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U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: Installation of an Airborne Low-Range Radio Altimeter System

Date: XX/XX/XX

Initiated By: AIR-626B

AC No: 20-199

This advisory circular (AC) provides guidance for the installation of a radio altimeter (RA) system to comply with the requirements of title 14, Code of Federal Regulations (CFR) § 91.220(b), for operation in the airspace of the 48 contiguous United States (U.S.) and the District of Columbia. An RA system consists of an RA transceiver, RA antenna(s), and display or indicator. This AC provides guidance for all of the components of the RA system as well as for the use of existing RA antenna(s) and display or indicator as part of the RA system installation. This AC includes guidance for the system installation and testing to assure proper functioning of the installed RA system, including the radio frequency interference tolerance, as well as proper functioning of integrated avionics and flight control systems that utilize the RA.

If you have suggestions for improving this AC, you may use the form at the end of this AC.

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Aircraft Certification Service

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CHAPTER 1. GENERAL INFORMATION

1.1 Purpose.

1.1.1 This advisory circular (AC) provides guidance for the installation of a radio altimeter (RA) system to comply with the requirements of title 14, Code of Federal Regulations (CFR) § 91.220(b), for operation in the airspace of the 48 contiguous United States (U.S.) and the District of Columbia. An RA system consists of an RA transceiver, RA antenna(s), and display or indicator. This AC provides guidance for all of the components of the RA as well as for the use of existing RA antenna(s) and display or indicator as part of the RA system installation. This AC includes guidance for the system installation (Chapter 2) and testing (Chapter 3) to assure proper functioning of the installed RA system, including the radio frequency interference (RFI) tolerance, as well as proper functioning of integrated avionics and flight control systems that utilize the RA. When equipment is properly installed in an aircraft, in accordance with applicable installation and operational approval guidance and regulations, it is expected that all aircraft level functional and operational performance criteria will be met.

1.2 Applicability.

1.2.1 This AC is for RA system design organizations, type certificate (TC) applicants (including amended type certificate and supplemental type certificate (STC) applicants), installers, operators, foreign regulatory authorities, FAA engineers, and the Administrator's designees.

1.3 Intent of this AC.

1.3.1 This is a guidance document. Its content is not legally binding in its own right and will not be relied upon by the Department as a separate basis for affirmative enforcement action or other administrative penalty. Conformity with the guidance document is voluntary only. Nonconformity will not affect rights and obligations under existing statutes and regulations.

1.3.2 This AC establishes an acceptable means, but not the only means, of compliance. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. Since the guidance material presented in this AC is not regulatory, terms having a mandatory definition, such as "shall" and "must," etc., as used in this AC, apply either to the reiteration of a regulation itself, or to an applicant who chooses to follow a prescribed method of compliance without deviation. If the FAA becomes aware of circumstances in which following this AC would not result in compliance with the applicable regulations, the FAA may require additional substantiation as the basis for finding compliance. This material does not change or create any additional regulatory requirements or authorize changes in or permit deviations from regulatory requirements.

1.4 **Related Material.**

1.4.1 See appendix D for related material that applies to this AC.

1.5 **Definition of Key Terms and Acronyms.**

1.5.1 See appendix E for terms and definitions and appendix F for acronyms that apply to this AC.

1.6 **Background.**

1.6.1 RA System Approval for Operations in the U.S.

1.6.1.1 Aircraft with RA systems must meet the interference tolerance requirements in § 91.220(b) by the deadlines indicated in §§ 91.220(a), 121.326, and 129.16. Operators can comply by operating aircraft that were demonstrated to meet those requirements under a design approval (including TC, ATC, and STC) that installs a next generation RA system (see the note in section 2.8.1.4 of this AC). This AC addresses those type certification and associated TSO authorizations.

1.6.2 RA System Description

1.6.3 An RA system consists of:

- A transmitter that generates and amplifies a modulated radio frequency (RF) signal.
- A transmitting antenna that radiates this RF signal from an aircraft toward the terrain surface beneath the aircraft.
- A receiving antenna that receives the reflected RF signal from the terrain surface and any surface features.
- A receiver that demodulates the received RF signal.
- A signal processor that measures the round-trip RF signal propagation time, converts this into a radio altitude value, and outputs this value to an indicator or display or other downstream systems.
- An indicator or display that visually presents the radio altitude to the pilot or flight crew.

1.6.4 Generally, the transmitter, receiver, and signal processing functionality are all implemented in a single component referred to as the transceiver.

1.6.5 RA System Configurations

1.6.5.1 For purposes of this AC, RA system configurations may be one of the following five configurations:

- RA transceiver, RA transmit antenna, RA receive antenna, and an indicator or display.
- RA transceiver, RA transmit and receive antenna, and an indicator or display.
- RA transceiver with integrated transmit or receive antenna, and an indicator or display.
- RA transceiver with integrated indicator or display, and transmit and receive antennas.
- RA transceiver with integrated indicator or display, and a transmit or receive antenna.

Note: In some aircraft, the radio altitude value may be presented on a downstream system such as a multifunction display system.

1.6.6 RA Integrated Systems

1.6.6.1 The RA system is an essential aeronautical safety system used to measure aircraft height above terrain and obstacles in all phases of flight. The height information supplied by RAs is utilized to support numerous navigation and safety functions including:

- Autoflight systems such as autopilot, flight director, autothrottle, autoflare, and alerting systems that are critical during approach and landing operations in low visibility conditions.
- Terrain avoidance systems including terrain awareness and warning systems (TAWS) and enhanced ground proximity warning systems, which provide information about terrain and obstacles to help flightcrews avoid controlled flight into terrain.
- Collision avoidance systems, including traffic/airborne collision avoidance systems (TCAS/ACAS), which detect nearby aircraft and provide guidance to help flightcrews avoid mid-air collisions.
- Wind shear protection systems that detect hazardous conditions and manage the flight path to alert and assist flightcrews that encounter wind shear conditions on takeoff and landing.
- Vision systems and operations, including enhanced flight vision systems (EFVS), synthetic vision systems (SVS), and night vision goggle operations, all of which increase pilot visibility and situational awareness.
- Other flight control systems, such as tailstrike avoidance systems and ground spoiler/speed brake deployment logic.
- Flight deck information, including alerts to aid flightcrews during landing and awareness of height above terrain.

1.6.6.2 Reference appendix A for standards and policy related to these functions, systems, and operations.

CHAPTER 2. RADIO ALTIMETER SYSTEM INSTALLATION

2.1 Intended Function.

2.1.1 The intended function of a radio altimeter system is to provide the height (and optionally rate of the change in height) of the aircraft above terrain and obstacles to ensure safe aircraft operations. This functionality is particularly critical during the approach, landing, and takeoff phases of flight, and when utilized by safety critical systems.

2.2 Aircraft Categories and Classes

2.2.1 This AC includes aircraft specific guidance for civil aircraft, including:

- Part 23 normal category airplanes.
- Part 25 transport category airplanes.
- Part 27 normal category rotorcraft.
- Part 29 transport category rotorcraft.

The AC may also be used by the Armed Forces when demonstrating compliance for military aircraft.

2.3 Interface to Downstream Systems

2.3.1 Compliance for subcomponents (e.g., converters, data concentrators, and translators), which are not included as part of the RA system or a design approval of an integrated system (e.g., TAWS), requires further analysis to ensure latency requirements for the overall integration are still met or that any additional latency does not compromise the downstream system performance. One means is to test the subcomponent as part of or with the RA system and show the RA system requirements are met at the output of the downstream subcomponent.

2.4 Flight Deck Interface

2.4.1 For all aircraft classes and categories, the following criteria should be used to assess the flight deck RA system integration. For Part 25 airplanes, reference 14 CFR 25.1302 and AC 25.1302-1, *Installed Systems and Equipment for Use by the Flight Crew* for additional requirements and guidance.

2.4.1.1 Controls and Monitors

2.4.1.1.1 RA system controls and monitors provided for operation in-flight should be readily accessible from the pilot's normal seated position. The flightcrew should have an unobstructed view of displayed data when in the normal seated position. It should not be possible to operate the controls in any position, combination, or sequence that would result in a condition detrimental to the reliability of the RA system equipment or operation of the aircraft. Controls that do not require adjustment during flight should not be readily accessible by the flight personnel while in flight. If necessary, such controls may be accessible to flight personnel and maintenance personnel while the aircraft is on ground.

2.4.1.2 Altitude Alert Input

2.4.1.2.1 If the RA system installation includes an adjustable visual or aural altitude alert indication threshold set by the flightcrew, an input interface must be provided (e.g., using knobs, buttons, softkeys, or touchscreen) in accordance with 14 CFR 23.2505, 25.1301, 27.1301, and 29.1301.

2.4.1.3 Decision Height (DH)

2.4.1.3.1 One possible implementation of the visual and aural altitude alert provided by the RA system may be for annunciation of a DH for Category II and III approaches and autoland operations.

2.4.1.4 Altitude Alert Output

2.4.1.4.1 The TC/STC applicant should verify the altitude alert output latency and thresholds from the RA system are appropriate for the aircraft and support the operations.

2.5 Environmental

2.5.1 The RA system equipment must be compatible with the environmental conditions present in the specific locations in the aircraft the equipment is installed. The equipment must not be the source of harmful interference, nor be adversely affected by interference from other equipment or systems installed in the aircraft. Reference 14 CFR 23.2500, 25.1309, 27.1309, 29.1309, 25.1431, and 29.1431.

2.6 Aircraft Power

2.6.1 The supply voltage and allowable variation must not exceed the equipment manufacturer's specifications during normal operations. Equipment voltage and frequency tolerance characteristics must be compatible with an aircraft power source of appropriate category as specified in DO-160G/ED-14G, *Environmental Conditions and Test Procedures for Airborne Equipment*. RA systems that perform critical functions or whose continued operation is required for safe flight and landing should be powered from suitably rated power sources, which may include requirements for redundant or separate power inputs. Power sources should be appropriately qualified. Reference 14 CFR 23.2500, 25.1309, 27.1309, and 29.1309.

Note: Different categories of aircraft and different types of equipment may have different requirements for operation through momentary loss of power or during switching of power sources.

2.7 HIRF and Lightning

2.7.1 Reference AC 20-158B, *The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-Intensity Radiated Fields (HIRF) Environment* and DO-160G/ED-14G section 20 for HIRF and AC 20-136B, *Aircraft Electrical and Electronic System Lightning Protection* and AC 20-155A, *Industry Documents to Support Aircraft Lightning Protection Certification* for lightning. Radiated and conducted RF susceptibility tests on an integrated system should be performed for level A systems (i.e., supporting catastrophic functions). Level B and C systems should be assessed in accordance with AC 20-158B. The HIRF certification requires the RA system to be subject to the external HIRF environments from 100 MHz to 18 GHz while the system is operating. Equipment HIRF tests and Interference Tolerance Mask (ITM) testing may be used to augment the integrated RA system HIRF tests where appropriate.

2.8 Radio Frequency Interference (RFI) – Reference § 91.220, *Radio Altimeter Systems*

2.8.1 The power flux density (PFD) levels for the RFI tolerance requirements represent the total exposure from all RFI sources within the relevant frequency bands. The RA system will be simultaneously exposed to both in-band and out-of-band RFI, and some sources of RFI may simultaneously present both types of interference at significant levels. Therefore, spectrum compatibility with the RA system is achieved only when all sources of RFI across the full frequency range from 3000 to 5600 MHz are kept to the levels specified in § 91.220(b) Table 1 (replicated in table 2-1 and depicted in figure 2-1 of this AC).

2.8.1.1 Aircraft Applicability

2.8.1.1.1 Regardless of the type of aircraft, the assumed external RFI environment is the same and the RA system and downstream aircraft systems need to perform their intended function while exposed to interference up to the ITM.

2.8.1.2 RA System Performance

2.8.1.2.1 In order to comply with 14 CFR 91.220(b), the RA system must meet the performance, availability, continuity, and integrity requirements when the RFI environment at the RA antenna(s) is at or below the PFD levels specified in table 2-1 of this AC.

2.8.1.3 RA Accuracy and Noise

2.8.1.3.1 In order to comply with 14 CFR 91.220(b), the RA system must meet the measurement validity, accuracy, and noise requirements when the RFI environment at the RA antenna(s) is at or below the PFD levels specified in table 2-1 of this AC.

2.8.1.4 TSO-C221/EASA TSO-C221 RA Transceiver

Editorial Note: RTCA and EUROCAE are developing a new minimum operational performance standard for next generation RA systems, and plan to publish the standard by March 2027. The FAA plans to reference that standard with a new TSO (TSO-C221). If the industry standard deviates from the final rule for §§ 91.220, 121.326, and 129.16 (see NPRM Document No.: 2026-00051, Docket No.: FAA-2025-5666), the FAA plans for the TSO to supersede the standard to ensure TSO equipment demonstrates compliance with § 91.220(b). When the TSO is published, the FAA may update this AC to address the use of equipment that obtains the TSO authorization. To support public comment on the proposed rule, preliminary guidance for that equipment is provided in this section for comment. This guidance assumes the final industry standard is identical to the baseline standard that the industry is validating.

2.8.1.4.1 (TBD) Installing airborne low-range RA transceiver(s) approved under FAA TSO-C221 or EASA TSO-C221 is an acceptable means of compliance with the performance requirements of § 91.220(b), which are also contained in table 2-1 of this AC. This applies to Class Alpha, Beta-1, Beta-2, Gamma-1, and Gamma-2 as specified in TSO-C221. The interference environment defined in Table 1 of § 91.220(b) is replicated in table 2-1 below.

2.8.1.5 TSO-C87()/EASA TSO-C87() RA Transceiver

2.8.1.5.1 For installations with airborne low-range RA equipment approved under TSO-C87() or EASA TSO-C87(), meeting the RFI interference criteria in this AC while retaining the existing TSO performance and testing basis is an acceptable means of compliance with the performance requirements of § 91.220(b). The interference environment defined in Table 1 of § 91.220(b) is replicated in table 2-1 below.

Note: Demonstration can be shown by the TC/STC applicant or by using documentation provided by the RA transceiver manufacturer.

2.8.1.5.2 RA transceiver manufacturers who obtain Technical Standard Order Authorization (TSOA) for their equipment are encouraged to declare the antenna and aircraft installation characteristics in the IM and provide any data necessary to support the TC/STC applicant’s demonstration of compliance. TSOA applicants should follow the means of compliance in section 2.17, section 3.2, 3.7.5 and appendix B as a non-TSO function.

Reference AC 21-46A, *Technical Standard Order Program* for additional information on design changes and non-TSO functions including substantiation data to support the installation design approval.

2.8.1.6 Antenna Gain

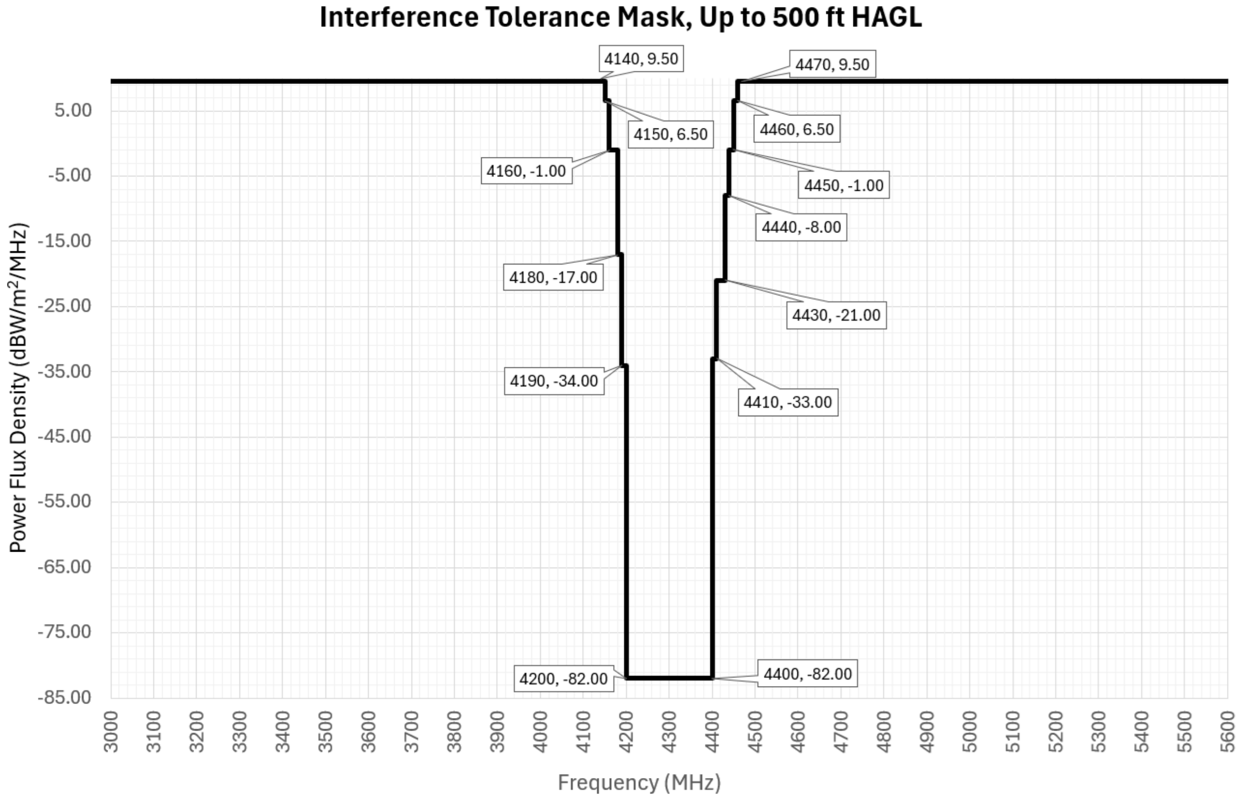
2.8.1.6.1 The PFD levels defined in Table 1 of § 91.220(b) (replicated in table 2-1 of this AC) must be met with the maximum RA antenna gain. Reference appendix B, note 1 for additional details on how the RA antenna gain is considered when the RA transceiver is tested to verify compliance with the interference requirements. This ensures full spectrum compatibility with RFI that may be directed into the RA at any angle including at boresight.

Table 2-1. Interference Tolerance Mask (ITM)

Frequency Range (MHz)	**Power Flux-Density, RMS (dBW/m²/MHz), 0–500 feet Height Above Ground Level (HAGL)**
3000 ≤ f < 4000	9.5
4000 ≤ f < 4100	9.5
4100 ≤ f < 4150	9.5
4150 ≤ f < 4160	6.5
4160 ≤ f < 4180	-1
4180 ≤ f < 4190	-17
4190 ≤ f < **4200**	-34
4200 ≤ f < 4400	-82
4400 < f ≤ 4410	-33
4410 < f ≤ 4430	-21
4430 < f ≤ 4440	-8
4440 < f ≤ 4450	-1
4450 < f ≤ 4460	6.5
4460 < f ≤ 4500	9.5
4500 < f ≤ 4600	9.5
4600 < f ≤ 5600	9.5

Note 1: The PFD levels define the maximum safely tolerable RFI environment at the surface of the RA antenna and are 6 dB higher than the expected, authorized environment to provide a safety margin. This safety margin is aligned with the International Civil Aviation Organization (ICAO) recommendations in ICAO Doc 9718, *Handbook on Radio Frequency Spectrum Requirements for Civil Aviation*, which specifies that a safety margin of 6 - 10 dB is to be applied for aeronautical safety systems.

Figure 2-1. Interference Tolerance Mask (ITM)



2.9 **RA Transceiver**

2.9.1 Installed System Accuracy

2.9.1.1 The installed RA system accuracy is determined by the:

- RA transceiver accuracy.
- RA antenna characteristics including average group delay (if it is not compensated by the RA transceiver) with group delay uncertainty (if the Installation Height Offset is defined by selectable aircraft installation delay (AID) values as specified in ARINC 707, *Radio Altimeter*) and group delay variation, all of which may add a fixed bias to the RA transceiver output accuracy.
- Installation and aircraft specific characteristics including cable (coax) lengths, calibration (manual or automatic), aircraft geometry (installation locations including multiplex installations), and aircraft pitch down at touchdown, all of which may add a fixed bias to the RA transceiver output accuracy.

2.9.1.2 Therefore, the TC/STC applicant should verify the installation is within the scope of the declarations and limitations of the RA transceiver installation manual (IM) or equivalent documentation for the antenna(s) and coaxial cables or transmission lines. For installations outside the scope, accuracy must be demonstrated at the aircraft level.

2.9.2 System Accuracy versus Frequency Selectivity Trade Space

2.9.2.1 There is a limit to the total near-band rejection that is achievable without compromising accuracy. TC/STC applicants should consider the frequency selectivity of both the transceiver and antenna as part of the RA system installation (i.e., an antenna with more frequency selectivity (interference rejection) should be paired with a transceiver with less frequency selectivity) in order to meet the total system performance requirements.

2.9.3 Installation Height Offset

2.9.3.1 The RA system may account for any installation height offset (or installation time delay) to establish the zero-height reference point through:

- Calibration,
- Configuration means, which could include fixed configurations that vary by part number, or
- Installation of the RA system (i.e., ARINC 707 AID combined with tuned lengths of coaxial cables).

2.9.3.2 This bias should be subtracted from the measurement result of the RA system to account for the length of coaxial cables or transmission lines between the RA transceiver and the RA antenna(s), the height of the RA antenna(s) above the terrain while the aircraft is on the ground with the main landing gear touching in a pre-established aircraft attitude (i.e., nose gear may not be touching), and any other system delays as needed to maintain the appropriate accuracy of the RA system and systems integrated with the RA. TC/STC applicants should pay particular attention to autoland systems used during low visibility conditions with the most demanding accuracy requirements.

Note: Examples of installation height offset input interfaces include interfaces that allow for a continuously configurable installation height offset (e.g., a set of discrete inputs or a manually tunable potentiometer), selectable AID values (reference ARINC 707), interfaces that initiate an automated self-calibration process to determine the installation height offset in a known operating condition, or external configuration modules that set known installation height offset values.

2.9.4 Altitude Transient Tracking

2.9.4.1 The installer should verify the RA system altitude transient logic is acceptable for operations (e.g. TCAS and TAWS) and expected terrain conditions. This includes abrupt changes or steps in terrain. To support autoland operations, the RA system must maintain track for an altitude step up to threshold elevation of 6m (20 ft.) at a point 60m (200 ft.) prior to the threshold. Reference AC 120-28D, *Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout* and ARINC 707.

2.9.5 Altitude Coasting

2.9.5.1 The TC/STC applicant should verify the altitude coasting of the RA system supports the integrated systems and operational performance requirements. This is critical during autoland operation during the flare to ensure the integrated system, including the use of other systems or sensors, is able to maintain the autoland performance, availability, and integrity with the RA system coasting logic implemented. Below 200 feet, the RA system should only maintain coasting for very short durations, on the order of 250 ms, to maintain accuracy. The installer should ensure the RA system or integration addresses multiple coasting events, which may indicate an equipment failure and need for the RA system to no longer remain valid, resulting in loss of the airplane system or operation. At higher altitudes, longer coasting durations (500 ms – 2 sec. depending on the aircraft) may be appropriate if accuracy is maintained to support the availability of integrated systems.

Note: Instead of freezing the last valid RA measurement and coasting, RA systems could utilize predictive extrapolation of the RA measurement. With either implementation, the RA system should not output a step in altitude when exiting coasting.

2.9.6 Installed System Integrity

2.9.6.1 The ability of the installed RA system to meet the integrity requirements due to false targets may be affected by the installation, specifically the coaxial cables or transmission lines and connectors and the antenna. Therefore, the TC/STC applicant should verify their installation is within the scope of the declarations and limitations of the transceiver IM or equivalent documentation. For installations outside the scope, the installer will need to demonstrate at the aircraft level that false targets are not produced due to internal reflections within the system that could arise if the RA transceiver, RA antenna(s), and installation are not fully compatible. TC/STC applicants should pay particular attention to low loss cabling with multiple connection points where the reflected signal transmitted may be significantly delayed but not attenuated representing a valid target far from the true altitude target.

2.9.7 Failure Protection

2.9.7.1 TC/STC applicants should consider techniques such as failure detection and annunciation, equipment redundancy, or other aircraft level mitigation to provide failure protection.

2.9.8 Failure Indication

2.9.8.1 The TC/STC applicant should ensure the RA failure indication logic is consistent with the integrated avionics and flight control system design and performance requirements, including requirements for latching of the failure indication after the failure condition has cleared, requirements addressing the conditions that clear a latched failure indication, and the failure indication recovery timing requirements.

2.9.9 Failure Indication Timing

2.9.9.1 To support autoland operations, the RA system installation must provide indication of an equipment failure resulting in an erroneous output within 500 ms of detection. For all aircraft, the TC/STC applicant should ensure the failure indication timing supports the integrated systems performance and safety requirements. Reference AC 120-28D, ARINC 707, and 14 CFR 23.2510, 25.1309, 27.1309 and 29.1309.

2.10 **Antenna(s)**

2.10.1 Use of Existing Previously Approved and Installed Antenna(s)

2.10.1.1 If the RA transceiver demonstrates compliance with the requirements in section 2.8 for an antenna with maximum gain of 11.5 dBi and without any frequency selectivity from the antenna, data for the antenna selectivity is not required to show compliance with the performance requirements of § 91.220(b). Therefore, previously approved and installed antennas may be used without further showing. As noted in section 2.9.2, the accuracy of the integrated system may be degraded if the selectivity (and corresponding group delay) exceeds the design expectations. TC/STC applicants should consider the requirements of the systems that use the RA output and the demonstrated RA accuracy to determine if additional accuracy testing is appropriate for the integrated system. If additional testing is needed, comparative testing of the accuracy of a previously approved RA and the RFI tolerant RA can be used to show acceptable performance. By using comparative analysis, the RF environment in section 2.8 need not be considered in the accuracy test.

2.10.2 Ground Plane Considerations

2.10.2.1 The ground plane on which the antenna(s) is installed may alter the antenna out-of-band gain and group delay variation. For antennas installed on a ground plane that is outside the scope and limitations of the RA transceiver IM, demonstration of the interference tolerance and accuracy requirements when integrated with the RA transceiver must be shown at the aircraft level.

2.10.3 Antenna Gain

2.10.3.1 The TC/STC applicant should verify the installed antenna gain is within the RA transceiver manufacturer's IM declarations and limitations in order to meet the interference tolerance and accuracy requirements. Reference section 2.10.1 for additional information regarding showing compliance with § 91.220(b) for existing installed antenna(s).

2.10.4 Antenna Offset Angle

2.10.4.1 For installations with separate transmit and receive antenna, each antenna has its own antenna fixed offset angle. The TC/STC applicant should verify that the minimum and maximum offset angle is within the RA transceivers manufacturer's IM. Installations outside the scope of the IM must demonstrate the interference tolerance and accuracy requirements when integrated with the RA transceiver at the aircraft level.

2.10.5 Antenna Separation

2.10.5.1 If the installation includes separate transmit and receive antennas, the TC/STC applicant should verify the maximum and minimum allowable separation distance between the antennas is within the RA transceiver's IM constraints. Installations outside the scope of the IM must demonstrate the interference tolerance and accuracy requirements when integrated with the RA transceiver at the aircraft level.

2.10.6 Average Group Delay and Average Group Delay Uncertainty

2.10.6.1 For airplanes that have implementations of the installation height offset utilizing the ARINC 707 AID combined with tuned lengths of coaxial cables (Part 25 airplanes), the TC/STC applicant should ensure the antenna average passband group delay uncertainty is bound to no greater than +/- 0.2 ns. This may be declared in the antenna manufacturer's IM or similar documentation.

2.10.7 Antenna Continuity Monitoring

2.10.7.1 For Part 25 airplanes, the TC/STC applicant should ensure the antenna continuity monitoring functionality is integrated properly into the installed RA system.

2.10.8 Antenna Aircraft Installation

2.10.8.1 The TC/STC applicant should verify the antenna functions properly without any interference from aircraft structural elements.

2.10.9 Antenna Icing

2.10.9.1 The amount of ice the RA antenna(s) may accrete will be installation specific. An analysis of the ice accumulation and need for ice protection drives the test requirement and pass/fail criteria for the DO-160G/ED-14G or similar icing test to ensure the antennas continue to perform their intended function in icing. The TC/STC applicant should show the RA antenna declared ice thickness and degradation in voltage standing wave ratio (VSWR) performance (if any) in the antenna manufacturer's IM is appropriate for their aircraft installation to claim Category C DO-160G/ED-14G section 24 icing testing was performed. For installation of a combined RA transceiver and antenna line replaceable unit (LRU), the equipment manufacturer's degradation in accuracy and noise also needs to be considered. The equipment manufacturer's testing may be used to show compliance if it is appropriate for the installation. It is up to the TC/STC applicant to show that the equipment being installed meets the minimum performance needed for the aircraft installation (reference AC 20-73A, *Aircraft Ice Protection*).

2.11 **Indicator or Display**

2.11.1 The indicator or display may be inside or outside the RA system boundary, such as for implementations that incorporate this functionality into a downstream system (e.g., MFD system).

2.11.1.1 Installation Considerations

2.11.1.1.1 For Part 25 airplanes, the TC/STC applicant should reference 14 CFR 25.1302 and 25.1322, AC 25.1302-1, AC 25.1322-1, *Flight Crew Alerting*, AC 25-11B, *Electronic Flight Displays*, and SAE ARP4102-7, *Electronic Displays* for installation requirements and guidance. For all aircraft classes and categories, the following specific criteria should be used to assess the indicator or display.

2.11.1.2 Visibility

2.11.1.2.1 Display intensity should be suitable for data interpretation under all ambient light conditions ranging from total darkness to reflected sunlight. Visors, glare-shields, or filters may be an acceptable means of obtaining daylight visibility. Operation of the equipment should not be adversely affected by aircraft maneuvering or changes in attitude encountered in normal flight conditions.

2.11.1.3 Use of Existing Previously Approved and Installed Display(s)

2.11.1.3.1 If the currently installed indicator(s) or display(s) meets the installed system regulations when integrated with the transceiver, applicants may show compliance by demonstration at the aircraft level or by reference to the RA transceiver manufacturer's IM, which may include compatible part numbers or performance characteristics, as well as any limitations or constraints.

2.11.1.3.2 TSO authorization and marking of an existing indicator or display design requires a new part number and submission of the TSO application including the technical data and other documentation required by the TSO and quality system to the FAA for the design and production approval.

2.11.1.4 Display Altitude Range

2.11.1.4.1 The TC/STC applicant should ensure the RA display range is capable of displaying a maximum radio altitude of at least the 2500 ft. minus the minimum allowable Installation Height Offset for the RA system.

2.11.1.5 Display Accuracy

2.11.1.5.1 The TC/STC applicant should verify the RA display accuracy for the visual indication of RA data supports the aircraft integrated systems and necessary operations. For displays that receive digital data that directly represents the value to be displayed with little to no processing, the display should meet an accuracy of ± 1 ft. Displays that need to determine the displayed value based upon receiving analog sensor data or upon receiving multiple inputs, which need to be processed together to determine the displayed value, should meet an accuracy of ± 2 ft. or 2% of the RA display input, whichever is greater.

2.11.1.6 Display Latency

2.11.1.6.1 The latency period induced by the display system should not be excessive and should consider the criticality of the data or alert and the required crew response time to the data or to minimize propagation of the failure condition. Reference AC 25-11B, for Part 25 aircraft.

2.11.1.7 Rotorcraft RA Analog Representation

2.11.1.7.1 For Part 27 and Part 29 rotorcraft, the TC/STC applicant should ensure an analog-type visual representation of the radio altitude is provided. An analog visual representation refers to a display presentation consisting of, for example, a dial, ribbon, or bar, and not solely a display of numbers. This type of representation allows for minimal interpretation, allowing for a quick, instantaneous read of the absolute height and the rate of change of height. This type of representation aids in the pilot's situational awareness for certain types of rotorcraft operations. Existing regulatory guidance specifies that such display representations are either required or strongly recommended for specific types of rotorcraft operations. Reference EASA AMC1 SPA.NVIS.110(b), *Equipment requirements for NVIS operations*, paragraph (a)(1) for rotorcraft operations with night vision imaging systems and EASA AMC2 CAT.IDE.H.145, *Radio altimeters*, for rotorcraft operations over water.

Note: If a flag is used on this type of analog display for failure indication or loss of measurement validity, the flag should be as large as practicable, commensurate with the display.

2.12 Transmission Lines (Cabling)

2.12.1 Cable Losses

2.12.1.1 The TC/STC applicant should verify that the minimum and maximum transmission line (cable) losses between the RA transceiver and antenna(s) are within the in-band and out-of-band losses specified in the equipment manufacturer's IM constraints. For cable losses outside the scope and limitations of the transceiver IM, demonstration of performance must be shown at the aircraft level.

2.12.2 Propagation Time Delays

2.12.2.1 The TC/STC applicant should verify the minimum and maximum propagation time delays of the transmission lines (cabling) between the RA transceiver and the antenna(s) are within the constraints specified in the equipment manufacturer's IM. For installations outside the scope and limitations of the transceiver IM, demonstration of the performance must be shown at the aircraft level.

2.12.3 Voltage Standing Wave Ratio (VSWR)

2.12.3.1 The TC/STC applicant should verify the constraints on the allowable RF transmission and reflection characteristics of the transmission lines (cabling) between the RA transceiver and the antenna(s) including, for example, the VSWR of coaxial cable connectors, the number of allowable connectors in the transmission line runs (including cable breaks or bulkhead connections), and the allowable location(s) of cable breaks or bulkhead connections. For installations outside the scope and limitations of the transceiver IM, demonstration of the performance must be shown at the aircraft level.

2.13 Multiplex Installation

2.13.1 Each RA system in a multiplex installation should be capable of working independently, such that the failure or removal of power to any individual system does not preclude the proper operation of the others. Reference the equipment manufacturers IM to determine the equipment's suitability for multiplex installation and operation, as well as appropriate configuration and procedures to ensure proper multiplex operation.

2.13.1.1 Antenna Isolation

2.13.1.1.1 The TC/STC applicant should verify the installation is within the minimum RF isolation between the ports of the RA antenna of each antenna.

2.14 RA System Performance

2.14.1 Operating Envelope

2.14.1.1 The TC/STC applicant should ensure the operating envelope of the RA system supports the integrated systems and operational performance requirements. The operating envelope includes the minimum and maximum HAGL, maximum allowable pitch and roll angles, minimum and maximum terrain closure rate, and maximum ground speed.

2.14.2 Terrain

2.14.2.1 The TC/STC applicant should ensure the performance is appropriate on the types of terrain surfaces that the RA system needs to be capable of tracking. This includes all types of terrain surfaces over which the RA system may foreseeably operate. The TC/STC applicant should pay careful attention to terrain that may result in multipath reflections or over airport reflector fields.

2.14.3 Weather

2.14.3.1 The TC/STC applicant should also ensure the performance of the RA system is acceptable when exposed to weather, which may be detected and tracked. This includes rain, hail, snow, clouds, or other atmospheric conditions that could be located beneath the aircraft and between the aircraft and the terrain surface, and which could be detected by the RA system. Just as a weather radar system onboard an aircraft needs to reject radar return signals from the terrain and only detect signals from atmospheric weather, the RA system should reject undesired radar return signals from weather only detecting and tracking desired radar return signals from the terrain and surface features.

2.15 Design Assurance

2.15.1 The Design Assurance Level (DAL) of the RA system must be adequate to support the classification appropriate to the aircraft level integration and hazards. The DAL appropriate for a given aircraft installation hazard classification is not the same for all aircraft types, and the contribution of the equipment to an aircraft level failure may vary depending on the aircraft and other installed equipment. The safety analysis must consider potential failure conditions of the RA transceiver, RA antenna(s), RA indicator or display, and any connections/cabling and subcomponents used to support the system, which may contribute to a loss of function of or erroneous output from the RA system. Reference AC 23.1309-1E, *System Safety Analysis and Assessment for Part 23 Airplanes*, AC 25.1309-1B, *System Design and Analysis*, AC 27-1B, *Certification of Normal Category Rotorcraft*, PS-ASW-27-15, *Safety Continuum for Part 27 Normal Category Rotorcraft Systems and Equipment*, and AC 29-2C, *Certification of Transport Category Rotorcraft*.

2.16 System Safety Assessment

2.16.1 The failure condition classification appropriate for the RA system will depend on the intended use and installation in a specific aircraft. The TC/STC applicant should document the loss of function and malfunction (erroneous) failure condition classification for which the system is designed, which must be adequate to support the classification appropriate to the system and aircraft level integration, including redundancy requirements and hazards.

Note: The hazard classification at the RA system level does not necessarily support the airplane installation top level hazard, but it does help to determine the level of redundancy (dual or triple installation) needed to support that airplane's top level hazard or any other hazards of the systems and operations the RA supports. In this situation, it is not expected that the hazard level of the RA system or hazards at the airplane integration will change and installing RFI tolerant RA systems will restore the assumptions at the time of the original certification (filtering out the unanticipated RFI environment). However, due to additional functionality or signal and timing impacts, the probability of failures could be affected; therefore, the TC/STC applicant should ensure that any impacts do not affect the System Safety Assessment or any of the integration.

2.17 **Installation Manual or Design Data (or appropriate documentation).**

2.17.1 The TC/STC applicant should reference the transceiver, antenna, or display IM (as appropriate), which should be developed and made available by the equipment manufacturer. The IM includes the performance characteristics, interface specifications, installation constraints/limitations, installation requirements, calibration (if applicable), on-aircraft testing, maintenance, troubleshooting procedures, and any necessary requirements for other integrated equipment. It is essential the TC/STC applicant verifies the IM criteria are consistent with the as-installed RA system on the aircraft. Any deviations will need to be fully analyzed, tested, and documented. The IM is a required compliance artifact for airworthiness certification of the RA system.

Note 1: This information may be provided in a system description document, interface control document, or maintenance manual as appropriate.

Note 2: Typically, the transceiver IM should include the information necessary to determine if the antenna and display is compatible for the RA system.

2.18 **Security**

2.18.1 TC/STC applicants should consider aircraft information security risk mitigation strategies in their system installation and integration. The TC/STC applicant should address any security vulnerabilities and associated mitigation techniques for the installation, as well as any propagation to downstream systems. This AC does not provide guidance for security threats other than RFI security threats. Guidance for airworthiness security risk assessments addressing cyber security is available in EASA AMC 20-42, *Airworthiness information security risk assessment*, RTCA DO-391, *Aeronautical Information System Security Framework Guidance*, DO-326B, *Airworthiness Security Process Specification*, DO-356A, *Airworthiness Security Methods and Considerations*, and DO-355A, *Information Security Guidance for Continuing Airworthiness*, and ASTM F3532, *Standard Practice for Protection of Aircraft Systems from Intentional Unauthorized Electronic Interactions*.

2.18.1.1 RFI Threat (Excessive Interference)

2.18.1.1.1 Aircraft may be subject to RFI threats beyond the ITM. Depending on the aircraft type, the RA system may or may not implement security measures. The TC/STC applicant should ensure the integrity of the use of RA system information in the presence of RFI threats.

2.18.1.2 RFI Threat

2.18.1.2.1 The TC/STC applicant, should demonstrate when exposed to an RFI threat, if the measurement validity is asserted, the RA system meets the accuracy and noise requirements. For RFI threats, it may be appropriate to de-assert validity or assert the failure indication.

2.18.1.3 RFI Threat Recovery

2.18.1.3.1 The TC/STC applicant should ensure the aircraft installation supports recovery from RFI threats without manual intervention once the threat is removed.

2.18.1.4 RFI Monitoring

2.18.1.4.1 For installations with RFI monitoring, the TC/STC applicant should pay particular attention to the design and implementation to ensure the monitor does not introduce an unacceptable risk to meeting the RA system performance requirements. The impact of false detections (i.e., detections of abnormal RFI within the acceptable ITM environment) on the availability and continuity of the system's intended function should be assessed. The TC/STC applicant should analyze any RFI monitor and its probability of false detections on the loss of function of the RA system.

2.19 Functional Test

2.19.1 Certain aircraft installations require an input interface to execute a functional test of the RA system. The TC/STC applicant should ensure the appropriate input interface is provided to initiate the functional test. The functional test must test the entire system (with or without an antenna) at a simulated altitude of less than 500 feet per 14 CFR Appendix A to Part 91 § 3.(c).(5). Reference AC 25-7D, *Flight Test Guide for Certification of Transport Category Airplanes*, paragraph 32.1.5.5.7 for further information.

2.20 Instructions for Continued Airworthiness

2.20.1 RFI Detection

2.20.1.1 If the RA system provides an RFI detection function, the Instructions for Continued Airworthiness, maintenance manual, or other applicable documentation should include means to communicate detected RFI for use by the appropriate stakeholders (i.e., pilot, maintenance personnel, regulator) This RFI detection indication may be used for:

- Differentiating between on-aircraft failures that require maintenance or evaluation and off-aircraft RFI events that do not.
- For use by the flightcrew to support identification of system or function failures and alerts related to abnormal RFI.
- Reporting likely interference to appropriate authorities for investigation.

Note: The RA system may be capable of having valid measurement output despite detected abnormal RFI or the RA system may become invalid. The usage of the RFI detection remains at the discretion of the aircraft integrator and operator.

2.21 Certification Documentation

2.21.1 The TC/STC applicant should provide a detailed certification plan that describes the installed RA system testing, including the specific allocations to lab testing, simulator testing, ground testing, flight test, and as appropriate the use of analysis for demonstration of compliance

2.21.2 Aircraft Flight Manual (AFM)

2.21.2.1 In the Normal Procedures, Normal Operations, or equivalent section of the AFM, AFM supplement or Pilot Operating Handbook, the applicant should include a statement that the aircraft has been demonstrated to meet § 91.220, *Radio Altimeter Systems*. That statement may be used by pilots or operators for demonstrating compliance to the operating requirements of §§ 91.220, 121.326, or 129.16 as appropriate. For example, the AFM may state: "This aircraft has an RA system that operates in the interference environment described in 14 CFR 91.220(b)."

CHAPTER 3. RADIO ALTIMETER SYSTEM TESTING

3.1 Radio Frequency Interference Testing – Reference § 91.220

3.1.1 The RFI injection test setup and requirements are specified in appendix B and may be done:

- At the RA transceiver LRU, or
- By testing the RF Filter Subassembly (RFFSA) and RA transceiver separately.

3.1.2 For the LRU level, the conducted interference power levels associated with the system ITM (power flux density levels) are directly injected into the RA transceiver RF ports. When testing the RFFSA and RA transceiver separately, the RFFSA should be tested to the maximum level (direct conducted), and data from that testing can be used to reduce the level of interference into the RA transceiver. The RA system must meet the measurement validity, accuracy, and noise requirements in the presence of the interference into the RA transceiver. Demonstration of compliance may be done using the RA transceiver manufacturer's data and an analysis showing the data is applicable to the installation.

3.2 Environmental Testing

3.2.1 It is up to the TC/STC applicant to show that the equipment being installed meets the performance needed for the installation. The operating environment will be installation specific, and an analysis should be done to ensure that equipment environmental testing and analysis done by the supplier is appropriate. Analysis should also be done to determine whether additional requirements and testing (per DO-160G/ED-14G or similar) are necessary to ensure the RA system and its components continue to perform their intended function under the airplane environmental conditions expected to be encountered in actual operations. Demonstration of compliance may be done using the RA transceiver, antenna, or display manufacturer's data and an analysis showing the data is applicable to the installation.

3.3 Installed RA System Testing

3.3.1 Installed RA system testing may include testing with the aircraft on the ground using simulated or real inputs or with the aircraft in flight using real inputs. The TC/STC applicant should:

- Demonstrate the RA system performs appropriately with real terrain returns for all integrated systems. Various types of complex terrain scenarios should be assessed.
- Demonstrate the accuracy and performance is not degraded by installing a new RA system. Negligible degradation may be acceptable if it is shown that all integrated systems continue to meet their intended function, safety, and performance requirements.

3.4 Integrated System Testing

3.4.1 The TC/STC applicant should perform regression and additional integrated system testing appropriate to the design change and its impact to the integrated systems. When replacing one RA with another, it is acceptable to demonstrate that any degradation in performance (e.g. accuracy) is within the integrated system performance requirements. Testing should be conducted as applicable to the systems, functions, and operations integrated into the aircraft. Reference appendix A of this AC.

3.5 Flight Deck Evaluation

3.5.1 The flight deck information should be assessed including annunciations to aid flightcrews during landing and awareness of HAGL. If the installation includes a visual or aural altitude alert indication, the installed system testing should verify the thresholds function as intended without toggling. If an input interface is provided to adjust the threshold, the input interface should be evaluated using the guidance in AC 20-175, *Controls for Flight Deck Systems.* Reference 14 CFR 25.1302 and AC 25.1302-1 for Part 25 airplanes.

3.6 Flight Testing

3.6.1 In addition to the flight test procedures specified in AC 25-7D, section 32.1.5.5, for Part 25 airplanes, the following flight testing should be done for all aircraft to confirm the intended function of the radio altimeter in real flight conditions as appropriate to the design change and its impact to the integrated systems. The TC/STC applicant should develop a detailed flight test procedure that addresses the following aspects for review and approval by the appropriate CAA.

3.6.2 Terrain

3.6.2.1 Radio altimeter systems are used over a wide variety of terrain surfaces with vastly different characteristics. The radio altimeter system design characteristics, including antenna patterns, aircraft pitch and roll, range resolution, sensitivity, etc., will dictate how a particular terrain surface will be observed to produce the altitude measurement. The installed RA system testing should include a variety of terrain surfaces with varying characteristics (e.g., smoothness, flatness, inclination, and surface features). As appropriate, it should also include approaches into mountainous terrain, flying through river valleys or canyons, operations at plateau runways, large structures on final approach, and rooftop helipads.

3.6.3 Altitude

3.6.3.1 In addition to the flight test assessing the RA and integrated system performance in the terrain conditions applicable to the aircraft, the RA and integrated system performance should be assessed at the altitudes applicable to the aircraft. The RA system measurement validity, accuracy, and noise should be verified at the altitudes in tables 3-1 through 3-3 of this AC for the specific aircraft type.

3.6.4 Aircraft Operating Envelope

3.6.4.1 The flight test cases should capture all aspects of the operating envelope (e.g., HAGL, pitch and roll angles, ground speed) in functionally or operationally relevant scenarios (e.g., hovering and other operations with low aircraft altitude and ground speed are limited to rotorcraft applications and present unique challenges for the RA system and, therefore, should be adequately assessed during flight test).

3.6.5 Flight Testing Accomplished Under TSOA

3.6.5.1 The RA system altitude accuracy in a particular system integration and aircraft installation depends upon accuracy contributions from the RA transceiver, RA antenna(s), and installation characteristics. The TC/STC applicant should ensure the accuracy of the specific installation and integration by either confirming flight testing done at the equipment level is applicable to the installation (i.e., the antenna and installation characteristics are within the manufacturer's IM limitations and constraints) or by performing any additional flight testing necessary. Demonstration of compliance may be done using the RA transceiver manufacturer's data and an analysis showing that the data is applicable to the installation.

3.6.6 Flight Test Configuration

3.6.6.1 The TC/STC applicant should identify all allowable RA system installation and operational configurations, including:

- Single installations.
- Multiplex installations with all RA systems operating.
- Multiplex installations with one or more RA system not operating.
- Variant installations with multiple installed equipment locations.

3.6.6.2 The TC/STC applicant should perform flight testing on each allowable installation configuration, or the TC/STC applicant should determine which of the allowable installation configurations will be the most constraining relative to the performance verified by each test case.

3.6.7 Flight Test Setup

3.6.7.1 The flight test includes a fully integrated RA system onboard the test aircraft. The TC/STC applicant should include one or more truthing systems in the flight test setup that has sufficient measurement precision and accuracy to evaluate the RA system performance being assessed in each flight test case.

3.6.8 Recording

3.6.8.1 The TC/STC applicant should continuously record the electrical height output, measurement validity, and any signal necessary from the truthing system to determine the true radio altitude. The determination of true radio altitude may be done either in real time or in post-processing.

3.6.9 Validity

3.6.9.1 While operating anywhere within the normal operating envelope, the RA system should indicate a valid measurement.

3.6.10 Loop Loss Transient

3.6.10.1 For flight test verification of the loop loss transient requirements, it is not necessary to quantify the amplitude of the change in external loop loss. Instead, a terrain transition is overflown, which is expected to produce an abrupt change in external loop loss (e.g. transitions between water and land). The TC/STC applicant should verify the measurement validity remains asserted and the RA system meets the accuracy and noise requirements are met.

3.6.11 Altitude Tracking Consistency in Multiplex Installations

3.6.11.1 For multiplex installations, each installed RA system should provide an electrical height output within two times the applicable accuracy bounds. It is not required for separately installed RA systems in a multiplex installation to have synchronized outputs and, in general, each will operate completely independent of each other.

3.6.12 Irregular Approach Terrain and Surfaces

3.6.12.1 The RA system should be evaluated to determine the performance characteristics in the presence of significant approach terrain variations. At a minimum, the following profiles should be examined:

- Sloping runway – slopes of 0.8%.
- Hilltop runway – 12.5% slope up to a point 200 ft. prior to the threshold.
- Sea wall – 20 ft. step up to the threshold elevation at a point 200 ft. prior to the threshold.
- Reflector field.

Note: In addition to the profiles described above, the TC/STC applicant should evaluate the profiles of known airports where operations are intended with significant irregular approach terrain or surfaces.

3.6.13 High Altitude and Steep Approach Landings (if applicable)

3.6.13.1 If applicable to the aircraft, the TC/STC applicant should verify during flight test the high altitude and steep approach landing performance. Negligible degradation may be acceptable if it is shown that the performance still meets the intended function, safety and performance requirements.

3.6.14 Autoland

3.6.14.1 If applicable to the aircraft, the TC/STC applicant should verify during flight test the autoland performance, paying particular attention to the flare maneuver and detection of the runway slope. The TC/STC applicant should verify the flight testing remains consistent with the autoland performance analysis (i.e., meeting the approach accuracy and landing and rollout "touchdown box" criteria). The autoland simulation and Monte Carlo analysis may need to be re-ran using the new RA system performance to demonstrate that the autoland performance continues to meet all requirements. Negligible degradation may be acceptable if it is shown that the equipment and performance still meets the intended function, safety (including integrity and availability), and performance requirements.

3.6.14.2 Reference AC 120-29A, *Criteria for Approval of Category I and Category II Weather Minima for Approach* and AC 120-28D.

Note: Short duration coasting may occur during the approach and landing. TC/STC applicants should verify the RA system coasting logic is consistent with the installed system capability (i.e., use of inertial or other integration) to ensure the continuity and availability of the autoland system continues to meet the requirements.

APPENDIX A. INTEGRATED SYSTEMS

Table A-1. Standards and Policy for Integrated Systems

Operational Application	System or Function	Reference TSO	Reference Advisory Circular
Terrain Avoidance[1]	TAWS	FAA or EASA TSO-C151d	AC 23-18 AC 25-23
	HTAWS	FAA or EASA TSO-C194 FAA or EASA TSO-2C522	AC 27-1B AC 29-2C
Collision Avoidance[1]	TCAS/ACAS I	FAA or EASA TSO-C118a	
	TCAS/ACAS II	FAA or EASA TSO-C119e	AC 20-131A AC 20-151C
	ACAS X	FAA or EASA TSO-C219a	
Windshear Protection[1]	Predictive Windshear	TSO-C63g ETSO-C63f	AC 25-12, AC 20-182A,
	Reactive Windshear	FAA or EASA TSO-C117b	
Flight Guidance Systems	Autopilot (AFGCS/FD)	FAA or EASA TSO-C198	AC 120-29A/120-28D, AC 25.1329-1(), AC 20-138()
	Autothrottle		
	Flight Guidance Alerting		
	Approach and Landing Systems (Including Autoflare)		
	FMS Guidance/ Approach		

[1] These safety systems are required by regulation for certain aircraft operations by multiple state aviation authorities.

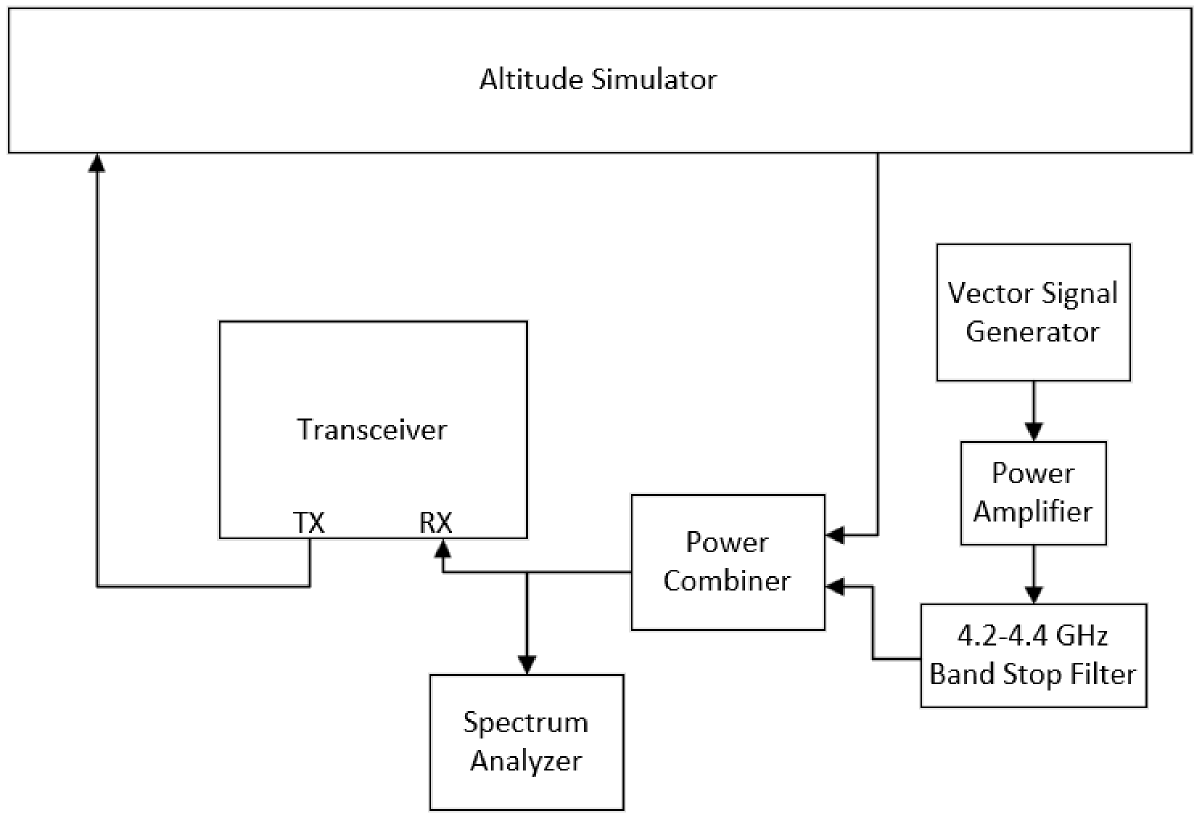
Operational Application	System or Function	Reference TSO	Reference Advisory Circular
Flight Control Systems	Tail Strike Avoidance	Performance and safety requirements tied to aircraft system integration	
	Ground Spoiler/ Speedbrake Deployment		
Cockpit Information	Instrument Approach DH Determination and Alerting (Audio or Visual)	Performance and safety requirements tied to aircraft operation	
	Crew Alerting System Triggers or Inhibitions for Various Warnings and Alerts		
	Situational Awareness of Radio Altitude		
Vision Systems	EFIS	SAE AS6296, SAE 8034B, FAA or EASA TSO-C209	AC 25-11B
	EVS/CVS/EFVS		AC 20-167(),
	SVS/SVGS		AC 20-185(),
	Night Vision Goggle Operations	FAA or EASA TSO-C164a	

APPENDIX B. RADIO FREQUENCY INTERFERENCE TOLERANCE TESTING

B.1 RF Interference Test Setup – Reverse Port (RX) Injection

A simplified block diagram of the test setup used for RF interference injection into the receive port of the RA transceiver either at the LRU level or as a subassembly is shown in figure B-1.

Figure B-1. RF Interference Test Setup – RX Injection

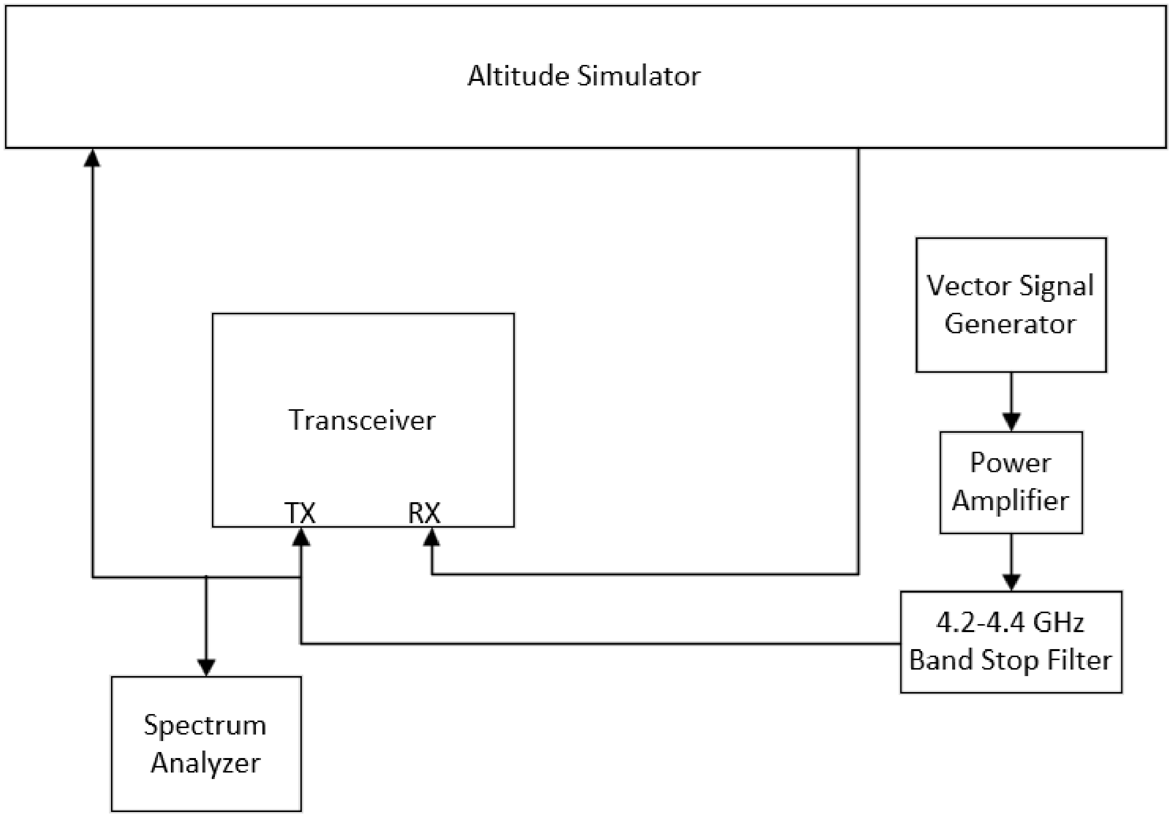


The 4.2–4.4 GHz band stop filter is used to suppress broadband noise from the power amplifier when performing out-of-band interference tests. When performing in-band tests where the required interference level does not necessitate the use of the power amplifier or near-band tests where the use of the band stop filter will unacceptably distort the interference waveform, the band stop filter and power amplifier can be omitted or bypassed.

B.2 RF Interference Test Setup – Transmit Port (TX) Injection

A simplified block diagram of the test setup used for RF interference injection into the transmit port of the RA transceiver, either at the LRU level or as a subassembly, is shown in figure B-2.

Figure B-2. RF Interference Test Setup – TX Injection

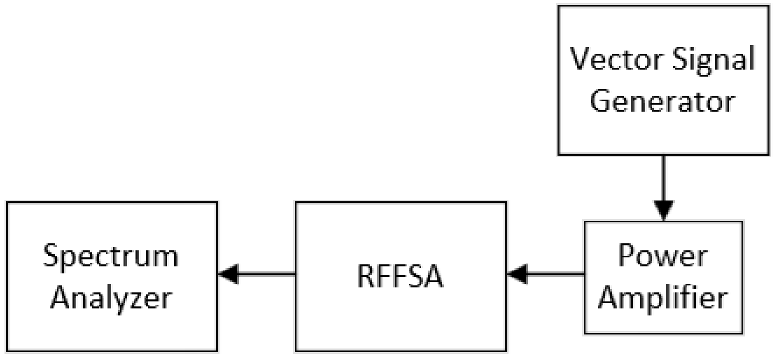


As in the RX injection test setup, the 4.2–4.4 GHz band stop filter and power amplifier can be omitted or bypassed when performing in-band tests where the required interference level does not necessitate the use of the power amplifier or near-band tests where the use of the band stop filter will unacceptably distort the interference waveform.

B.3 RF Interference Test Setup – RF Filter Subassembly

A simplified block diagram of the test setup used for RF interference testing of an RFFSA of the RA transceiver is shown in figure B-3. This test setup is only used when the RFI testing is performed through a combination of subassembly tests rather than a full LRU level test.

Figure B-2. RF Interference Test Setup Subassembly



B.4 **RA Transceiver RFI Injection Test**

The RA system must meet the measurement validity, accuracy, and noise when injecting RFI into the RF port(s) of the RA transceiver with a conducted power level calculated using equation B-1:

(Equation B-1)

$$P_{test}(f_c) = PFD\left(f_c \pm \frac{BW \times 10^6}{2}\right) + 30 - 10 \times \log_{10}(4\pi) + 20 \times \log_{10}\left(\frac{c}{f_c}\right) + G(f_c) + 10 \times \log_{10}(BW) - L_{coax}$$

Where:

$P_{test}(f_c)$ = input power at RA Transceiver TX or RX port, in dBm

$PFD(f)$ = power flux density specified in table1 at the frequency f, in $dBW/m^2/MHz$

c = speed of light, in meters per second

f_c = center frequency of waveform specified in table 1, in Hz

$G(f_c)$ = assumed RA antenna gain at the frequency f_c, in dBi

BW = bandwidth of waveform specified in table 1, in MHz

L_{coax} = coaxial cable loss between the RA antenna and the RA transceiver, in dB

Note 1: The assumed antenna gain must be as specified in the IM as being sufficient performance, and it may include engineering judgment to bound the realized antenna gain at all frequencies in real aircraft installations.

Note 2: For RFI injection testing into the TX port, the coaxial cable loss is the minimum required cable loss in the TX path specified in the IM. For RFI injection testing into the RX port, the coaxial cable loss in is the minimum required cable loss in the RX path as specified in the IM.

B.5 RF Filter Subassembly (RFFSA) and RA Transceiver RFI Injection Test

If the RFI injection testing is performed using separate tests of an RFFSA and a transceiver subassembly, the measurement validity, accuracy, and noise must meet the requirements with the test levels at the RF port(s) of the transceiver subassembly calculated using either equation B-2, if the RFFSA is tested with continuous waveform (CW) only, or equation B-3, if the RFFSA is tested with the same waveforms as the transceiver subassembly.

(Equation B-2)

$$P_{TXR}(f_c, W_n) = P_{test}(f_c, W_n) - \min\left[FDR\left(f_c - \frac{BW}{2}\right), FDR\left(f_c + \frac{BW}{2}\right)\right]$$

Where:

$P_{TXR}(f_c, W_n)$= input power at transceiver subassembly TX or RX port, in dBm

$P_{test}(f_c, W_n)$ = test level at input port of RFFSA calculated from equation B-1, in dBm

$FDR(f)$ = RFFSA frequency-dependent rejection at frequency f measured with CW, in dB

f_c = center frequency of waveform W_n, as specified in table 1, in MHz

BW = bandwidth of waveform W_n, as specified in table 1, in MHz

(Equation B-3)

$$P_{TXR}(f_c, W_n) = P_{test}(f_c, W_n) - FDR(f_c, W_n)$$

Where:

$P_{TXR}(f_c, W_n)$= input power at transceiver subassembly TX or RX port, in dBm

$P_{test}(f_c, W_n)$ = test level at input port of RFFSA calculated from table 1, in dBm

$FDR(f_c, W_n)$ = RFFSA frequency-dependent rejection at frequency f_c measured with waveform W_n, in dB

f_c = center frequency of waveform W_n, as specified in table 1, in MHz

APPENDIX C. RELATED MATERIAL

C.1 Title 14, Code of Federal Regulations (14 CFR).

The following 14 CFR regulations are related to this AC. You can download the full text of these regulations from the Federal Register website at www.ecfr.gov.

- § 23.2500 Airplane level systems requirements.
- § 23.2505 Function and installation.
- § 23.2510 Equipment, systems, and installations.
- § 23.2515 Electrical and electronic system lightning protection.
- § 23.2520 High-intensity Radiated Fields (HIRF) protection.
- § 23.2600 Flightcrew interface.
- § 23.2605 Installation and operation.
- § 23.2610 Instrument markings, control markings, and placards.
- § 23.2615 Flight, navigation, and powerplant instruments.
- § 23.2620 Airplane flight manual.
- § 25.1301 Function and installation.
- § 25.1302 Installed systems and equipment for use by the flightcrew.
- § 25.1309 Equipment, systems, and installations.
- § 25.1316 Electrical and electronic system lightning protection.
- § 25.1317 High-intensity Radiated Fields (HIRF) Protection.
- § 25.1321 Arrangement and visibility.
- § 25.1322 Flightcrew alerting.
- § 25.1329 Flight guidance system.
- § 25.1331 Instruments using a power supply.
- § 25.1333 Instrument systems.
- § 25.1431 Electronic Equipment.
- § 27.1301 Function and installation.
- § 27.1303 Flight and navigation instruments.
- § 27.1309 Equipment, systems, and installations.
- § 27.1316 Electrical and electronic system lightning protection.
- § 27.1317 High-intensity Radiated Fields (HIRF) Protection.
- § 27.1321 Arrangement and visibility.
- § 27.1322 Warning, caution, and advisory lights.
- § 27.1329 Automatic pilot and flight guidance system.
- Part 27 Appendix B /29.1431
- § 29.1301 Function and installation.
- § 29.1303 Flight and navigation instruments.
- § 29.1309 Equipment, systems, and installations.
- § 29.1316 Electrical and electronic system lightning protection.
- § 29.1317 High-intensity Radiated Fields (HIRF) Protection.
- § 29.1321 Arrangement and visibility.
- § 29.1322 Warning, caution, and advisory lights.
- § 29.1329 Automatic pilot and flight guidance system.

- § 29.1331 Instruments using a power supply.
- § 29.1333 Instrument systems.
- § 29.1431 Electronic Equipment
- § 91.220 Radio Altimeter Systems
- § 135.160 Radio altimeters for rotorcraft operations

C.2 **FAA Advisory Circulars.**

The following ACs are related to the guidance in this AC. The latest version of each AC referenced in this document is available on the FAA website at FAA Advisory Circulars and on the Dynamic Regulatory System.

- AC 20-73A, Aircraft Ice Protection
- AC 20-115D, Airborne Software Development Assurance Using EUROCAE ED-12() and RTCA DO-178()
- AC 20-131A, Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II) and Mode S Transponders
- AC 20-136B, Aircraft Electrical and Electronic System Lightning Protection
- AC 20-138D, Airworthiness Approval of Positioning and Navigation Systems
- AC 20-151C, Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (TCAS II), Versions 7.0 & 7.1 and Associated Mode S Transponders
- AC 20-152A, Development Assurance for Airborne Electronic Hardware
- AC 20-155A, Industry Documents to Support Aircraft Lightning Protection Certification
- AC 20-158B, The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-Intensity Radiated Fields (HIRF) Environment
- AC 20-167B, Airworthiness Approval of Enhanced Vision System, Synthetic Vision System, Combined Vision System, and Enhanced Flight Vision System Equipment
- AC 20-175, Controls for Flight Deck Systems
- AC 20-185A, Vision Systems, Synthetic Vision Guidance Systems and Aircraft State Awareness Synthetic Vision Systems
- AC 21-16G, RTCA Document DO-160 versions D, E and F, "Environmental Conditions and Test Procedures for Airborne Equipment"
- AC 21-46A, Technical Standard Order Program
- AC 23-8C, Flight Test Guide for Certification of Part 23 Airplanes
- AC 23-17C, Systems and Equipment Guide for Certification of Part 23 Airplanes and Airships
- AC 23-18, Installation of Terrain Awareness and Warning System (TAWS) Approved for Part 23 Airplanes
- AC 23.1309-1E, System Safety Analysis and Assessment for Part 23 Airplanes
- AC 23.1311-1C, Installation of Electronic Display in Part 23 Airplanes
- AC 25-7D, Flight Test Guide for Certification of Transport Category Airplanes
- AC 25-11B, Electronic Flight Displays

- AC 25-12, Airworthiness Criteria for the Approval of Airborne Windshear Warning Systems in Transport Category
- AC 25-23, Airworthiness Criteria for the Installation Approval of a Terrain Awareness and Warning System (TAWS) for Part 25 Airplanes
- AC 25.1302-1, Installed Systems and Equipment for Use by the Flightcrew
- AC 25.1309-1B, System Design and Analysis
- AC 25.1322-1, Flight Crew Alerting
- AC 25.1329-1C, Approval of Flight Guidance Systems
- AC 25.1701-1, Certification of Electrical Wiring Interconnection Systems on Transport Category Airplanes
- AC 27-1B, Certification of Normal Category Rotorcraft
- AC 29-2C, Certification of Transport Category Rotorcraft
- AC 120-28D, Criteria for Approval of Category III Weather Minima for Takeoff, Landing, and Rollout
- AC 120-29A, Criteria for Approval of Category I and Category II Weather Minima for Approach

C.3 **FAA Technical Standard Orders.**

The following TSOs are related to the guidance in this AC. The latest version of each AC referenced in this document is available on the Dynamic Regulatory System.

- TSO-C63g, Airborne Weather Radar Equipment
- TSO-C87(), Airborne Low-Range Radio Altimeter
- TSO-C117b, Airborne Windshear Warning and Escape Guidance Systems for Transport Airplanes
- TSO-C118a, Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS I
- TSO-C119e, Traffic Alert And Collision Avoidance System (TCAS) Airborne Equipment, TCAS II With Hybrid Surveillance
- TSO-C151d, Terrain Awareness and Warning Systems (TAWS)
- TSO-C164a, Night Vision Goggles
- TSO-C194, Helicopter Terrain Awareness and Warning System (HTAWS)
- TSO-C198, Automatic Flight Guidance and Control System (AFGCS) Equipment
- TSO-C209, Electronic Flight Instrument System (EFIS) Display
- TSO-C219a, Airborne Collision Avoidance System (ACAS) Xa/Xo
- TSO-C221, Airborne Low-Range Radio Altimeter Transceiver

C.4 **ASTM Consensus Standards.**

FAA-accepted consensus standards for Part 23 normal category airplanes, including any required changes for acceptance, are available online at https://www.faa.gov/aircraft/air_cert/design_approvals/small_airplanes/small_airplanes_regs.

- F3061, Standard Specification for Systems and Equipment in Small Aircraft

- F3117, Standard Specification for Crew Interface in Aircraft
- F3233, Standard Specification for Instrumentation in Small Aircraft
- F3367, Standard Practice for Simplified Methods for Addressing High-Intensity Radiated Fields (HIRF) and Indirect Effects of Lightning on Aircraft
- F3532, Standard Practice for Protection of Aircraft Systems from Intentional Unauthorized Electronic Interactions

C.5 **RTCA.**

The following RTCA (formerly Radio Technical Commission for Aeronautics) documents are related to the guidance in this AC. Unless otherwise specified, use the latest FAA-accepted revision for guidance. If the document is revised after publication of this AC, you should verify that the FAA accepts the subsequent revision or update as an acceptable form of guidance. This document can be ordered online at https://www.rtca.org.

- DO-160G, Environmental Conditions and Test Procedures for Airborne Equipment
- DO-161A, Minimum Performance Standards-Airborne Ground Proximity Warning Equipment
- DO-178C, Software Consideration in Airborne Systems and Equipment Certification
- DO-185B, Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II (TCAS II) Airborne Equipment
- DO-197A, Minimum Operational Performance Standards for an Active Traffic Alert and Collision Avoidance System I (Active TCAS I)
- DO-220B, Minimum Operational Performance Standards (MOPS) For Airborne Weather Radar Systems
- DO-300A, Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCASII) Hybrid Surveillance
- DO-309, Minimum Operational Performance Standards (MOPS) for Helicopter Terrain Awareness and Warning System (HTAWS) Airborne Equipment
- DO-315B, Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight Vision Systems
- DO-325, Minimum Operation Performance Standards (MOPS) for Automatic Flight Guidance and Control Systems and Equipment
- DO-326B, Airworthiness Security Process Specification
- DO-355A, Information Security Guidance for Continuing Airworthiness
- DO-356A, Airworthiness Security Methods and Considerations
- DO-359, Minimum Aviation System Performance Standards (MASPS) for Synthetic Vision Guidance Systems
- DO-367, Minimum Operational Performance Standards (MOPS) for Terrain Awareness and Warning Systems (TAWS) Airborne Equipment
- DO-376, Minimum Operational Performance Standard for Offshore Helicopter Terrain Awareness and Warning System (HTAWS)

- DO-385A, Minimum Operational Performance Standards for Airborne Collision Avoidance System X (ACAS X) (ACAS Xa and ACAS Xo)
- DO-391, Aeronautical Information System Security Framework Guidance
- DO-405, Minimum Operating Performance Standard (MOPS) for Helicopter Terrain Awareness Warning System (HTAWS) for Onshore Helicopter Operations

C.6 **European Organization for Civil Aviation Equipment (EUROCAE).**

The following EUROCAE documents are related to the guidance in this AC. Unless otherwise specified, use the latest FAA-accepted revision for guidance. If the document is revised after publication of this AC, you should verify that the FAA accepts the subsequent revision or update as an acceptable form of guidance. The documents are available online at: https://www.eurocae.net.

- ED-14G, Environmental Conditions and Test Procedures for Airborne Equipment
- ED-30, MPS for Airborne Low Range Radio (radar) Altimeter Equipment
- ED-202B, Airworthiness Security Process Specification
- ED-203A, Airworthiness Security Methods and Considerations
- ED-204A, Information Security Guidance for Continuing Airworthiness

C.7 **Society of Automotive Engineers (SAE) International.**

The following SAE Aerospace Recommended Practice (ARP) documents are related to the guidance in this AC. Unless otherwise specified, use the latest FAA-accepted revision for guidance. If the document is revised after publication of this AC, you should verify that the FAA accepts the subsequent revision or update as an acceptable form of guidance. The documents are available online at: https://www.sae.org.

- AS6296, Electronic Flight Instrument System (EFIS)
- AS8034B, Minimum Performance Standard for Airborne Multipurpose Electronic Displays
- ARINC 707-7, Radio Altimeter
- ARP4754B, Guidelines for Development of Civil Aircraft and Systems
- ARP4761A, Guidelines for Conducting the Safety Assessment Process on Civil Aircraft, Systems, and Equipment

C.8 **International Civil Aviation Organization (ICAO)**

- ICAO Doc 9718, the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation.

APPENDIX D. DEFINITION OF KEY TERMS

The following definitions apply for the purpose of this AC:

D.1 **Decision Height (DH)**

See 14 CFR 1.1, *General Definitions.*

Note: During operation of the approach procedure, the RA system is the only source of determining (or annunciating) when the decision height has been reached.

D.2 **Electrical Height Output**

The reported RA quantity from the RA system provided on an electrical output interface signal. The output interface may be analog or digital.

D.3 **Height Above Ground Level (HAGL)**

The distance from the portion of aircraft structure in which the RA antenna(s) is/are installed to the terrain surface at a given point along a flight path.

D.4 **In-Band Radio Frequency Interference (RFI)**

External RFI signals within the RA operating frequency (4.2 – 4.4 GHz).

D.5 **Installation Time Delay**

The actual round-trip RF signal propagation time delay in an RA system installation on an aircraft relative to the desired zero-height reference point. This may include, for example, the propagation delays in the coaxial cables or transmission lines between the RA transceiver and the RA antenna(s), and the free-space propagation from the RA antenna(s) to the terrain surface when the aircraft is on the ground with the main landing gear touching in a pre-established aircraft attitude (i.e., nose gear may not be touching).

D.6 **Installation Height Offset**

A value, determined by calibration, configuration, or installation of the RA system, which defines a constant bias to be subtracted from the measurement result of the RA transceiver in order to account for the height of the RA antenna(s) above the terrain while the aircraft is on the ground (with the main landing gear touching in a pre-established aircraft attitude, the length of coaxial cables or transmission lines between the RA transceiver, and the RA antenna(s) and any other system delays as needed).

D.7 **Installation Manual (IM)**

A document developed and made available by the equipment manufacturer of a system, subsystem, or component that specifies the performance characteristics, interface specifications, installation constraints and limitations, installation requirements, calibration (if applicable), on-aircraft testing, maintenance, troubleshooting procedures, and any necessary requirements for other integrated equipment.

D.8 **Interference Tolerance Mask (ITM)**

The specification that defines the maximum amount of RFI at the RA antenna(s) that the RA system can safely tolerate.

D.9 **Irregular Approach Terrain**

Includes cliffs, valleys, sea walls, hilltops, sloping runways, etc. in the area of final approach, within approximately 1500 ft. of the landing threshold.

D.10 **Loop Loss**

The round-trip attenuation of a radio return signal.

D.11 **Multiplex Installation**

An installation of more than one RA system of the same type onboard a single aircraft. Typically, this will consist of either a dual or triplex installation.

D.12 **Out-of-Band Radio Frequency Interference (RFI)**

External RFI signals outside the RA operating frequency band (i.e., at frequencies less than 4.2 GHz or greater than 4.4 GHz).

D.13 **Radio Altimeter Antenna**

The subsystem or component of the RA system that takes a conducted RF signal provided by the transceiver and radiates it toward the terrain and receives a radiated RF signal reflected from the terrain and provides a conducted RF signal to the transceiver. An RA system will include one or multiple RA antennas.

D.14 **Radio Altimeter Indicator or Display**

The subsystem or component of the RA system that provides a visual indication of the measured altitude result determined by the RA transceiver. An RA system may include one, multiple, or no RA indicators or displays. It may be a standalone indicator or display component for the sole purpose of displaying RA system outputs, or it may be a function incorporated into a MFD system, such as an EFIS.

D.15 **Radio Altimeter System**

A complete system consisting of receiver and transmitter, one or more antennas, RF cables (if the antenna(s) are not integrated into the same LRU as the receiver and transmitter), and input/output interfaces (which may include a display of altitude information as a visual output interface, either integrated or as a part of a separate display or indicator component).

D.16 **Radio Altimeter Transceiver**

The subsystem or component of the RA system that generates and transmits the RF signal and receives, processes, and determines a measured altitude result from the RF signal reflected from the terrain. An RA will include one and only one RA transceiver.

D.17 **RF Filter Subassembly (RFFSA)**

A subassembly implemented within the RA transceiver LRU that selectively filters RF signals outside of the RA band. The RA transceiver could be implemented with an RFFSA at the transmitter output port, the receiver input port, or both.

D.18 **Transceiver Subassembly**

A subassembly implemented within the RA transceiver LRU that performs all of the normal functions of the RA, with the exception of the selective filtering implemented in one or more RFFSAs.

D.19 **Terrain Smoothness**

Ranging from smooth to rough (where rough terrains may be further characterized by the feature size and density of the surface roughness).

D.20 **Terrain Flatness**

Ranging from flat to undulating (where undulating terrains may be further characterized by the depth and period of their undulations).

D.21 **Terrain Inclination**

Ranging from level to sloped (where sloped terrains may be further characterized by the angle of the terrain slope).

D.22 **Terrain Surface Features**

Ranging from bare to densely featured. Terrains may be further characterized by the density of the surface features (e.g., sparsely featured or densely featured, as well as the size of the surface features).

APPENDIX E. ACRONYMS

Acronym	Definition
AC	Advisory Circular
ACAS	Airborne Collision Avoidance System
AFGCS	Automatic Flight Guidance and Control System
AID	Aircraft Installation Delay
ARP	Aerospace Recommended Practice
ATC	Air Traffic Control
CAA	Civil Aviation Authority
CAA	Civil Aviation Authority
CAS	Crew Alerting System
CAT	Category
CS	Certification specification
CW	Continuous waveform
DAL	Design Assurance Level
DH	Decision Height
EASA	European Union Aviation Safety Agency
EFIS	Electronic Flight Instrument System
EFVS	Enhanced flight vision systems
EUROCAE	European Organization for Civil Aviation Equipment
HAGL	Height above ground level
HIRF	High-Intensity Radiated Fields
HTAWS	Helicopter Terrain Awareness and Warning System
IB	In-Band
ICA	Instructions for Continued Airworthiness
ICAO	International Civil Aviation Organization
IM	Installation Manual
ITM	Interference Tolerance Mask
LRU	Line replaceable unit
MASPS	Minimum Aviation System Performance Standards
MFD	Multifunction Display
MOPS	Minimum Operational Performance Standards
MSD	Minimum Separation Distance
PFD	Power Flux Density
RA	Radio altimeter
RF	Radio frequency
RFFSA	RF Filter Subassembly
RFI	Radio Frequency Interference
RTCA	Radio Technical Commission for Aeronautics
SAE	Society of Automotive Engineers
SVS	Synthetic vision systems
STC	Supplemental Type Certificate
TAWS	Terrain Awareness and Warning System

Acronym	Definition
TC	Type Certificate
TCAS	Traffic Alert and Collision Avoidance System
TSO	Technical Standard Order
VSWR	Voltage Standing Wave Ratio

<Add feedback form on last page before submitting AC to DMO in .pdf>