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| U.S. Radiocommunications Sector  Fact Sheet | | |
| **Working Party:** ITU-R WP 5B | **Document No:** USWP5B\_xyz | |
| Ref: Resolution 256 (WRC-23) | **Date:** 2/8/25 | |
| **Document Title:** Additional technical information for sharing studies  under WRC-27 agenda item 1.7 | | |
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| **Purpose/Objective:** This contribution presents additional information on radio altimeters and WAIC operating in the 4.2-4.4 GHz band. | | |
| **Abstract:** This contribution presents additional information for WP 5B’s consideration when developing their response liaison station to WP 5D concerning WRC-27 agenda item 1.7. | | |

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| Subject: WRC-27 agenda item 1.7 | Document 5B/USA-E |
| Date 2025 |
| English only |
| United States of America | |
| Additional technical information for sharing studies under WRC-27 agenda item 1.7 | |

**Summary**

At the last meeting (November 2024), Working Party 5B, as a contributing group for WRC-27 agenda item 1.7, informed the CPM-27 Steering Committee that more time is required to develop technical characteristics, protection criteria, and operational consideration of Radio Altimeters and Wireless Avionics Intra Communication (WAIC) systems in the frequency bands 4 200-4 400 MHz which will be essential for sharing and compatibility studies.

In the attached, the United States presents a draft reply liaison to Working Party 5B regarding this topic.

In addition, the United States provides a technical analysis of recent aviation testing of Radio Altimeter (RA) performance for altitudes other than operational altitude and an analysis of the ICAO proposed WAIC requirements, which are both discussed in the draft liaison.

**Radio Altimeter Performance Analysis**

As observed from aviation industry test data, RAs operating at lower heights, near terrestrial services, are resilient to both receiver overload and unwanted in-band emissions. As an example, in the United States, the aviation industry measurements were performed by the Aerospace Vehicle Systems Institute (AVSI), a cooperative research environment which included major aerospace companies and government organizations. These measurement data sets are publicly available.

It should be noted that the performance depicted in Rec. ITU-R M.2059 was specific to the edge of coverage – where the receiver is operating at its weakest level before losing the link, which is at high altitude.  The RA performance (both in band and from unwanted emissions into the 4.2 – 4.4 GHz band) at heights lower than the operating altitude would be better since the desired signal would be stronger. As observed from aviation industry test data, RAs operating at lower heights, near terrestrial services, are resilient to both receiver overload and unwanted in-band emissions. The aviation industry measurements were performed by the Aerospace Vehicle Systems Institute (AVSI), a cooperative research environment which included major aerospace companies and government organizations. These measurement data sets are publicly available.

**RA Receiver Overload Findings Using Publicly Available Measurement Data**

Publicly available aviation industry test data for receiver overload confirms that RA performance is better at lower heights in the critical phases of flight versus at the maximum operational altitude. The Aerospace Vehicle Systems Institute’s (AVSI) Volume III report provided Commercial/Transport RA test data collected by RA manufacturers over a broad range of out-of-band center frequencies. Volume III data indicated that the RA’s receiver overload threshold is typically 13 to 24 dB better (higher) at 200 feet height versus the threshold at the maximum height tested. This is summarized in Table 1[[1]](#footnote-2) where “Delta” quantifies the improvement in receiver overload performance at the lower height.

**Table 1: RA Receiver Overload Performance is Better at Low Aircraft Altitude[[2]](#footnote-3)**



The tables below compare receiver overload thresholds in M.2059 (at maximum operational height) versus those tested by AVSI at the lower height corresponding to the critical takeoff and landing scenarios.

The M.2059 guidance is significantly different than the aviation test data at low heights. Table 2 compares the AVSI-tested RAs against the five best-performing RAs in M.2059.[[3]](#footnote-4) The M.2059 guidance varies from the RA test data by 25 to 42 dB.

**Table 2: AVSI RA Receiver Overload Threshold Data versus Best-performing M.2059 RAs**



When comparing test data to M.2059’s [worst-performing] RAs, the test data is 41 to 53 dB better as shown in Table 3.

**Table 3: AVSI RA Receiver Overload Threshold Data versus Worst-performing M.2059 RAs**



The reason for the large deltas between AVSI’s measured receiver overload threshold and that of M.2059 is the following: at low heights, the RA’s path loss is smaller than at the maximum operational height. Since the wanted signal is stronger at low heights, the RA’s receiver is more resilient.

The manufacturer-reported data in AVSI’s Volume III closely matched the earlier test results by AVSI reported in Volume I, which focused on out-of-band signals below 4000 MHz.[[4]](#footnote-5) The RTCA 2020 Report[[5]](#footnote-6) employed the Volume I receiver overload and Volume II unwanted emissions test results.

Table 4 shows the Volume I data has a similar delta of up to 47 dB from the M.2059 guidance. An improvement of 47 to 53 dB is a factor of 50,000 to nearly 200,000. Any sharing and compatibility study should appropriately make note of this much-improved RA performance at low height.

**Table 4: AVSI Vol. I Comparison to M.2059 Worst/Most Sensitive Thresholds[[6]](#footnote-7)**



Based on publicly available data from aviation industry testing, more up-to-date measurements of altimeter performance are available and should be used in sharing and compatibility studies.[[7]](#footnote-8) Finally, while some administrations have been implementing RA filters/retrofits to improve their RF blocking performance on categories of airplanes, those filters cannot be assumed to be installed on all aircraft and should only be modelled as part of a sensitivity analysis.[[8]](#footnote-9)

**RA Receiver Desensitization Findings Using Publicly Available Measurement Data**

The publicly available AVSI data of RA receiver desensitization from unwanted (IMT) emissions into the RA band shows a similar pattern of improved performance at low height, just as the RA receiver overload data sets indicated.

Table 5 compares the RA’s desensitization threshold at maximum height tested versus 200 ft height, from AVSI’s Volume II data set.

**Table 5: Receiver Desensitization Performance is Better at Low Aircraft Height[[9]](#footnote-10)**



As shown in Table 5, the receiver desensitization performance was better (higher desense threshold) by 14 to 40 dB at 200 ft versus at the highest height tested.

Comparing the public data to the M.2059 guidance for receiver desensitization shows a larger improvement in the commercial RA performance of up to 49 dB, a factor of nearly 80,000 times. This is shown in Table 6.

**Table 6: RA Desensitization Performance is Much Improved in AVSI Vol. II versus M.2059**



In summary, for sharing and compatibility studies considering lower heights than operational altitude, publicly available aviation industry test data for RA receiver overload and desensitization should be used.

**WAIC Technical Analysis**

The WAIC SARPS-derived other-band interference threshold of -120 dBm/MHz contains a technical error. The SARPS assumed that external sources of interference are additive to the thermal noise level prior to accounting for the receiver’s own noise, as shown in Table 7 below.

**Table 7: WAIC SARPS Incorrect Calculation of Permissible External Interference**



The correct approach to incorporating an external interference level is to reference it at the detector, following the summation of the internal receiver noise, consisting of thermal noise plus the noise figure, resulting in -110 dBm/MHz as shown in Table 8.

**Table 8: Correct Derivation of Permissible External Interference**



More importantly, the WAIC SARPS approach ignored the real-world environment of the 4200-4400 MHz band, in which aviation systems with co-channel emissions exist and exert a distinct impact on the WAIC link budget. Several scenarios are presented below to illustrate that even Table 8’s corrected external interference threshold is far below the ambient noise environment. The WAIC SARPS must be corrected to reflect the noisier operational environment, and correspondingly higher permissible external interference threshold.

***Scenario 1: Landing Aircraft RAs Interfering with Taxiway WAIC Receiver***

The first scenario assumes the landing aircraft scenario from the RTCA 2020 Report, Figure A-2, part c), reproduced below in Figure 1.

**Figure 1: RTCA 2020 Report Landing Scenario**

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The landing aircraft’s RAs are transmitting during the landing approach. A second aircraft, on the taxiway nearby, is operating WAIC co-channel as envisioned by M.2067. The RA interference level at the WAIC receiver well exceeds the other-band interference threshold defined in the WAIC SARPS, as shown in Table 9.

**Table 9: Landing Aircraft RA Interfering with WAIC**



In this scenario from the RTCA 2020 Report, the ambient RF environment exceeds the WAIC SARPS by 45 dB.

The RAs on the landing aircraft greatly increase the WAIC ambient noise level to such a degree that any WAIC receivers located outside of the aircraft will not work, as shown in Table 10. The WAIC receiver requires a desired signal to be 41.6 dB stronger to be detected in this environment.

**Table 10: Landing Aircraft RA Interference Precludes WAIC Service Outside the Aircraft**



***Scenario 2: Overflight – RA to WAIC Interference***

The second scenario assumes one aircraft with three RAs is flying 1,000 feet above a second aircraft, on a different heading, equipped with WAIC.[[10]](#footnote-11) The resulting RA signal levels at the WAIC receiver are calculated in Table 11.

**Table 11: RA Interference to WAIC In Flight: 1,000 ft**



An RA-equipped aircraft passing 1,000 ft above an aircraft operating WAIC would exceed the other-band interference threshold proposed in the WAIC SARPS by 44 dB.

Another example of overflight involves two aircraft traveling in the same direction, with a vertical separation of 2,000 ft. Table 12 shows that the WAIC exceedance is 38 dB.

**Table 12: RA Interference to WAIC In Flight: 2,000 ft**



In both overflight scenarios, the RA interference is large enough to preclude WAIC operation outside of the aircraft. The link budget for the 2,000 ft separation distances is shown in Table 13.

**Table 13: RA Overflight Interference Precludes WAIC Service Outside the Aircraft**



**WAIC Conclusions**

As the new WAIC systems are being proposed to operate co-channel with radio altimeters, the WAIC SARPS external interference threshold of -120 dBm/MHz should be re-evaluated (or revised upward significantly), given the high levels of interference from other co-channel aviation services.

Attachment

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| REPLY LIAISON STATEMENT TO WORKING PARTY 5D  (COPY FOR INFORMATION TO WORKING PARTIES 1B, 3K, 3M,  4A, 4C, 5A, 5C, 7B, 7C, 7D AND ICAO) |
| **Additional technical information for sharing studies  under WRC-27 agenda item 1.7** |

Working Party (WP) 5B would like to thank WP 5D for its liaison statements (Document [5B/147](https://www.itu.int/md/R23-WP5B-C-0147/en)) requesting additional information on radio altimeter performance in the frequency band 4200- 4400 MHz and updates to considerations of WAIC as noted in the liaison statement to WP 5D from ICAO (Document [5D/257](https://www.itu.int/md/R23-WP5D-C-0257/en)).

**Radio Altimeters**

A radio altimeter (RA) is a radar system mounted to the underside of an aircraft. A radio altimeter is the only system that provides a continuous measurement of the aircraft’s height above ground, clearance height above obstacles, and the rate of change of those measurements. Modern aviation would not have the safety record it does without this system. Radio altimeters are integrated into several safety critical aircraft functions; such systems include, but are not limited to, the flight control system, airborne collision avoidance systems, and terrain awareness warning system. These systems combined enable and enhance several safety and navigation functions throughout all phases of flight on all commercial aircraft and a wide range of other civil aircraft.

As noted in WP 5B’s liaison statement to WP 5D, Rec. [**ITU-R M.2059-0**](https://www.itu.int/rec/R-REC-M.2059/en) provides the technical and operational characteristics, and protection criteria of radio altimeters, which operate during all phases of flight. Representative radio altimeter operational and technical characteristics are contained in Annex 1 and Annex 2; and radio altimeter protection criteria are contained in Annex 3. It should be noted that the evaluation of potential interferers, notably for aggregate effects, should use the “operational altitude” in Tables 1 and 2.

As observed from aviation industry test data, RAs operating at lower heights, near terrestrial services, are resilient to both receiver overload and desensitization. Based on publicly available data from aviation industry testing, more up-to-date measurements of altimeter performance are available and should be used in sharing and compatibility studies.[[11]](#footnote-12)

Finally, while some administrations have been implementing RA filters/retrofits to improve their RF blocking performance on categories of airplanes, those filters cannot be assumed to be installed on all aircraft and should only be modelled as part of a sensitivity analysis.[[12]](#footnote-13)

**Modelling of Cross-Border Interference / Operational Scenarios**

While ICAO provided a general overview of operational scenarios for interference modelling, many of those scenarios are more applicable to domestic scenarios (e.g. on the runway), where co-coverage of IMT in one country would not include an airport in a neighboring country. To model the cross-border protection of radio altimeters…. [*text to be developed with interested USWP 5B participants so we can ensure accurate modelling to ensure the protection of the service in the context of ITU/cross-border analysis.*]

**Wireless Avionics Intra-Communication systems (WAIC)**

WAIC systems provide safety-related wireless communication over short distances between two or more points onboard a single aircraft. They are installed at various locations both within and on the outside of the aircraft, and operate during all phases of flight, including on the ground (as described in Report [ITU-R M.2283-0](https://www.itu.int/pub/R-REP-M.2283-2013)). WAIC systems do not provide air-to-ground, air-to-satellite, or air-to-air communications. They are only used for aircraft communications related to the safety and regularity of flight, allowing greater flexibility and redundancy to the existing internal aircraft wiring. One example of communications provided by WAIC systems is sensor information used to monitor the health of an aircraft structure and critical systems, and to communicate this information to a central onboard entity.

WP 5B has previously provided Rec.[ITU-R M.2067-0](https://www.itu.int/rec/R-REC-M.2067/en) which gives the technical and operational characteristics and protection criteria for WAIC systems operating in the frequency band 4 200-4 400 MHz, as described in its Annex.

WP 5B also notes that ICAO is in the process of publishing WAIC standards and recommended practices (SARPs) to be contained in ICAO Annex 10 to the Convention on International Civil Aviation. Based on technical analysis submitted to WP 5B, it appears that WAIC usage outside of aircraft, especially with ICAO proposed requirements, indicate that it cannot work in the current interference environment with other operational systems who have spurious emissions falling into the 4.2 – 4.4 GHz band. However, this coexistence issue does not occur if a reasonable interference threshold is specified and the WAIC receiver is inside the fuselage. Thus, the parameters proposed in Rec. ITU-R M.2067 should be used only for studies considering indoor WAIC receivers, where the interference signal of radio altimeters will be additionally attenuated due to the aircraft fuselage.

Working Party 5B requests to be kept informed on the progress of the studies under WRC-27 agenda item 1.7.

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1. *AFE 76s2 Report Derivation of Radar Altimeter Interference Tolerance Masks Volume III: Manufacturer-Provided Test Results*, AVSI, Doc ID 76s2-REP-05, Apr 2022. Maximum height data from Tables 6-28, 6-33, 8-17, 8-18, and Figure 9-11. Low height data from Tables 6-7, 6-9, 8-8, 8-10, and Figure 9-9. Pass/fail criteria of +/- 2% or No Computed Data. The third criterion, mean error of 0.5%, has no basis in aviation standards, and RAs are not designed to meet a 0.5% accuracy level. Furthermore, a mean +/-0.5% criterion requires a longer-term RA exposure to a static IMT environment; however, the scenario assessed of a non-nominal takeoff or landing with the aircraft flying past an IMT base station is an event in the multi-millisecond time scale. The IMT emissions would not be present long enough in the time domain to affect the long-term mean reported height. See *Honeywell Component Maintenance Manual Part No. 066-50007*, October 10, 2007, Table 3, p. 3, +/- 1.5 ft or 2%; RTCA *DO-155 Minimum Performance Standards Airborne Low-Range Radar Altimeters*, November 1, 1974, p. 3 Table 1, +/- 3% from 100 to 500 ft; ARINC *Characteristic 707-7*, April 6, 2009, +/-1.5 ft or 2%, whichever is greater; FAA TSO C87a, Airborne Low Range Radio Altimeter, 5/31/12, referencing EUROCAE ED-30 Tables 1 and 2, +/-3% or +/-5%; FAA TSO C87, Airborne Low Range Radio Altimeter, 2/1/66, Table 1: +/- 3 ft or +/-3%, whichever is greater. Most RAs flown today were certified under FAA TSO C87 with the accuracy requirement of +/-3% over 95% measurements – more relaxed than AVSI’s +/-2% with a 1%/99% exceedance. [↑](#footnote-ref-2)
2. Receiver overload thresholds reported herein are measured in dBm/100 MHz, with no added margin. [↑](#footnote-ref-3)
3. Recommendation ITU-R M.2059, *Operational and Technical Characteristics and Protection Criteria of Radio Altimeters Utilizing the Band 4200-4400 MHz,* (02/2014), Tables 1 and 2. Best five RAs are Models A1, D1, A4, A5, A6, D4. Note that A4, A5, A6, and D4 are identical at -40. Worst five RAs are A3, A2, D3, D2, and the four-way tie of A4, A5, A6 and D4. [↑](#footnote-ref-4)
4. AVSI, *AFE 76s2 Report Derivation of Radar Altimeter Interference Tolerance Masks Volume I: Introduction, Test Procedures, and Fundamental Test Results*, Doc ID 76s2-REP-03, Dec. 2021, Table 3-1. [↑](#footnote-ref-5)
5. RTCA, *Assessment of C-Band Mobile Telecommunications Interference Impact on Low Range Radar Altimeter Operations*, RTCA Paper No. 274-20/PMC-2073 (Oct. 7, 2020). [↑](#footnote-ref-6)
6. NB means no breakpoint, or flawless operation, up to the maximum interference power of the test setup. [↑](#footnote-ref-7)
7. The recent multi-stakeholder coexistence study conducted by CEPT culminating in ECC Report 362, with robust aviation and wireless industry participation, relied on the publicly available AVSI data to derive the pass/fail thresholds. The report did not rely on M.2059 guidance. [↑](#footnote-ref-8)
8. The publicly available aviation data pre-dates all filter/retrofit programs. [↑](#footnote-ref-9)
9. AVSI, *AFE 76s2 Report Derivation of Radar Altimeter Interference Tolerance Masks Volume II: Spurious Test Results*, Doc ID 76s2-REP-04, Dec. 2021, Table 4-2. [↑](#footnote-ref-10)
10. *Instrument Procedures Handbook*, FAA-H-8083-168, Federal Aviation Administration, Department of Transportation, 2017, at 2-2. “When operating under IFR, between the surface and an altitude of Flight Level (FL) 290, no aircraft should come closer vertically than 1,000 feet.” [↑](#footnote-ref-11)
11. Add link to reference material or place material/analysis in WP 5B Chair’s Report. [↑](#footnote-ref-12)
12. The publicly available aviation data pre-dates all filter/retrofit programs. [↑](#footnote-ref-13)