



Recommendation ITU-R M.2059-0
(02/2014)

**Operational and technical characteristics
and protection criteria of radio altimeters
utilizing the band 4 200-4 400 MHz**

M Series
**Mobile, radiodetermination, amateur
and related satellite services**



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Foreword

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P	Radiowave propagation
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SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.

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RECOMMENDATION ITU-R M.2059-0

Operational and technical characteristics and protection criteria of radio altimeters utilizing the band 4 200-4 400 MHz

(2014)

Scope

This Recommendation describes the technical and operational characteristics, and protection criteria of radio altimeters used in the aeronautical radionavigation service.

The ITU Radiocommunication Assembly,

considering

- a) that radio altimeters are an essential component of aeronautical safety-of-life systems, including precision approach, landing, ground proximity and collision avoidance systems;
- b) that radio altimeter systems operate in the aeronautical radionavigation service;
- c) that radio altimeters have been fitted for decades to all types of aircraft;
- d) that radio altimeters are operational during and must operate without harmful interference for the entire flight;
- e) that a radio altimeter system on a single aircraft consists of up to three identical radio altimeters;
- f) that there is a need to document the spectrum usage characteristics and deployment of radio altimeter systems on a worldwide basis;
- g) that coexistence between radio altimeters located on the same aircraft is achieved by technical and operational mitigation methods,

recognizing

- a) that the aeronautical radionavigation service is a safety service;
- b) that radio altimeter systems operate in the frequency band 4 200-4 400 MHz on a worldwide basis;
- c) that representative technical and operational characteristics and protection criteria of radio altimeter systems are required for spectrum management and deployment planning;
- d) that the airworthiness certification of radio altimeters is a lengthy and costly process;
- e) that radio altimeters require a bandwidth of 196 MHz,

noting

- a) that, in accordance with RR No. **4.10**, the safety aspects of radionavigation and other safety services require special measures to ensure their freedom from harmful interference;
- b) that regulatory requirements for radio altimeters are specified by the International Civil Aviation Organization (ICAO);
- c) that Recommendation ITU-R M.1461 is used as a guideline in analysing the compatibility between radars (including radio altimeters) operating in the radiodetermination service with systems in other services,

recommends

- 1 that operational and technical characteristics of the radio altimeters described in Annex 1 and Annex 2 should be considered representative of those systems operating in the frequency band 4 200-4 400 MHz and should be used when conducting compatibility studies;
- 2 that the protection criteria provided in Annex 3 should be used for protection of radio altimeters operation.

Annex 1

Operational characteristics

1 Introduction

The band 4 200-4 400 MHz is currently allocated to the aeronautical radionavigation service (ARNS) and is reserved exclusively for radio altimeters installed onboard aircraft and for the associated transponders on the ground by Radio Regulations footnote No. **5.438**.

The basic function of a 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 representing a wide variety of reflectivity. Such information is used for many purposes and the high degree of accuracy and integrity of those measurements must be achieved regardless of the Earth surface, such as during final approach and flare guidance in the last stages of automated approach to land. It is also used to determine the particular altitude in which the aircraft can safely land and as an input to the terrain awareness warning system (TAWS), which gives a “pull up” warning at a predetermined altitude and closure rate; and as an input to the collision avoidance equipment and weather radar (predictive wind shear system), auto-throttle (navigation), and flight controls (autopilot).

Radio altimeter systems are designed to operate for the entire life of the aircraft in which they are installed. The installed life can exceed 30 years, resulting in a wide range of equipment age, performance and tolerance.

2 Altimeters

There are two types of radio altimeters in use today. One type utilizes Frequency Modulated Continuous Wave (FMCW) modulation, the second utilizes pulsed modulation. The following sections provide information regarding these types of radio altimeters.

2.1 Frequency Modulated Carrier Wave Altimeters

2.1.1 Operational description

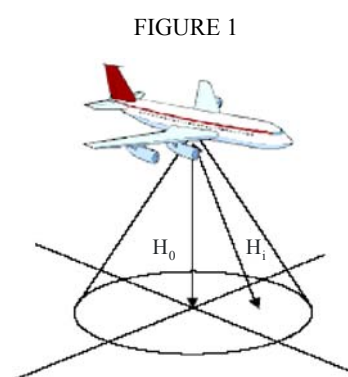
The purpose of a radio altimeter is to provide the aircraft with an accurate, independent and absolute measurement of the minimum distance to the Earth surface below that aircraft. Typically, radio altimeters have a measurement range from –6 metres to 6 000 metres (–20 feet to 19 685 feet). However, there are exceptions where some altimeters have a measurement range greater than 15 000 metres (49 213 feet). Radio altimeters are an essential component of aeronautical

safety-of-life systems, including precision approach, landing, ground proximity and collision avoidance systems. Radio altimeters are essential for landing on autopilot and in low-visibility conditions. Additionally, radio altimeters are employed when landing manually to help alert a pilot when to or automatically engage in a manoeuvre known as a “flare”, which is performed just before touchdown to lessen the force upon landing with the ground. A radio altimeter also functions as part of an aircraft’s terrain avoidance warning system providing predictive forward-looking capability on the flight deck, and if necessary a warning, when an aircraft descends beneath a certain altitude or too close to the ground.

Because of the importance of radio altimeters to the safe operation of an aircraft, they are included in the minimum equipment list on aircraft certified for passenger service. Furthermore, they must be certified at a safety criticality rating or Design Assurance Level (DAL) of “A”, “Where a software/hardware failure would cause and/or contribute to a catastrophic failure of the aircraft flight control systems” for all transport aircraft and a DAL of “B”, “Where a software/hardware failure would cause and/or contribute to a hazardous/severe failure condition in the flight control systems” for business and regional aircraft. Design assurance level is a safety criticality rating from level A to E, with level A/B being the most critical and requiring the most stringent certification process.

Radio altimeter systems on a single aircraft consist of up to three identical radio altimeter transceiver (Tx/Rx) units with their associated equipment. All Tx/Rx units operate simultaneously and independently from one another. The radio altitude is computed from the time interval a signal, originating from the aircraft, is reflected from the ground. Radio altimeters designed for use in automated landing systems are required to achieve an accuracy of 0.9 metres (3 feet). Several methods utilized either individually or in combination are used to avoid altimeter to altimeter mutual interference. First, the centre frequency of each altimeter can be offset. Second, transmissions can be offset in time. Third, transmissions can be offset by frequency bandwidth and/or modulation period. Using one or a combination of these options will cause the occupied bandwidth on a single aircraft to be greater than the required bandwidth of any single radio altimeter.

Figure 1 shows the location and direction of transmissions of the radio altimeter signal.



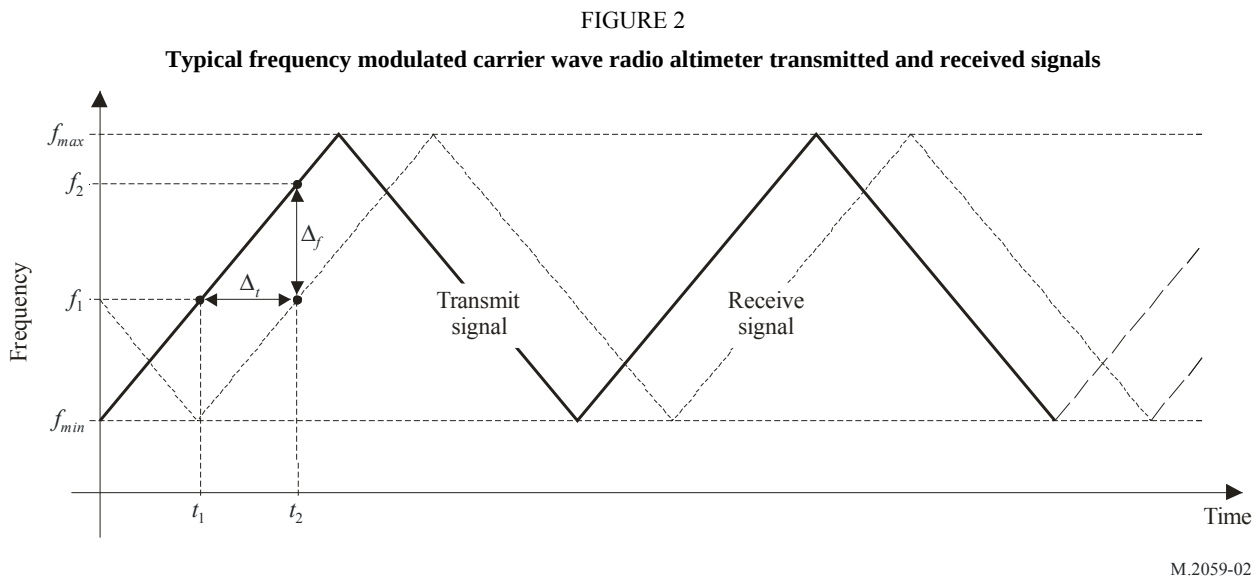
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2.1.2 Principles of operation

FMCW radio altimeters operate by a Tx/Rx working in conjunction with separate transmit/receive antennas. Operation requires a signal from the transmit antenna to be directed to the ground. When the signal hits the ground it is reflected back to the receive antenna. The system then performs a time calculation to determine the distance between the aircraft and ground, as the altitude of the aircraft is proportional to the time required for the transmitted signal to make the round trip.

The frequency modulated (FM) signal produced by the Tx/Rx is not tunable from the flight deck. The calculation is based upon the stipulation that a signal transmitted in the 4 200-4 400 MHz band will return at the same frequency. However, during the time it takes for the signal to travel to the ground and return, the transmitter frequency has changed. The difference between the transmit and receive frequencies (Δf) is directly proportional to the height of the aircraft above the ground and depends on the exact slope of the FMCW modulation (span vs. period) as shown in Fig. 2.

As illustrated by Fig. 2, an altitude is calculated by determining the difference between the frequency f_1 of the reflected signal and the frequency f_2 of the signal being transmitted at the instant t_2 the reflected signal is received. This difference frequency Δf is directly proportional to the time Δt required for the reflected signal to traverse the distance from the aircraft to the terrain and back to the aircraft.



The period of the triangle FMCW waveform could be variable depending upon the altitude. At every instant, a beat signal is obtained by mixing the transmitted wave (with frequency f_2) and the received wave (with frequency f_1). The frequency Δf of this signal is equal to:

$$\Delta f = f_2 - f_1 \quad (1)$$

Knowing either Δt or Δf , the height above terrain can be calculated using the following formula:

$$H_0 = \frac{c\Delta t}{2} = \frac{c\Delta f}{2(df/dt)} \quad (2)$$

where:

- H_0 : height above the terrain (m)
- c : speed of light (m/s)
- Δt : measured time difference (s)
- Δf : measured difference in frequency (Hz)
- df/dt : transmitters frequency shift per unit time (Hz/s).

2.2 Pulsed altimeters

2.2.1 Operational description

Similar to FMCW, pulsed altimeters provide the aircraft with accurate, independent and absolute measurement of the minimum distance to the Earth surface below that aircraft. Typical pulsed radio altimeters have a range of reported altitude from –6 metres to 2 500 metres (–20 feet to 8 200 feet) and an operational altitude of 12 km (39 360 feet).

Any analysis of the aggregate effects of potential interferers must be computed at the Operational Altitude, where the altimeters continue to search for the ground and are vulnerable to interference that may result in a false altitude track. Functions of pulsed radio altimeters also include precision approach, landing, ground proximity and collision avoidance systems that are essential for landing on autopilot, and in low-visibility conditions, function as part of an aircraft's terrain avoidance warning system providing predictive forward-looking capability on the flight deck, and if necessary a warning, when an aircraft descends beneath a certain altitude or too close to the ground.

2.2.2 Pulsed altimeter principles of operation

The pulsed-type radio altimeter uses a pulse of radio-frequency energy transmitted towards the earth to measure the absolute height above the terrain immediately underneath the aircraft. The time difference between the transmitted pulse and the received pulse is measured. Where the velocity of propagations of electrometric energy is known and is a constant, the time is proportional to the height of the aircraft.

The function of the pulsed radar altimeter is to provide terrain clearance or altitude between the ground and the bottom of the aircraft. The pulsed altimeter may also provide vertical rate of climb or descent and selectable low altitude warning. Performance characteristics are designed to match particular applications where altitude tracking at high vertical rates may be necessary. Pulsed radar altimeters are also designed to support automatic landing and also auto-hover function on helicopters.

2.3 Application

Radio altimeters designed for use in automated landing systems are required to achieve an accuracy of 0.9 metres (3 feet) or more. Such elevation readings are transmitted to a pilot's visual display and to several automatic safety components. Radio altimeters provide an essential informational component of the automatic flight control system¹ for approach and landing, ground proximity warning system², terrain awareness and warning system³, flight management guidance computer, flight control systems, electronic centralized aircraft monitoring⁴ and engine-indicating and

¹ A system which includes all equipment to control automatically the flight of an aircraft to a path or altitude described by references internal or external to the aircraft.

² This system alerts the flight crew when certain thresholds are exceeded, such as excessive descent rate, between 50 and 2 450 feet radio altitude.

³ This is an enhanced version of the ground proximity warning system.

⁴ A system that monitors aircraft functions and relays them to the pilots. The system displays corrective action to be taken by the pilot, as well as system limitations after the failures.

crew-alerting system⁵. In addition, elevation information from radio altimeters is transmitted to the traffic collision-avoidance system and automatic dependent surveillance-broadcast system, which are used to monitor the airspace around an aircraft and to warn pilots of any threat of a mid-air collision.

Information from radio altimeters is especially critical in low-visibility conditions, but is always imperative. Generally, if a system's check before take-off indicates that the radio altimeters are non-functioning, a flight must be suspended. If the signal from the radio altimeters is lost during flight, the collision-avoidance and other safety systems listed above are significantly impaired. If the radio altimeters are not functioning properly when an aircraft is approaching and landing, autopilot systems would be unable to function properly. Under the best situation, a crew would manually fly the approach or divert to another airport. However, this increases crew workload and degrades the approach capability, which can result in a "go around" missed approach. Such repeated landing attempts can significantly impact already congested landing patterns, increase air traffic control workload and create safety concerns. In addition, for certain category airports and weather conditions, loss of the radio altimeter system would prevent the authorized landing of the aircraft. Thereby forcing the aircraft to either fly a holding pattern until weather improves or divert to another airport. Because of the importance of radio altimeter functions, the spectrum allocated and used by these devices must be protected from harmful interference and be sufficient to meet accuracy requirements.

2.3.1 Operational scenarios

Aircraft approach and landing

Analysing a typical landing profile from 18.5 km (10 nm) to the runway threshold for an aircraft, the avionics system components predominantly in use are the instrument/microwave landing systems, distance measurement equipment, satellite navigation systems radio altimeters, inertial reference systems and the air data computers providing barometric altitude and airspeed. The flight-management and flight-control computers continuously monitor sensor data input and correlate this data to ensure they are within specific parameter limits, particularly that the radio altimeter height readings between the sensors are correlated to be within tolerance. Auto-throttle is engaged; a stabilized approach with controlled descent rate and speed is maintained. At a pre-established height, the glide-path vertical information sensor data is phased out of the equation by the flight-management computer and the vertical height above the runway surface is provided by the radio altimeter with aural annunciation in feet to initiate flare of the aircraft to touchdown. The flare phase is controlled by the autopilot system using information from the radio altimeter. This flight profile can be achieved in normal or low-visibility conditions.

If an aircraft loses or receives erroneous radio altimeter data, several consequences can occur depending upon the aircraft type, airport landing requirements or classification, and weather. Loss of radio altimeter data will disable the autopilot resulting in the pilot and co-pilot manually flying and landing the aircraft. Some airport categories or certain weather conditions would prohibit the landing of some types of aircraft without altimeter data. If only one radio altimeter is operational, then the height above ground when the decision to land the aircraft is made must be adjusted to a higher altitude. If visibility is poor, then the aircraft might be forced to wait until the weather gets better or land at a different airport. If the radio altimeter signal receives harmful interference during the final stages of landing, then a hazardous or catastrophic situation could

⁵ A system used in modern aircraft to provide aircraft crew with engines' and other systems' instrumentation. The system displays corrective action to be taken by the pilot in the form of a "checklist".