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| **US Radiocommunications Sector****Fact Sheet** |
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| **Purpose/Objective:** This document will provide a validation of ITU-R M.2059’s radio altimeter characteristics with measured radio altimeter data  |
| **Abstract:** Due to various national efforts over the last several years, there is a limited amount of measured radio altimeter data publicly available, and it would be useful to compare this data with the contents of ITU-R M.2059 as a validation. This effort may help in discussions in how to apply the data in ITU-R M.2059 in sharing studies.  |

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| Working Document Towards a Preliminary Draft new report iTU-R M.[ITU-R M.2059 Validation]Validation of ITU-R M.2059 with measured radio altimeter data |

# 1 Introduction

ITU-R Recommendation M.2059 was approved in 2015 and provides characteristics of radio altimeters, a system that operates under the aeronautical radionavigation service, including background information of how the system is used on aircraft. The characteristics include three protection criteria to ensure the operations of this system that is critical for the safe operation of aircraft. Since the publication of ITU-R Rec. M. 2059, some radio altimeter data has been published, and it is useful to validate data within ITU-R Rec. M.2059 with this data.

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| Working Document Towards a Preliminary Draft new report iTU-R M.[ITU-R M.2059 Validation] |
| Validation of ITU-R M.2059 with measured radio altimeter data |

1. **Introduction**

ITU-R Recommendation M.2059, Operational and Technical Characteristics and Protection Criteria of Radio Altimeters, was approved in 2015 and provides characteristics of radio altimeters, a system that operates under the aeronautical radionavigation service, including background information of how the system is used on aircraft. The characteristics include three protection criteria to ensure the operations of this system that is critical for the safe operation of aircraft. Since the publication of ITU-R Rec. M.2059, some radio altimeter data has been published, and it is useful to validate data within ITU-R Rec. M.2059 with this data.

1. **ITU-R Recommendation M. 2059 Operational and Technical Characteristics and Protection Criteria of Radio Altimeters**
	1. **Radio Altimeter Description**

As described in ITU-R Rec. M.2059, the basic function of the radio altimeter is to provide accurate height measurements above the Earth surface with a high degree of accuracy and integrity during the approach, landing, and climb phases of aircraft operation. These operations can occur over surfaces with a wide variety of reflectivity, which may impact the radio altimeter’s performance. The distance measured by the radio altimeter is referred to as Height above Terrain (HAT), which is the distance from the terrain to the aircraft. This is a different measurement than altitude which is referenced to sea-level.

The information provided by the altimeter not only gives the flight crew (pilots) situational awareness, it also can be used by many other onboard safety systems. These systems can include automatic throttles (navigation), thrust reversers (used to stop the aircraft on the runway), terrain awareness warning systems (TAWS), terrain collision avoidance system (TCAS), the predictive wind shear system, as well as the autopilot, which includes numerous automatic landing systems.

Altimeters can be installed on a variety of aircraft and connect to any combination of the systems mentioned above, the aircraft types that an altimeter may be installed from range from small single pilot aircraft, small ‘business’ aircraft including jets, regional commercial airliners, and large airliners. Radio altimeters are also installed on a variety of helicopters.

Installation details vary by the aircraft types, but one, two, or three altimeters may be installed on aircraft. Typically, large airliners have two or three altimeters installed to ensure that the required precision data is available for aircraft systems.

* 1. **Radio Altimeter Characteristics**

The radio altimeter model specific parameters contained in Recommendation ITU-R M.2059 utilized in protection criteria calculations discussed in Section 2.3 are provided below in Table 2.2-1.

**Table 2.2-1: Select Radio Altimeter Model Specific Parameters**

| **Parameter** | **Units** | **Radio Altimeter Model** |
| --- | --- | --- |
| **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **D1** | **D2** | **D3** | **D4** |
| **Input Power Threshold****(“**$P\_{T,RF}$**”)** | **dBm** | -30 | -53 | -56 | -40 | -40 | -40 | -30 | -43 | -53 | -40 |
| **Detection Threshold****(“**$DT$**”) (Note 1)** | **dBm / 100 Hz** | -143 | -143 | -143 |  |  |  | -143 | -143 | -143 |  |
| **Cable Loss****(“**$L\_{c}")$ | **dB** | 6 | 6 | 2 | 6 | 6 | 6 | 6 | 0 | 2 | 0 |
| **IF bandwidth****(“**$BW\_{IF}$**”)** | **MHz** | 2 | 0.25 | 2 | 9.2 | 6 | 16 | 0.312 | 1.95 | 2 | 30 |
| **Noise Figure****(“**$N\_{F}$**”)** | **dB** | 10 | 6 | 6 | 10 | 10 | 10 | 8 | 9 | 8 | 10 |
| **Chirp Bandwidth****(“**$BW\_{C}$**”) (Note 1)** | **MHz** | 104 | 132.8 | 133 |  |  |  | 150 | 176.8 | 133 |  |
| Note 1: Models with a listed $BW\_{C}$ and $DT $are FMCW radio altimeters, and models without are pulsed radio altimeters |

* 1. **Radio Altimeter Protection Criteria**

There are three protection criteria described in ITU-R M.2059, Receiver Desensitization, Receiver Front-end Overload, and False Altitude Generation.

* + 1. **Receiver Desensitization**

Receiver desensitization 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 desensitization is defined at the receiver input, therefore the thermal noise power (approx. −114 dBm/MHz), cable loss(“$L\_{c}$”), IF bandwidth $\left("BW\_{IF}"\right)$, noise figure at the receiver input $\left("N\_{F}"\right)$, and chirp bandwidth $\left("BW\_{C}"\right)$ must be considered to calculate the receiver desensitization at the receive port of the radio altimeter receive antenna ($"RD\_{Rx}"$). The $RD\_{Rx}$ is bounded over the frequency range 4 200‑4 400 MHz, calculated using Equation 2.3-1 for frequency modulated carrier wave (“FMCW”) radio altimeters, calculated using Equation 2.3‑2 for the pulsed radio altimeters, and provided in Table 2.3-1 for each specified radio altimeter model.

For FMCW radio altimeters:

 $RD\_{Rx}=$ $-114+10\*\left(log\_{10}\left(BW\_{IF}\right)-log\_{10}\left(^{2BW\_{IF}}/\_{BW\_{C}}\right)\right)+N\_{F}+L\_{c}-6$

 $-114+10\*log\_{10}\left(BW\_{C}\right)+N\_{F}+L\_{c}-9$

Equation 2.3-1

For pulsed radio altimeters:

$RD\_{Rx}=-114+10\*log\_{10}\left(BW\_{IF}\right)+N\_{F}+L\_{c}-6$

Equation 2.3-2

**Table 2.3-1: Radio Altimeter Model Specific Receiver Desensitization**

| **Parameter** | **Units** | **Radio Altimeter Model** |
| --- | --- | --- |
| **A1** | **A2** | **A3** | **A4** | **A5** | **A6** | **D1** | **D2** | **D3** | **D4** |
| $$RD\_{Rx}$$ | **dBm /****BW** | -86.8 / 104 MHz | -89.8 /132.8 MHz | -93.8 / 133 MHz | -94.4 / 9.2 MHz | -96.2 / 6 MHz | -92.0 / 16 MHz | -87.2 /150 MHz | -91.5 / 176.8 MHz | -91.8 / 133 MHz | -95.2 /30 MHz |
| $$RD\_{Rx}$$ | **dBm / MHz** | -107 | -111 | -115 | -104 | -104 | -104 | -109 | -114 | -113 | -110 |

* + 1. **Receiver Front-end Overload**

Receiver front-end overload occurs when sufficient power from an interfering signal saturates the front-end of a radio altimeter receiver.

The receiver front-end overload is defined at the receiver input. The input power threshold (“$P\_{T,RF}$”), $L\_{c}$, and frequency dependent rejection factor (“$FDR\_{f}$”) must be considered to calculate the receiver front-end overload at the receive port of the radio altimeter receive antenna as a function of frequency (“$RFO\_{Rx}(f\_{0})$”). The $RFO\_{Rx}(f\_{0})$is calculated using Equation 2.3-3 and plotted in Figure 2.3-1:

$$RFO\_{Rx}(f\_{0})= P\_{T,RF}+L\_{c}+FDR\_{f}\left(f\_{0}\right)$$

Equation 2.3-3

where:

$f\_{0}$: Frequency of interest in MHz.

$FDR\_{f}\left(f\_{0}\right)$: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 2.3-4

Note: The following formula 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)

$FDR\_{f}\left(f\_{0}\right)=$$Min\left(40 , 24\*log\_{2}\left(^{4200}/\_{f\_{0}}\right)\right)$*,* for $f\_{0} $≤ 4 200

$0$*,* for 4 200 < $f\_{0} $< 4 400

$Min\left(40 , 24\*log\_{2}\left(^{f\_{0}}/\_{4400}\right)\right)$*,* for $f\_{0} $≥ 4 400

Equation 2.3-4



**Figure 2.3-2: Radio Altimeter Model Specific Receiver Front-end Overload Over the Frequency Range of 1 000 MHz to 15 000 MHz**

* + 1. **False Altitude Generation**

Unique to FMCW radio altimeter’s, false altitude generation occurs 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 ($"DT"$) of the radio altimeter. The $DT$ for all FMCW radio altimeter models is ‑143 dBm/100 Hz.

The $DT$ is defined at the receiver input, therefore the $L\_{c}$ and $BW\_{C}$ must be considered to calculate the false altitude generation at the receive port of the radio altimeter receive antenna $("FA\_{Rx}")$. The $FA\_{Rx}$ is bounded over the frequency range 4 200‑4 400 MHz, calculated using Equation 2.3‑5, and provided in Table 2.3-2 for each specified radio altimeter model.

 $FA\_{Rx}=$ $DT-10\*log\_{10}\left(^{2\*100}/\_{BW\_{C}\*10^{6}}\right)+L\_{c}$

 $DT+10\*log\_{10}\left(BW\_{C}\right)+L\_{c}+37$

Equation 2.3-5

**Table 2.3-2: Radio Altimeter Model Specific False Altitude Generation**

| **Parameter** | **Units** | **Radio Altimeter Model** |
| --- | --- | --- |
| **A1** | **A2** | **A3** | **D1** | **D2** | **D3** |
| $$FA\_{Rx}$$ | **dBm /****BW** | -79.8 / 104 MHz | -78.8 /132.8 MHz | -82.8 / 133 MHz | -78.2 /150 MHz | -83.5 / 176.8 MHz | -82.8 / 133 MHz |
| $$FA\_{Rx}$$ | **dBm / MHz** | -100 | -100 | -104 | -100 | -106 | -106 |

1. **Radio Altimeter Measured Data**
	1. **Radio Altimeter Measured Data Background**

As a result of spectrum allocation changes in many administrations, there was a need to better understand the behaviour of radio altimeters due to interference from adjacent and nearby frequency bands. Much of this data is considered proprietary, but some data was publicly released by the aviation industry. The data[[1]](#footnote-1) is not comprehensive and only provides a snapshot to individual units that were tested. The data is available as three volumes, the first volume[[2]](#footnote-2) specifically provides data regarding the 3700-3980 MHz frequency band, the second volume provides data regarding interference into the 4200-4400 MHz frequency band, and the third volume is a collection of additional test results of radio altimeters from altimeter manufacturers.

1. Data is published at [https://avsi.aero/avsi-publishes-volume-iii-of-the-afe-76s2-report/](https://avsi.aero/avsi-publishes-volume-iii-of-the-afe-76s2-report/%20) [↑](#footnote-ref-1)
2. This volume also contains some compatibility analysis studies that will not be used in this document, only the radio altimeter data will be extracted [↑](#footnote-ref-2)