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| U.S. Radiocommunications SectorFact Sheet |
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| **Document Title:** WP 5D Chair’s 49th meeting Report Chapter 4, Annex 4.11, Attachment 6, Study F (USA)) Update |
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| **Purpose/Objective:** To update the USA compatibility study between radio altimeters operating in the ARNS allocation in the 4 200 – 4 400 MHz band and IMT systems in the 4 400 – 4 800 MHz band. |
| **Abstract:** WP 5D is developing a working document towards a preliminary draft new report on the sharing and compatibility studies in relation to WRC-27 Agenda Item 1.7. This contribution proposes updates in the document to the WP 5D Chair’s 49th meeting Report Chapter 4, Annex 4.11, Attachment 6, Study F (USA)  |

[Editor’s Note: Any content removed is for convenience only. All changes proposed are highlighted in cyan]

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| **Radiocommunication Study Groups** |  |
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| **English only** |
| Annex 4.11 to Working Party 5D Chair’s Report |
| ANNEX 1 – SHARING AND COMPATIBILITY STUDIES BETWEEN SERVICES TO WHICH THE BAND IS CURRENTLY ALLOCATED AND IMT SYSTEMS IN THE FREQUENCY BAND 4 400-4 800 MHZ UNDER WRC-27 AGENDA ITEM 1.7 |

attachment 6

Compatibility of the aeronautical radionavigation service (RR No. 5.438) operating in the frequency band 4 200-4 400 MHz and IMT operating in the
frequency band 4 400-4 800 MHz

[Editor’s note: This Attachment contains sharing and compatibility studies of the aeronautical radionavigation service (RR No. **5.438**) operating in the frequency band 4 200-4 400 MHz and IMT operating in the frequency band 4 400-4 800 MHz. Note that the technical characteristics are provided from the inputs listed section 2 in the main body of the document, with the relevant information summarized in sections 3 and 4 above. In the case of studies related to Appendix **30B**, an alternative format to provide the information of studies may need to be considered.]

[Editor’s note: The studies below have not been discussed in detail and are not agreed and will need to be carefully examined and possibly updated depending on comments, agreed parameters and information on updates to the propagation modelling.]

[Editor’s note: The Editor’s notes in this attachment were not fully reviewed nor agreed at the DG4GHz in the WP5D meeting #49 in June/July 2025.]

[Editor’s Note:

At the WP5D meeting #49 in June/July 2025, there was the comments below were raised.

- should harmonize tables of protection criteria for radio altimeters so as to enable direct comparison between study results.

- There is a need to clarify how the information provided by WP 5B (5D/127) was applied in the studies, these include the following notes:

“evaluation of potential interferers, notably for aggregate effects, should use the “operational altitude” in Tables 1 and 2. Additional information on operational considerations and appropriate technical characteristics/protection criteria for the other altitudes in the “Range of Altitude”, including ground manoeuvres, continue to be collected and liaised to WP 5D.”

- further discussion is needed to determine what should be the baseline scenarios to conduct the studies noting the requirements in Res. 256 for IMT to not impose technical or regulatory constraints on incumbent systems. See RR Chapter 8. Additional elements regarding the discussion on possible scenarios are included in the SWG Chair’s of 49 WP 5D Meeting.]

# A6.1 Technical Analysis

## A6.1.6 Study F [USA 766]

This study assesses a compatibility scenario between an IMT network and a radio altimeter system. It assumes the assessed IMT base stations are using an AAS that is servicing UEs within the service area. This study assumes the protection criteria of desensitization, false altitude generation, and front‑end overload contained in Recommendation ITU‑R M.2059, as provided, are applicable only at altitudes ranging from the upper limit of the “Range of reported altitude” () to the “Operational Altitude” () stipulated in Tables 1 and 2 of the Recommendation. Altitude adjustment factors () specific to each altimeter model are considered for each failure mode for altitudes less than the .

In this study the radio altimeter system is placed outside the service area of an IMT network, i.e, beyond the cell radius of the outermost IMT BSs in a network. Figure A6.1.6-2 in the methodology section of this study depicts an illustrative example compatibility operational scenario between an IMT network and a radio altimeter system along a two-dimensional plane at a single point in time and space.

### A6.1.6.1 Technical characteristics

#### A6.1.6.1.1 Technical and operational characteristics of IMT systems operating in the frequency band 4 400-4 800 MHz

From, Annex 4.15 of the Report on the 48th meeting of Working Party 5D titled, Working document on characteristics of terrestrial component of IMT for sharing and compatibility studies in preparation for WRC-27, ([5D/563/Annex4.15](https://www.itu.int/dms_ties/itu-r/md/23/wp5d/c/R23-WP5D-C-0563%21H4-N4.15%21MSW-E.docx)) the below listed technical and operational characteristics of IMT systems operating in the frequency band 4 400-4 800 MHz are utilized in this study:

‒ AAS BS IMT technology related parameters contained in Table 2,

‒ Suburban macro deployment-related IMT base station parameters contained in Table 11,

‒ Suburban UE parameters contained in Table 12,

‒ Extended AAS model summarized in Table 17,

‒ Macro Suburban IMT base station AAS beamforming characteristics contained in Table 18,

Recommendation ITU-R M.2101-0 is used to model and simulate an IMT network.

##### A6.1.6.1.1.1 IMT AAS BS Adjacent Band Modelling

This section provides the assumed IMT AAS BS antenna characteristics in the adjacent frequency band.

When considering the immediately lower adjacent frequency band(s) to the band proposed for IMT, the AAS array can be modelled using the extended AAS model summarized in Table 17 and Macro Suburban IMT base station AAS beamforming characteristics contained in Table 18 of [5D/563/Annex 4.15](https://www.itu.int/dms_ties/itu-r/md/23/wp5d/c/R23-WP5D-C-0563%21H4-N4.15%21MSW-E.docx) with an adjustment to the element spacing parameter by using a proxy array with different spacings. The mathematical relationship to calculate this proxy array spacing (for the adjacent band is found by Equation A6.1.6‑1.

 (A6.1.6-1)

where:

 is the spacing specified in Document [5D/563/Annex 4.15](https://www.itu.int/dms_ties/itu-r/md/23/wp5d/c/R23-WP5D-C-0563%21H4-N4.15%21MSW-E.docx) Table 18;

 is the centre frequency of the proposed IMT frequency band; and

 is centre frequency of the adjacent frequency band;

 Note: The typical channel bandwidth of the IMT frequency band can be used to calculate the value for . For example, assuming a 100 MHz typical channel bandwidth, the first lower value is 4 350 and the second lower value is 4 250.

Equation A6.2.1-1 also remains valid for the second adjacent band.

#### A6.1.6.1.2 Technical/operational characteristics and protection criteria of aeronautical radionavigation service (RR No. 5.438) operating in the frequency band 4 200‑4 400 MHz

Recommendation (Rec) ITU-R M.2059 Annex 2 provides the peak antenna gain and ‒3 dB beam width for the various radio altimeter types. Report ITU-R M.2319-0 has additional radio altimeter antenna assumptions which are considered in this study.

Rec ITU-R M.2059 Annex 3 provides protection criteria of radio altimeters via three different electromagnetic interference coupling mechanisms, receiver front end overload, receiver desensitization, and false altitude generation. Each failure mode corresponds to different mechanisms and assumptions and may apply to different frequency ranges. This study assesses against all modes. This study assumes an adjustment in these failure modes based on the altitude of the aircraft.

##### A6.1.6.1.2.1 Radio Altimeter Antenna

While the maximum gain and beamwidth for the various radio altimeter types are provided in Recommendation ITU-R M.2059, the antenna patterns are not. Therefore, a circular-symmetric parabolic shape is assumed for the radio altimeter antenna pattern. This assumption has also been used in Report ITU-R M.2319-0 Annex 3 Section A-3.1.1. This study also assumes the antenna parameters provided for 4 300 MHz are applicable over the 4 200‑4 400 MHz specified frequency range and the adjacent 4 400-4 800 MHz. This assumption provides an estimate of the radio altimeter antenna performance.

The antenna gain is defined by the 3dB‑beamwidth (“”) and the peak antenna gain (“”). Because of symmetry, a single incident angle (“”), which represents the combination of azimuth and elevation, is necessary to specify the antenna gain, in dBi, as a function of angle (“”). The is described by Equation A.6.1.6-2

 (A6.1.6-2)

Rec. ITU-R M.2059 states “the peak gain … of the radio altimeter antenna should be used if propagation paths are within ±30° of a vector orthogonal to the bottom of the aircraft.” However, this study assumes two approaches:

The first approach assumes the aircraft remains at a pitch and roll of 0 degrees at every sampled iteration. The second approach assumes the pitch and roll of the aircraft are randomly assigned for each sampled iteration of the Monte Carlo analysis. For both approaches, the peak gain of the radio altimeter antenna is only used for interfering signal path vectors orthogonal to the bottom of the aircraft.

In typical aviation operations, aircraft will perform pitch and roll manoeuvres appropriate for the altitude at which the aircraft is flying. The pitch and roll at each sampled iteration will be determined by using two randomly selected variables and , based on equations A.6.1.6-3 and A.6.1.6-4

 (A6.1.6-3)

 (A6.1.6-4)

where:

 : A uniformly sampled variable used to control radial distribution:

 for

 for

 0 for

 for

 : A uniformly sampled variable used to control the directional distribution

The second approach models a random aircraft attitude uniformly spread within a maximum cone of ±30° for an altitude greater than or equal to 122 m, a cone of ±20° for an altitude greater than or equal to 30 m and less than 122 m, and so on based on the distribution.

##### A6.1.6.2.2.2 Receiver Front-end Overload Threshold

Receiver front-end overload occurs when sufficient power from an interfering signal saturates the front-end of a radio altimeter receiver. The input power threshold (“”), cable loss(“”), frequency dependent rejection factor (“”), and must be considered to calculate the receiver front-end overload threshold at the receive port of the antenna as a function of frequency and altitude (“”). The for this compatibility study is bounded over the frequency range 4 200‑4 800 MHz, and calculated using Equation A6.1.6-5:

(A6.1.6-5)

where:

 : Frequency of interest in MHz.

 :Frequency dependent rejection factor, in dB. This factor is modelled as an attenuation of 24 dB per octave up to a maximum of 40 dB and is defined by Equation A6.1.6-6. (Note)

 Note: This study assumes 24 dB per octave indicates 24 dB of attenuation is realized at 8 800 MHz (at a frequency ratio of 2:1 compared to 4 400 MHz) and 2 100 MHz (at a frequency ratio of 1:2 compared to 4 200 MHz)

 *,* for ≤ 4 200

 *,* for 4 200 < < 4 400

 *,* for ≥ 4 400

(A6.1.6-6)

##### A6.1.6.1.2.3 Receiver Desensitization Threshold

The receiver desensitization threshold occurs when the interfering signal causes a noise floor increase within the radio altimeter receiver of 1 dB; an interference to noise ratio of -6 dB. The receiver thermal noise power (approx. −114 dBm/MHz), , IF bandwidth , noise figure at the receiver input , chirp bandwidth , and are considered to calculate the receiver desensitization at the receive port of the antenna as a function of frequency altitude (). For this study, the is bounded over the frequency range 4 200‑4 400 MHz, calculated using Equation A6.1.6-7 for frequency modulated carrier wave (“FMCW”) radio altimeters, and calculated using Equation A6.1.6-8 for the pulsed radio altimeters.

For FMCW radio altimeters:

(A6.1.6-7)

For pulsed radio altimeters:

(A6.1.6-8)

##### A6.1.6.1.2.4 False Altitude Generation

Unique to FMCW radio altimeter’s, false altitude reports occur when interference signals are detected as frequency components during spectral frequency analysis of the overall IF bandwidth. This occurs when the received interference power at the radio altimeter detector is greater than the detection threshold () of the radio altimeter. The for all FMCW radio altimeter models is ‑143 dBm/100 Hz. The , , and are considered to calculate the false altitude generation at the receive port of the antenna as a function of altitude . For this study, the is bounded over the frequency range 4 200‑4 400 MHz, assumed to be, and calculated using Equation A6.1.6-9.

(A6.1.6-9)

##### A6.1.6.1.2.5 Altitude Adjustment Factors

The altitude adjustment factor is used to approximate the radio altimeters improved resilience to interfering signals at lower altitudes. This assumption is supported by publicly available test data, including radio altimeter breakpoints and interference tolerance thresholds from Annex 3.6 of the Report on the 34th meeting of Working Party 5B ([5B/315](https://www.itu.int/dms_ties/itu-r/md/23/wp5b/c/R23-WP5B-C-0315%21H3-N03.06%21MSW-E.docx)), which show that radio altimeters are typically more resilient to interference at lower altitudes. This increased resilience is assumed to occur primarily due to two mechanisms: (1) the received signal is typically stronger at lower altitudes due to a reduction in signal loop loss, and (2) the receiver may implement automatic gain control, which reduces sensitivity to undesired signals as the desired signal strength increases.

For all three failure modes the is assumed to follow Equation A6.1.6-10 for FMCW radio altimeters and Equation A6.1.6-11 for pulsed radio altimeters.

For FMCW radio altimeters:

 for

 , for

(A6.1.6-10)

For pulsed radio altimeters:

 for

 , for

(A6.1.6-11)

The above approach overlayed with data from Annex 3.6 of the Report on the 34th meeting of Working Party 5B is provided in Figure A6.1.6-1.

Figure A6.1.6-1

Recommendation ITU-R M.2059 Receiver Desensitization With the Altitude Adjustment Factor Applied and AVSI Report Vol II BPs at 4 300 MHz



##### A6.1.6.1.2.6 Radio Altimeter Parameters Used in Protection Criteria Calculations

Table A6.1.6-1 provides the parameters for each radio altimeter model.

Table A6.2.1-1

Recommendation ITU-R M.2059 Radio Altimeter Model Specific Parameters

| Parameter | Units | Radio Altimeter Model |
| --- | --- | --- |
| A1 | A2 | A3 | A4 | A5 | A6 | D1 | D2 | D3 | D4 |
|  | **m** | 2500 | 2438 | 6000 | 1524 | 1524 | 457 | 1676 | 1737 | 6000 | 2424 |
|  | **km** | 12 | 12 | 20 | 12 | 12 | 12 | 12 | 12 | 20 | 12 |
|  | **dBi** | 10 | 10 | 10 | 13 | 11 | 11 | 11 | 10 | 11 | 13 |
|  | **degrees** | 60 | 55 | 60 | 35 | 45 | 45 | 60 | 60 | 60 | 45 |
|  | **dBm** | -30 | -53 | -56 | -40 | -40 | -40 | -30 | -43 | -53 | -40 |
| **(Note 1)** | **dBm/100 Hz** | -143 | -143 | -143 |  |  |  | -143 | -143 | -143 |  |
|  | **dB** | 6 | 6 | 2 | 6 | 6 | 6 | 6 | 0 | 2 | 0 |
|  | **MHz** | 2 | 0.25 | 2 | 9.2 | 6 | 16 | 0.312 | 1.95 | 2 | 30 |
|  | **dB** | 10 | 6 | 6 | 10 | 10 | 10 | 8 | 9 | 8 | 10 |
| **(Note 1)** | **MHz** | 104 | 132.8 | 133 |  |  |  | 150 | 176.8 | 133 |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |
| Note 1: Models with a listed are FMCW radio altimeters, and models without are pulsed radio altimeters |

#### A6.1.6.1.3 Propagation models used in the study

[Editor’s note: This section and the methodology section currently use FSPL as a placeholder. These sections are being updated to incorporate the model from ITU-R Recommendation P.528 and recommendations discussing terrain and clutter losses]

### A6.1.6.2 Methodology

This study assesses a compatibility scenario between an IMT network and a radio altimeter system.

A two-dimensional plane with discrete coordinates is established for the placement of the radio altimeter system; the plane exists along the (y, z) axis at x = 0 and starts at the edge of an IMT network. The plane is orthogonal to one of the outermost IMT sectors and extends 70 km in the y direction and 20 km in the z direction. The step size in the y direction is 10 km and the step size in the z direction is 10 m. The lowest studied altitude (lowest studied z-coordinate) is 10 m and the highest is 20 km. This study assumes a radio altimeter system may occupy any grid point that exists within this plane. The aircraft pitch and roll for each snapshot is randomly determined by Equations A6.1.6-3 and A6.1.6-4. See Figure A6.1.6‑2.

Figure A6.1.6-2

Illustrative Example Compatibility Operational Scenario Between an IMT Network and a Radio Altimeter System at a Single Point in Time and Space



Recommendation ITU-R M.2101-0, *“contains the methodology for modelling and simulation of IMT networks for use in sharing and compatibility studies between IMT and other systems and/or applications*.” Given this study is concerned with the emissions of the IMT BS and not the IMT UE, the downlink simulation setup is considered. A network topology consisting of a cluster of nineteen BS sites, each site with three sectors, and each sector randomly populated with a certain number of UEs is generated. One of the outermost BSs within the network is centred about the (0,0,0) grid point. Three UEs per sector are randomly chosen from among those passing the minimum SINR check to receive service. This configuration represents one sample iteration of an IMT network configuration. A minimum of 100,000 iterations for each individual aircraft location are sampled to collect the statistics.

Every possible occupied radio altimeter (0,y,z) coordinate is assessed against each IMT configuration to determine the minimum horizontal distance (“”) needed from a BS in an IMT network to ensure that the protection criteria of the associated radio altimeter model at the receive port of the antenna, in dBm/MHz of a radio altimeter is not exceeded.

A (0,y,z) coordinate is flagged as an exceedance when the aggregated power of all IMT signals at the radio altimeter antenna receive port is greater than protection criteria (, , or , i.e. (“”)), after accounting for losses in the propagation path, and any other prescribed study factors. Equation A6.1.6-12 provides the inequality condition to flag an (0,y,z) coordinate.

(A6.1.6-12)

Where:

 : The total number of active BS transmitting in the sampled iteration.

 : The kth active sector in the sampled iteration.

 : the e.i.r.p. in the direction of the assessed (0,y,z) coordinate of the kth active sector in the sampled iteration, in dBm/MHz

 : The path loss between the BS and the radio altimeter, in dB

 : The incident angle at which the interfering signal enters the radio altimeter system, in degrees

 : Study factor(s), in dB.

Once all (0,y,z) coordinates are assessed, the lateral distance to nearest IMT BS is collected and reported as . If the result for all iterations indicates no (0,y,z) airspace is impacted the is reported as the cell size. The results at each individually studied (0,y,z) coordinate will be a CDF of power at the receive port of the radio altimeter antenna where a vertical line for each will indicate the percent of sampled iterations that studied location where the power exceeds the protection criteria. The result of summarizes all the individual CDF results indicating a lateral separation distance between the radio altimeter and a BS in an IMT network. Noting this study provides no information regarding if an aircraft within the bounds of the modelled IMT network will receive interference.

### A6.1.6.3 Study results

[Editor’s note: This section provides the sharing and compatibility study results of this study.]

### A6.1.6.4 Summary and analysis of the results of Study F

[Editor’s note: This section provides the summary and analysis of the results of this study for both the protection of incumbent services (in band and adjacent bands) and without imposing additional regulatory or technical constraints on those incumbent services.]