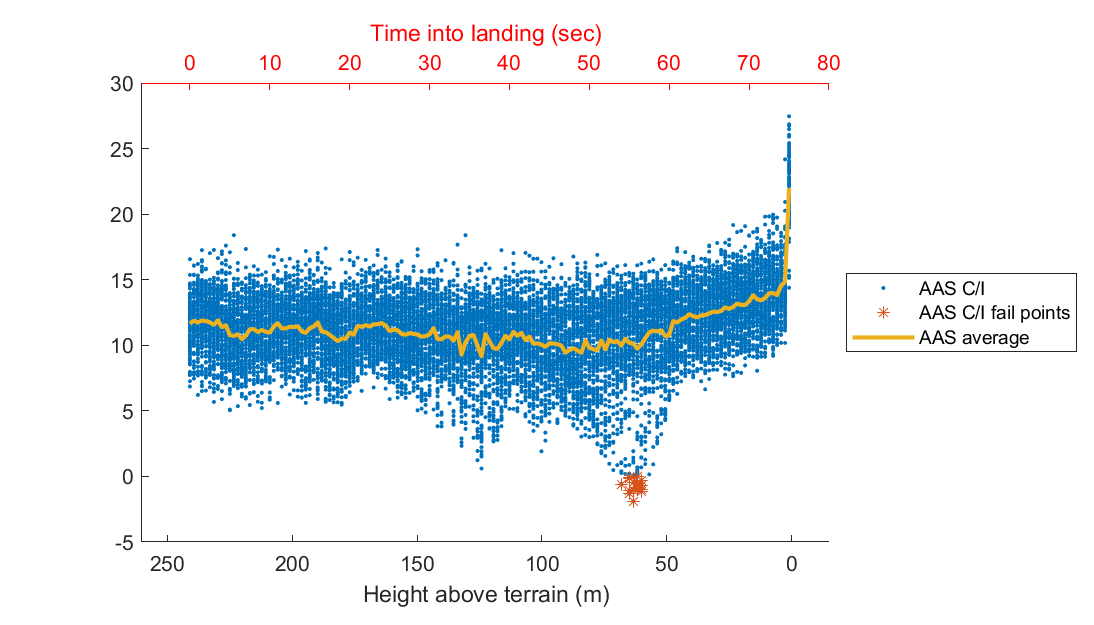
Percentage of test points that fail the C/I threshold

|  |  |
| --- | --- |
| Increase in TRP | Percentage |
| No increase | 0.0066 |
| 0.5 | 0.0331 |
| 1 | 0.0728 |
| 1.5 | 0.1126 |
| 2.0 | 0.1987 |
| 2.5 | 0.2649 |
| 3.0 | 0.3245 |

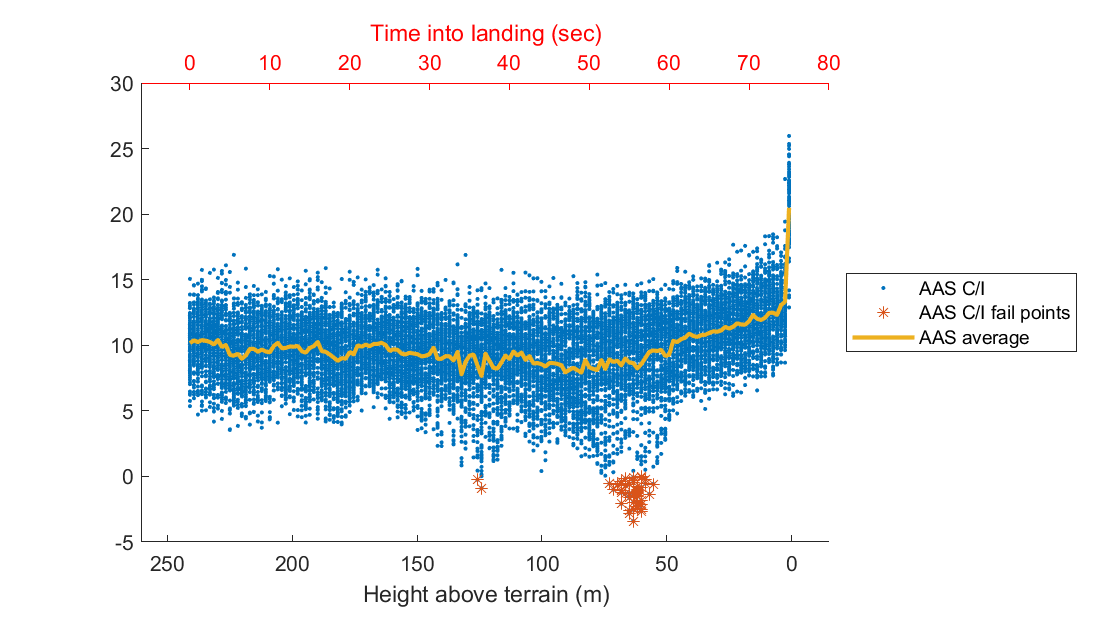
AAS Overload C/I scatter plot with no increase in TRP



1. AAS Overload C/I scatter plot with 1.5 dB increase in TRP



1. AAS Overload C/I scatter plot with 3 dB increase in TRP



## Non-AAS unwanted emission limit boundary

Percentage of time that fails the C/I threshold

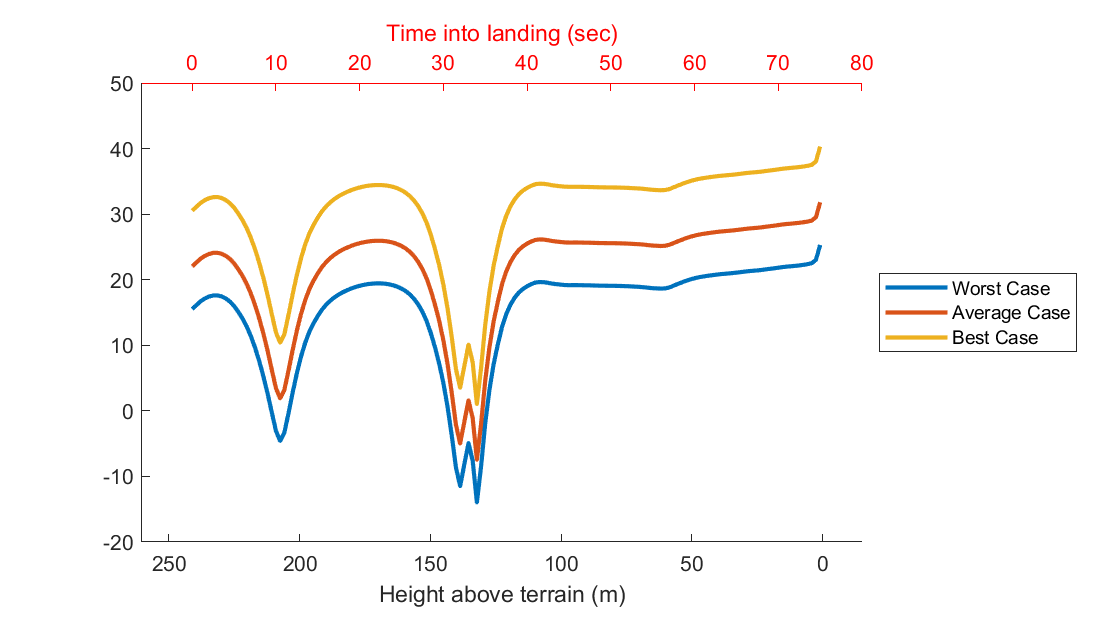
|  |  |
| --- | --- |
| Increase in TRP | Percentage |
| Worst Case | 9.2105 |
| Average | 3.9474 |
| Best Case | 0 |

Reduction of worst case unwanted emissions power to percentage of time failed

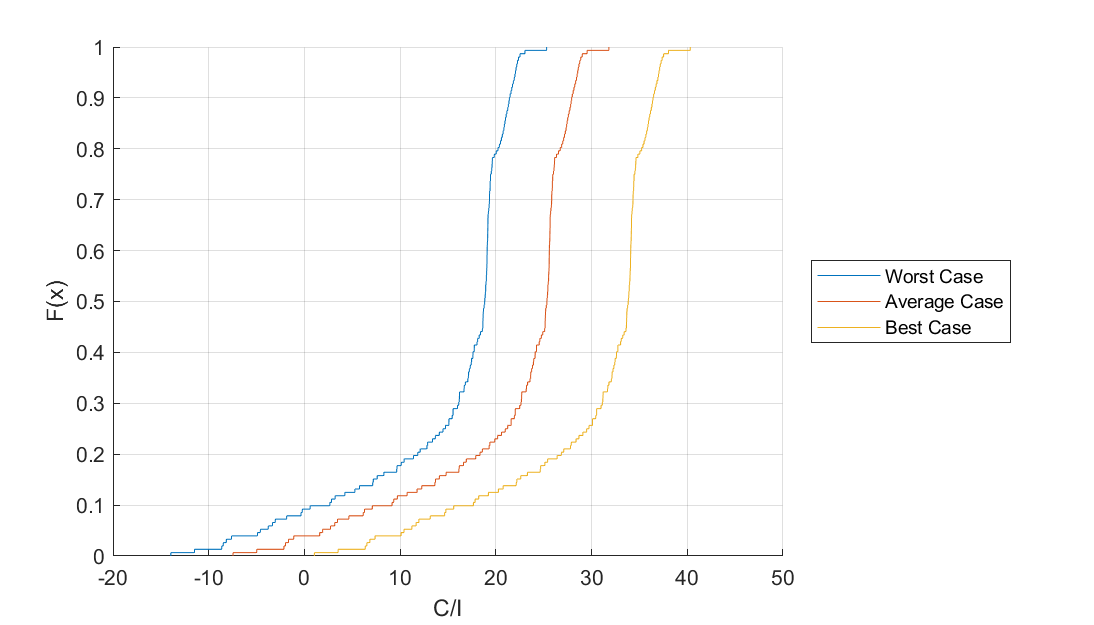
The landing sequence for non-AAS cases has 152 (151 timesteps plus the starting time) data points, as a result the resulting percentage intervals are course (1 data point is 0.6579 percent).

|  |  |
| --- | --- |
| Reduction in base station interference power (dB) | Percentage |
| -9 | 1.3158 |
| -12 | 0.6579 |
| -15 | 0 |

Non-AAS unwanted emissions C/I



Non-AAS unwanted emissions CDF



# Discussion

Base stations employing AAS have a low probability of causing interference, while non-AAS base stations have some potential to cause interference to radio altimeters. For AAS it would take an increase of 1.5 dB over currently operating power to have a fail rate over 0.1% of test points, which is considered an acceptably small amount.

### Mechanical down tilt and antenna height limits

Increasing the mechanical down tilt of base station sectors and restricting the antenna heights of the base stations provide very little improvement to radio altimeter performance. For non-AAS increasing the mechanical down tilt reduces the interference from stations further away from the flight path but interference from stations close to or under the flight path does not improve. In the AAS case, restricting antenna heights can make radio altimeter performance worse for most of the flight path until the last 25m above terrain.

### Reducing TRP

Reducing the TRP of the base stations may be an effective way to reduce the interference to radio altimeters for AAS and non-AAS. For the AAS cases, running the studies with the same seed and different TRP produces the same average curves only translated in C/I magnitude. It is therefore possible to approximate changing TRP levels by applying a flat dB increase or decrease to the modelled data.

### Unwanted emissions

Similar to the overload case, for unwanted emissions non-AAS base stations have the potential to cause interference to radio altimeters while AAS base stations have very low probability. The overload case studies have factors that can significantly influence the results.

The unwanted emissions definitions in the LCD define a boundary at 4240 MHz which makes it difficult to model the power level into the radio altimeter band. The interfering base station powers used for the overload case are the worst case, but the level of interference can vary from the worst case up to 15 dB improvement depending on where in frequency band the radio altimeter is operating.

### Distance and extended flight paths

Stations within 800 m of the aircraft landing path dominate the interference power on the radio altimeters, and the effect of close stations is observable but less at higher altitudes earlier in the flight. Modelling more stations further away from the flight path shows a decrease in the average radio altimeter performance of around 2.5 dB but the interference from close stations is unaffected.

**Other considerations**

The results of the study are highly dependent on the parameters used for the altimeter and the base stations in the study. The specifications of the altimeters are currently from ITU-R M.2059-0 and using the specifications from an altimeter that is used by aircraft can provide more accuracy.

These studies do not consider AAS base stations scanning above the horizon.

# Summary

Non-AAS base stations have some potential to cause interference to radio altimeters on aircraft, AAS base stations have minimal potential. This is reflected in both overload and unwanted emissions cases. Increasing antenna down tilt or applying an antenna height limit on base stations do not effectively reduce the level of interference to radio altimeters, reducing the TRP of base stations may be effective.

The results of these studies are highly dependent on the parameters used. Unwanted emissions definitions in the LCD result in a range of potential performance values for unwanted emissions interference cases which can vary up to 15 dB.

Stations closest to the flight path dominate the interference effects on the radio altimeters, and their effects are worse the closer the aircraft is to the end of the flight path.

1. From a) of <https://www.itu.int/rec/R-REC-M.2059/en> [↑](#footnote-ref-2)
2. The ITU-R study group document cannot be released to the TLG but those with ITU-R accounts can access it. It can be publicly found as part of, [ECC PT1(21)188](https://cept.org/Documents/ecc-pt1/65959/ecc-pt1-21-188_gsa-mfcn-characteristics-for-wi-on-radio-altimeters). [↑](#footnote-ref-3)
3. <https://en.wikipedia.org/wiki/Aircraft_approach_category> [↑](#footnote-ref-4)
4. Only the parallel runway is modelled in this study as it was found to be the worst case in previous study versions [↑](#footnote-ref-5)
5. This parameter is taken into account by scaling the TRP value [↑](#footnote-ref-6)
6. This parameter is taken into account by scaling the TRP value [↑](#footnote-ref-7)
7. <https://www.itu.int/rec/R-REC-F.1336/en> [↑](#footnote-ref-8)
8. The radio altimeter operating band extends beyond the frequency range of the unwanted emission limit, however this value is used as a worst case scenario [↑](#footnote-ref-9)
9. Global coordinate system with 90 degrees at the horizon. The coverage range does not change with changes in the mechanical tilt. [↑](#footnote-ref-10)
10. The radio altimeter operating band extends beyond the frequency range of the unwanted emission limit, however this value is used as a worst case scenario [↑](#footnote-ref-11)
11. See Table 7-2 on page 39 of the RTCA report and figure 9-10 on page 54. [↑](#footnote-ref-12)
12. <https://www.itu.int/rec/R-REC-M.2059/en> [↑](#footnote-ref-13)
13. This parameter is not used in the study [↑](#footnote-ref-14)
14. ICAO paper <https://www.icao.int/safety/acp/ACPWGF/ACP-WG-F-30/ACP-WGF30-WP14%20Radio%20Altimeter%20Adjacent%20Bands%20Compatibility%20Study%20with%20IMT-FINAL%20Rev1.docx>. [↑](#footnote-ref-15)
15. For radio altimeter A3 in ITU-R M.2059-0 antenna gain is 10 dBi [↑](#footnote-ref-16)
16. For radio altimeter A3 in ITU-R M.2059-0 cable loss is 2–7 dB [↑](#footnote-ref-17)
17. LPF – Single sided [↑](#footnote-ref-18)