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

# Advisory Circular

**Subject:** The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-Intensity Radiated Fields (HIRF) Environment

**Date:** 5/20/24

**Initiated By:** AIR-626

**AC No:** 20-158B

This advisory circular (AC) will provide information and guidance on how to show compliance with §§ 23.1308 (Amendment 23-57), 23.2520 (Amendment 23-65), 25.1317, 27.1317, and 29.1317 of title 14, Code of Federal Regulations (14 CFR) for the certification of aircraft electrical and electronic systems for operation in the high-intensity radiated fields (HIRF) environment.

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# 1 PURPOSE

1.1 This AC provides guidance for a new type certificate (TC) or a change to an existing TC when the certification basis requires you to address the HIRF certification requirements of §§ 23.1308 (Amendment 23-57), 23.2520 (Amendment 23-65), 25.1317, 27.1317, or § 29.1317.

1.2 This revision incorporates recommendations from the Certification Authorities for Transport Airplanes. These recommendations address inconsistencies in the interpretation and application of the HIRF rules and provide a harmonized compliance approach for transport category airplanes.

1.3 Additionally, this AC contains guidance from the Federal Aviation Administration (FAA) policy statement, PS-ACE-23-10, *HIRF/Lightning Test Levels and Compliance Methods for 14 CFR Part 23 Class I, II, and III Airplanes*, dated October 3, 2017, which describes an acceptable means on how to show compliance with §§ 23.1308 (Amendment 23-57) and 23.2520. The applicant may also use a means of compliance, which may include consensus standards, accepted by the FAA under§ 23.2010.

# 2 APPLICABILITY

2.1 The guidance provided in this AC is for manufacturers, modifiers, foreign regulatory authorities, and FAA engineers, and their designees.

2.2 The contents of this AC do not have the force and effect of law and are not meant to bind the public in any way. This AC is intended only to provide information to the public regarding existing requirements under the law or agency policies. Conformity with the guidance is voluntary only and nonconformity will not affect rights and obligations under existing statues and regulations. The FAA will consider other methods of demonstrating compliance that an applicant may elect to present. Terms such as “should,” “may,” and “must” are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance in this document is used. 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.

2.3 This material does not change or create any additional regulatory requirements or authorize changes in or permit deviations from existing regulatory requirements.

# 3 CANCELLATION

This AC cancels AC 20-158A, *The Certification of Aircraft Electrical and Electronic Systems for Operation in a High-intensity Radiated Field (HIRF) Environment*, dated May 30, 2014.

## 4 RELATED MATERIAL

### 4.1 Title 14, Code of Federal Regulations (14 CFR).

The full text of these regulations is available at https://www.ecfr.gov.

- Section 23.1308 (Amendment 23-57), *High-intensity Radiated Fields (HIRF) Protection*.
- Section 23.1529, *Instructions for Continued Airworthiness*.
- Section 23.2000, *Applicability and definitions*.
- Section 23.2520 (Amendment 23-65), *High-intensity Radiated Fields (HIRF) Protection*.
- Section 25.1317, *High-intensity Radiated Fields (HIRF) Protection*.
- Section 25.1529, *Instructions for Continued Airworthiness*.
- Section 25.1729, *Instructions for Continued Airworthiness: EWIS*.
- Section 26.11, *Electrical wiring interconnection systems (EWIS) maintenance program*.
- Section 27.1317, *High-intensity Radiated Fields (HIRF) Protection*.
- Section 27.1529, *Instructions for Continued Airworthiness*.
- Section 29.1317, *High-intensity Radiated Fields (HIRF) Protection.*
- Section 29.1529, *Instructions for Continued Airworthiness*.

### 4.2 FAA Advisory Circulars.

The following FAA ACs are related to the guidance in this AC. You should refer to the latest AC version for guidance, which is available on the Dynamic Regulatory System (DRS) at https://drs.faa.gov/browse.

- AC 21-16, *RTCA Document DO-160 versions E, F, and G, Environmental Conditions and Test Procedures for Airborne Equipment*.
- AC 23.1309-1, *System Safety Analysis and Assessment for Part 23 Airplanes*.
- AC 25.1309-1, *System Design and Analysis*.
- AC 27-1, *Certification of Normal Category Rotorcraft*.
- AC 29-2, *Certification of Transport Category Rotorcraft*.
- AC 33.28-3, *Guidance Material For 14 CFR§ 33.28, Engine Control Systems*.

### 4.3 FAA Policy Statement.

The following FAA policy statement is related to the guidance in this AC. If the policy statement is revised after publication of this AC, you should refer to the latest version for guidance, which is available on the DRS at https://drs.faa.gov/browse.

PS-ACE-23-10, *HIRF/Lightning Test Levels and Compliance Methods for 14 CFR Part 23 Class I, II, and III Airplanes*.

4.4 ASTM Consensus Standards.

FAA-accepted consensus standards for part 23 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.

- FAA Accepted Means of Compliance for Part 23 Airplanes (Pre-Amendment 23-64).
- FAA Accepted Means of Compliance for Part 23 Airplanes (Amendment 23-64 or later).

4.5 European Union Aviation Safety Agency (EASA).

The following certification specification (CS) documents can be ordered by mail at Postfach 10 12 53, D-50452 Cologne, Germany; telephone +49 221 8999 000; fax: +49 221 8999 099; or obtained online at https://www.easa.europa.eu/home.

- CS-23, *Normal-Category Aeroplanes.*
- CS-25, *Large Aeroplanes.*
- CS-27, *Small Rotorcraft.*
- CS-29, *Large Rotorcraft*.

4.6 RTCA.

The following RTCA (formerly Radio Technical Commission for Aeronautics) document is 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.

RTCA/DO-160E, *Environmental Conditions and Test Procedures for Airborne Equipment.*

**Note:** Installers may use section 20, Radio Frequency Susceptibility (Radiated and Conducted), of RTCA/DO-160E, as specified in AC 21-16. RTCA/DO-160E and EUROCAE ED-14E, referenced below, are technically equivalent. You may use RTCA/DO-160E whenever there is a reference to EUROCAE ED-14E in this AC.

4.7 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.

- EUROCAE ED-14E, *Environmental Conditions and Test Procedures for Airborne Equipment*.
- EUROCAE ED-107A, *Guide to Certification of Aircraft in a High Intensity Radiated Field (HIRF) Environment*.

**Note:** ED-107A and SAE ARP5583A, referenced below, are technically equivalent. This AC means either document when referring to "the user's guide." EUROCAE ED-14E and RTCA/DO-160E are technically equivalent. You may use EUROCAE ED-14E whenever there is a reference to RTCA/DO-160E in this AC.

4.8 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.

- SAE ARP4754A, *Guidelines for Development of Civil Aircraft and Systems*.
- SAE ARP4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*.
- SAE ARP5583A, *Guide to Certification of Aircraft in a High-Intensity Radiated Field (HIRF) Environment*.

**Note:** SAE ARP5583A and EUROCAE ED-107A, referenced above, are technically equivalent. This AC means either document when referring to "the user's guide."

## 5 DEFINITIONS

- Adverse Effect. A response (caused by exposure to HIRF) that results in an unexpected and unacceptable operation of an aircraft system, or in an unexpected and unacceptable operation of a function performed by the system.
- Attenuation. A decrease in electromagnetic field strength in transmission from one point to another. Attenuation may be expressed as a scalar ratio of the input magnitude to the output magnitude or in decibels (dB).
- Automatically Recover. To return to normal operations without flightcrew action.
- Bulk Current Injection (BCI). A method of electromagnetic interference (EMI) testing that involves injecting current into wire bundles through a current injection probe.
- Channel. A subset of a system consisting of equipment, components, and interconnections, which performs an aircraft function provided by the system. A system could be composed of redundant similar or dissimilar channels to maintain the function at the aircraft level in case of failure on one or several channels.

- Continued Safe Flight and Landing. Capability for continued controlled flight and landing at a suitable location, possibly using emergency procedures but without requiring exceptional pilot skill or strength. Some aircraft damage may occur because of a failure condition during flight or on landing. For part 23 airplanes, it is not necessary to land at an airport. For part 25 airplanes, the pilot must be able to land safely at a suitable airport. For part 27 and part 29 rotorcraft, the rotorcraft must continue to cope with adverse operating conditions, and the pilot must be able to land safely at a suitable site.

  **Note:** The above definition should be used, regarding the method provided by this AC, for all aircraft except normal category airplanes with a part 23 (Amendment 23-64 or later) certification basis, for which the definition of "continued safe flight and landing" in § 23.2000(b) applies.

- Continuous Wave (CW). Radio frequency (RF) signal consisting of only the fundamental frequency with no modulation in amplitude, frequency, or phase.
- Coupling. Process whereby electromagnetic energy is induced in a system by radiation produced by a RF source.
- Current Injection Probe. Inductive device designed to inject RF signals directly into wire bundles when clamped around them.
- Direct Drive Test. EMI test that involves electrically connecting a signal source directly to the unit being tested.
- Electrical and Electronic System. An electrical and electronic system means all electrical and electronic equipment, components, and the electrical interconnections that are required to perform a particular function.
- Equipment. Component of an electrical and electronic system with interconnecting electrical conductors.
- Equipment Electrical Interface. Location on a piece of equipment where an electrical connection is made to the other equipment in a system of which it is a part. The electrical interface may consist of individual wires or wire bundles that connect the equipment.
- External HIRF Environment. Electromagnetic RF fields at the exterior of an aircraft.
- Field Strength. Magnitude of the electromagnetic energy propagating in free space expressed in volts per meter (V/m).
- Function. The specific action of a system, equipment, and flightcrew performance aboard the aircraft that, by itself, provides a completely recognizable operational capability. For example, "display aircraft heading to the pilots" is a function. One or more systems may perform a specific function, or one system may perform multiple functions.
- HIRF Environment. Electromagnetic environment created by the transmission of high-power RF energy into free space.

- HIRF Vulnerability. Susceptibility characteristics of a system that cause it to suffer adverse effects when performing its intended function because of having been subjected to a HIRF environment.
- Immunity. Capacity of a system or piece of equipment to continue to perform its intended function, in an acceptable manner, in the presence of RF fields.
- Interface Circuit. Electrical or electronic device connecting the electrical inputs and outputs of equipment to other equipment or devices in an aircraft.
- Internal HIRF Environment. The RF environment inside an airframe, equipment bay, or cavity. The internal RF environment is described in terms of the internal RF field strength or wire bundle current.
- Margin. Difference between equipment susceptibility or qualification levels and the aircraft internal HIRF environment. Margin requirements may be specified to account for uncertainties in design, analysis, or test.
- Modulation. Process whereby certain characteristics of a wave, often called the carrier wave, are varied in accordance with an applied function.
- Normal Operation. The status where the system is performing its intended function. When addressing compliance with §§ 23.1308(a)(2), 23.2520(a)(2), 25.1317(a)(2), 27.1317(a)(2), and 29.1317(a)(2), the function whose failure may prevent the continued safe flight and landing should be in the same undisturbed state as before exposure to the HIRF environment.
- Non-Normal Situation. An event, condition, or situation that requires non-normal, abnormal, emergency, or unusual procedures or configurations for operating the aircraft.
- Pulse Modulation. RF signal in the form of pulses with varied amplitudes and widths (narrowband or broadband).
- Radio Frequency. Frequency within the range used for radio transmission. The present practical range of RF transmissions are roughly 10 kilohertz (kHz) to 100 gigahertz (GHz). Within this frequency range, electromagnetic energy may be detected and amplified as an electric current at the wave frequency.
- Reflection Plane. Conducting plate that reflects RF signals.
- Similarity. Process of using existing HIRF compliance documentation and data from a system or aircraft to demonstrate HIRF compliance for a nearly identical system or aircraft of equivalent design, construction, and installation having equivalent internal and external environmental conditions.
- Square Wave. RF signal that alternates amplitude, with the same duration, between fixed minimum and maximum values.
- Susceptibility. Aspect of a piece of equipment that describes its inability to function acceptably when subjected to unwanted electromagnetic energy.

- Susceptibility Level. Level where the effects of interference from electromagnetic energy become apparent.
- Timely Manner. The necessary period for a system to reconfigure safely after a disruption.

  **Note:** Timely recovery has been introduced to account for this period. The meaning of 'in a timely manner' depends on the function performed by the system being evaluated, the specific system design, the interactions between the system and the flightcrew, and the phase of flight. The definition of 'in a timely manner' should be determined for each system and for the specific functions performed by the system. The applicable definition may be included in the HIRF safety assessment.

- Transfer Function. Ratio of the electrical output of a system to the electrical input of a system, expressed in the frequency domain. For HIRF, a typical transfer function is the ratio of the current on a wire bundle to the external HIRF field strength, as a function of frequency.
- Upset. Impairment of system operation, either permanent or momentary. For example, a change of digital or analog state that may or may not require a manual reset.

## 6 BACKGROUND

Electrical and electronic systems installed in aircraft may exhibit performance degradation when exposed to a HIRF environment. These systems perform functions whose failure may prevent the continued safe flight and landing of the aircraft or cause an adverse operating condition.

### 6.1 HIRF Environment.

The electromagnetic HIRF environment is created because of the transmission of electromagnetic RF energy from radar, radio, television, and other ground-based, shipborne, or airborne RF transmitters. The user's guide, SAE ARP5583A or EUROCAE ED-107A, provides a detailed description of the derivation of these HIRF environments.

### 6.2 Aircraft Protection.

Concerns over the need to protect aircraft electrical and electronic systems have increased substantially because of:

- Greater dependence on electrical and electronic systems performing functions required for continued safe flight and landing of an aircraft;
- Reduced electromagnetic shielding afforded by some composite materials used in aircraft designs;
- Increased susceptibility of electrical and electronic systems to HIRF because of increased data bus and processor operating speeds, higher density integrated circuits, and greater sensitivities of electronic equipment;

- Expanded frequency usage, especially above 1 GHz;
- Increased severity of the HIRF environment because of an increase in the number of RF transmitters; and
- Adverse effects experienced by some aircraft when exposed to HIRF.

## 7 STEPS FOR SHOWING COMPLIANCE

7.1 HIRF Certification Program.

The following activities should be elements of a proper HIRF certification program. You should:

- Identify the systems to be assessed;
- Perform a HIRF safety assessment;
- Establish the applicable aircraft external HIRF environment;
- Establish the test environment for installed systems;
- Apply HIRF compliance verification method;
- Verify HIRF protection effectiveness; and
- Take corrective measures (if needed).

**Note:** The user's guide, SAE ARP5583A or EUROCAE ED-107A, contains more detailed information on HIRF certification compliance.

7.2 Identify the Systems to be Assessed.

7.2.1 You should identify the aircraft systems that will need a HIRF safety assessment. You should define the elements of the system performing a function, considering redundant or backup equipment that makes up the system. The process used for identifying these systems should be similar to the process for showing compliance with §§ 23.1309, 23.2510, 25.1309, 27.1309, and 29.1309, as applicable. You should assess the effects of a HIRF encounter to determine the degree to which the aircraft and its systems' safety may be affected.

7.2.2 You should assess the operation of the aircraft systems separately and in combination with, or in relation to, other systems. This assessment should cover all:

- Normal aircraft operating modes, stages of flight, and operating conditions;
- HIRF-related failure conditions and their subsequent effect on aircraft operations and the flightcrew; and
- System responses and any required flightcrew actions.

7.3 HIRF Safety Assessment.

You should perform a safety assessment related to HIRF to establish and classify the equipment or system failure condition. Table 1 provides the corresponding failure condition classification and system HIRF certification level (HCL) for the appropriate HIRF regulations. The failure condition classifications and terms used in this AC are like those used in AC 23.1309-1, AC 25.1309-1, AC-27-1, and AC-29-2, as applicable. Only those systems identified as performing or contributing to functions whose failure would result in catastrophic, hazardous, or major failure conditions are subject to HIRF regulations. Based on the failure condition classification established by the safety assessment, the systems should be assigned appropriate HCLs, as shown in table 1. The safety assessment should consider the common cause effects of HIRF, particularly for highly integrated systems and systems with redundant elements. The HIRF safety assessment determines the consequences of failures for the aircraft functions that are performed by the system.

### 7.3.1 HCL Classification

The HCL classification assigned to the system and functions may be different from the design assurance level assigned for equipment redundancy, software, and complex electronic hardware. This is because HIRF environments can cause common cause effects. The term “design assurance level” should not be used to describe the HCL because of the potential differences in assigned classifications for software, complex electronic hardware, and equipment redundancy. The HIRF safety assessment should include all electrical and electronic equipment, components, and electrical interconnections, and should assume that they are potentially affected by HIRF. It is not appropriate to use the HIRF immunity data for electrical and electronic equipment, components, and electrical interconnections as input information on the HIRF safety assessment. This information should only be used in the next phase activity in the section below to show compliance with the applicable paragraph of the HIRF regulations, after the required HCL for the system is determined by the HIRF safety assessment. The HIRF safety assessment should have input from and be coordinated between the applicant’s safety specialists, system specialists, and HIRF specialists. This process may vary from applicant to applicant. Further guidance on performing the safety assessment can be found in AC 23.1309-1, AC 25.1309-1, AC-27-1, AC-29-2, SAE ARP4754A, SAE ARP4761, and SAE ARP5583A.

**Note:** Considering that HIRF and lightning environments may have similar effects on electronic systems (disturbing electrical signals causing upsets or damage to circuits) and that the regulations for each are similarly structured, the system HCL and lightning certification level may be the same.

### Table 1. HIRF Failure Conditions and System HIRF Certification Levels

| HIRF REQUIREMENTS EXCERPTS FROM §§ 23.1308, 25.1317, 27.1317, AND 29.1317 | MOST SEVERE FAILURE CONDITION OF THE FUNCTION | SYSTEM HCL |
|---|---|---|
| Each electrical and electronic system that performs a function whose failure would prevent the continued safe flight and landing of the rotorcraft/airplane… | Catastrophic | A |
| Each electrical and electronic system that performs a function whose failure would significantly reduce the capability of the rotorcraft/airplane or the ability of the flightcrew to respond to an adverse operating condition… | Hazardous | B |
| Each electrical and electronic system that performs a function whose failure would reduce the capability of the rotorcraft/airplane or the ability of the flightcrew to respond to an adverse operating condition… | Major | C |
| **HIRF REQUIREMENTS EXCERPTS FROM § 23.2520 (Amendment 23-65)** | **MOST SEVERE FAILURE CONDITION OF THE FUNCTION** | **SYSTEM HCL** |
| Each electrical and electronic system that performs a function, the failure of which would prevent the continued safe flight and landing of the airplane… | Catastrophic | A |
| For airplanes approved for instrument flight rules (IFR) operations, each electrical and electronic system that performs a function, the failure of which would significantly reduce the capability of the airplane or the ability of the flightcrew to respond to an adverse operating condition… | Hazardous | B |

7.3.2 **Scope of HCL A Systems**.

You must show compliance with §§ 23.1308(a), 23.2520(a), 25.1317(a), 27.1317(a), or § 29.1317(a) for each electrical and electronic system that performs a function whose failure would prevent continued safe flight and landing of the aircraft. Additionally, as required by §§ 23.1308(a)(2), 23.2520(a)(2), 25.1317(a)(2), 27.1317(a)(2), or § 29.1317(a)(2), the electrical and electronic system must recover normal operation of the function in a timely manner after the airplane is exposed to the HIRF environment, unless the system's recovery conflicts with other operational or functional requirements of the system. The electrical and electronic system includes all equipment, components, and electrical interconnections required for normal operation. Electrical and electronic equipment, components, and electrical interconnections that are operational only in non-normal situations do not have to meet the requirements of §§ 23.1308(a), 23.2520(a), 25.1317(a), 27.1317(a), or § 29.1317(a), provided all electrical and electronic equipment, components and electrical interconnections required for normal operation comply with these regulations.

7.3.3 **Scope of HCL B and C Systems**.

You must show compliance with§ 23.1308(b) and (c), 23.2520(b), 25.1317(b) and (c), 27.1317(b) and (c), or§ 29.1317(b) and (c) for each system that performs a function whose failure would significantly reduce or reduce (paragraph (b) or (c) of the applicable HIRF regulations) the capability of the aircraft or the ability of the flightcrew to respond to an adverse operating condition when all electrical and electronic equipment, components, and electrical interconnections are exposed to HIRF test level 1, 2, or 3, respectively. As required by§ 23.2520(b), for IFR operations, the system must also recover normal operation of the function in a timely manner after the aircraft is exposed to the HIRF environment.

7.3.4 **Failure Conditions**.

The HIRF safety assessment should consider all potential adverse effects due to system failures, malfunctions, or misleading information. The HIRF safety assessment may show some systems have different failure conditions in different phases of flight. Therefore, the HCL in table 1 corresponds to phase of flight with the most severe failure condition. For example, an automatic flight control system may have a catastrophic failure condition for autoland, while automatic flight control system operations in cruise may have a hazardous failure condition.

7.4 Establish the Applicable Aircraft External HIRF Environment.

The external HIRF environments I, II, and III, as published in §§ 23.1308, 25.1317, 27.1317, and 29.1317, are shown in tables 2, 3, and 4, respectively. The field strength values for the HIRF environments and test levels are expressed in root-mean-square (rms) units measured during the peak of the modulation cycle. Section 23.2520 does not specify external HIRF environments.

**Note:** For part 23, the applicant may use the guidance in this AC as a means of compliance, which may include ASTM consensus standards, accepted by the Administrator in accordance with § 23.2010 (See paragraph 4.4).

**Table 2. HIRF Environment I**

| FREQUENCY | FIELD STRENGTH (V/m) PEAK | FIELD STRENGTH (V/m) Average |
|---|---|---|
| 10 kHz - 2 MHz | 50 | 50 |
| 2 MHz - 30 MHz | 100 | 100 |
| 30 MHz - 100 MHz | 50 | 50 |
| 100 MHz – 400 MHz | 100 | 100 |
| 400 MHz – 700 MHz | 700 | 50 |
| 700 MHz - 1 GHz | 700 | 100 |
| 1 GHz - 2 GHz | 2,000 | 200 |
| 2 GHz - 6 GHz | 3,000 | 200 |
| 6 GHz - 8 GHz | 1,000 | 200 |
| 8 GHz - 12 GHz | 3,000 | 300 |
| 12 GHz - 18 GHz | 2,000 | 200 |
| 18 GHz - 40 GHz | 600 | 200 |

**Note:** In this table, the higher field strength applies at the frequency band edges.

**Table 3. HIRF Environment II**

| FREQUENCY | FIELD STRENGTH (V/m) PEAK | FIELD STRENGTH (V/m) AVERAGE |
|---|---|---|
| 10 kHz – 500 kHz | 20 | 20 |
| 10 kHz – 500 kHz | 20 | 20 |
| 500 kHz - 2 MHz | 30 | 30 |
| 2 MHz - 30 MHz | 100 | 100 |
| 30 MHz – 100 MHz | 10 | 10 |
| 100 MHz – 200 MHz | 30 | 10 |
| 200 MHz – 400 MHz | 10 | 10 |
| 1 GHz - 2 GHz | 1,300 | 160 |
| 2 GHz - 4 GHz | 3,000 | 120 |
| 4 GHz - 6 GHz | 3,000 | 160 |
| 6 GHz - 8 GHz | 400 | 170 |
| 8 GHz - 12 GHz | 1,230 | 230 |
| 12 GHz - 18 GHz | 730 | 190 |
| 18 GHz - 40 GHz | 600 | 150 |

**Note:** In this table, the higher field strength applies at the frequency band edges.

**Table 4. HIRF Environment III**

| FREQUENCY | FIELD STRENGTH (V/m) PEAK | FIELD STRENGTH (V/m) AVERAGE |
|---|---|---|
| 10 kHz – 100 kHz | 150 | 150 |
| 100 kHz – 400 MHz | 200 | 200 |
| 400 MHz – 700 MHz | 730 | 200 |
| 700 MHz - 1 GHz | 1,400 | 240 |
| 1 GHz - 2 GHz | 5,000 | 250 |
| 2 GHz - 4 GHz | 6,000 | 490 |
| 4 GHz - 6 GHz | 7,200 | 400 |
| 6 GHz - 8 GHz | 1,100 | 170 |
| 8 GHz - 12 GHz | 5,000 | 330 |
| 12 GHz - 18 GHz | 2,000 | 330 |
| 18 GHz - 40 GHz | 1,000 | 420 |

**Note:** In this table, the higher field strength applies at the frequency band edges.

7.5 Establish the Test Environment for Installed Systems.

The external HIRF environment will penetrate the aircraft and establish an internal RF environment to which installed electrical and electronic systems will be exposed. The resultant internal RF environment is caused by a combination of factors, such as aircraft seams and apertures, reradiation from the internal aircraft structure and wiring, and characteristic aircraft electrical resonance.

7.5.1 **Level A Systems.**

The resulting internal HIRF environments for level A systems are determined by aircraft attenuation to the external HIRF environments I, II, or III, as defined in appendix J to part 23 (Amendment 23-57), appendix L to part 25, appendix D to part 27, and appendix E to part 29, as applicable. The attenuation is aircraft- and zone-specific and should be established by aircraft test, analysis, or similarity. Paragraph 10 of this AC contains the steps for showing level A systems HIRF compliance.

7.5.2 **Level B Systems.**

The internal RF environments for level B systems are defined in appendix J to part 23 (Amendment 23-57), appendix L to part 25, appendix D to part 27, and appendix E to part 29, as applicable, as equipment HIRF test levels 1 or 2. Paragraph 11 of this AC contains the steps for showing level B systems HIRF compliance.

### 7.5.3 Level C Systems.

The internal RF environment for level C systems is defined in appendix J to part 23 (Amendment 23-57), appendix L to part 25, appendix D to part 27, and appendix E to part 29, as applicable, as equipment HIRF test level 3. Paragraph 11 of this AC contains the steps for showing level C systems HIRF compliance.

## 7.6 Apply the Appropriate Method of HIRF Compliance Verification.

Tables 5 and 6 summarizes the relationship between the aircraft performance requirements in sections (a), (b), and (c) of the applicable HIRF regulations, and the HIRF environments and test levels. Paragraph 7.8 below discusses section (d) of the HIRF regulations regarding previously issued special conditions.

### 7.6.1 Pass/Fail Criteria.

You should establish specific HIRF compliance pass/fail criteria for each system as they relate to the applicable HIRF regulation performance criteria. Paragraph 5 of this AC provides the definitions of “normal operation” and “automatically recover” in the context of the requirement in §§ 23.1308(a)(2), 25.1317(a)(2), 27.1317(a)(2), and 29.1317(a)(2). Section 23.2520(a)(2) and (b) uses the phrase “recovers normal operation,” which allows manual recovery (flightcrew action) or automatic recovery of a system’s function after exposure to HIRF. You should present these pass/fail criteria to the FAA for approval. The means for monitoring system performance relative to these criteria should be established by the applicant and approved by the FAA. All effects defining the pass/fail criteria should be the result of identifiable and traceable analysis that includes both the separate and interdependent operational characteristics of the systems.

### 7.6.2 Evaluate Failures.

The analysis should evaluate the failures, either singularly or in combination, which could adversely affect system performance. This should include failures that could negate any system redundancy or influence more than one system performing the same function.

**Table 5. HIRF Certification Requirements Summary for Parts 23 (Amendment 23-57), 25, 27, and 29**

| HIRF FAILURE CONDITION FROM §§ 23.1308, 25.1317, 27.1317, AND 29.1317 | PERFORMANCE CRITERIA | ITEM THE ENVIRONMENT OR TEST LEVEL APPLIES TO | HIRF ENVIRONMENT OR TEST LEVEL |
|---|---|---|---|
| Each electrical and electronic system that performs a function whose failure would prevent the continued safe flight and landing of the airplane/rotorcraft must be designed and installed so that— | each function is not adversely affected during and after the time… | airplane/rotorcraft… | is exposed to the HIRF environment I. |
| Each electrical and electronic system that performs a function whose failure would prevent the continued safe flight and landing of the rotorcraft must be designed and installed so that | each electrical and electronic system automatically recovers normal operation of that function, in a timely manner after… | airplane/rotorcraft… | is exposed to HIRF environment I, unless this conflicts with other operational or functional requirements of that system. |
| Each electrical and electronic system that performs a function whose failure would prevent the continued safe flight and landing of the airplane/rotorcraft must be designed and installed so that | each electrical and electronic system is not adversely affected during and after… | airplane/rotorcraft… | is exposed to the HIRF environment II. |
| Each electrical and electronic system that performs a function whose failure would prevent the continued safe flight and landing of the rotorcraft must be designed and installed so that | each function required during operation under visual flight rules is not adversely affected during and after… | rotorcraft…. | is exposed to HIRF environment III (Parts 27 and 29 only). |
| Each electrical and electronic system that performs a function whose failure would significantly reduce the capability of the airplane/rotorcraft or the ability of the flightcrew to respond to an adverse operating condition must be designed and installed so that— | the system is not adversely affected when… | equipment providing these functions… | is exposed to equipment HIRF test level 1 or 2. |
| Each electrical and electronic system that performs such a function whose failure would reduce the capability of the airplane/rotorcraft or the ability of the flightcrew to respond to an adverse operating condition must be designed and installed so that— | the system is not adversely affected when… | equipment providing these functions… | is exposed to equipment HIRF test level 3 |

**Table 6. HIRF Certification Requirements Summary for Part 23 (Amendment 23-65)**

| HIRF FAILURE CONDITION FROM § 23.2520 | PERFORMANCE CRITERIA | ITEM THE ENVIRONMENT OR TEST LEVEL APPLIES TO | HIRF ENVIRONMENT OR TEST LEVEL |
|---|---|---|---|
| Each electrical and electronic system that performs a function, the failure of which would prevent the continued safe flight and landing of the airplane, must be designed, and installed such that— | the function at the airplane level is not adversely affected during and after the time… | airplane… | is exposed to the HIRF environment. |
| Each electrical and electronic system that performs a function, the failure of which would prevent the continued safe flight and landing of the airplane, must be designed, and installed such that— | the system recovers normal operation of that function in a timely manner after… | airplane… | is exposed to the HIRF environment unless the system's recovery conflicts with other operational or functional requirements of the system |
| For airplanes approved for IFR operations, each electrical and electronic system that performs a function, the failure of which would significantly reduce the capability of the airplane or the ability of the flightcrew to respond to an adverse operating condition, must be designed and installed such that— | the system recovers normal operation of that function in a timely manner after… | airplane… | is exposed to the HIRF environment. |

7.7 Verify HIRF Protection Effectiveness.

You should show that the RF current on system and equipment wire bundles and the RF fields on the system, created by the HIRF environment, are lower than the equipment or system HIRF qualification test levels.

7.8 Previously Issued HIRF Special Conditions.

Until December 1, 2012, the installation of a level A electrical and electronic system, was allowed under section (d) of the HIRF regulations, if it could be shown the system intended for installation previously complied with HIRF special conditions prescribed under 14 CFR 21.16 and issued before December 1, 2007. This provision was available for a 5-year period. Therefore, section (d) of the HIRF regulations is no longer applicable.

## 8 MARGINS

Margins are not needed if your HIRF compliance is based on tests of the specific aircraft model and system undergoing certification. Margins are also not required if your HIRF compliance is based on analysis or similarity if the process validation is robust and the datawell substantiated. Where data has limited substantiation, a margin may be needed depending on the available justifications. When a margin is needed, include a justification for the selected margin in the HIRF compliance plan, as discussed in paragraph 9.

## 9 HIRF COMPLIANCE

9.1 HIRF Compliance Plan.

You should establish an overall compliance plan to clearly identify and define HIRF certification requirements, HIRF protection development, and the design, test, and analysis activities intended to be part of the compliance effort. This plan should provide definitions of the aircraft systems, installations, and protective features against which HIRF compliance will be assessed. You should discuss the HIRF compliance plan with, and submit it to, the FAA for approval before initiating HIRF compliance activities. If the aircraft, system, or installation design changes after approval, you should submit a revised HIRF compliance plan to the FAA for approval. The HIRF compliance plan should include the following:

- HIRF compliance plan summary;
- Identification of the aircraft systems, with classification based on the safety assessment as it relates to HIRF (see paragraphs 7.2 and 7.3);
- HIRF environment for the aircraft and installed systems; and
- Verification methods, such as test, analysis, or similarity.

9.2 HIRF Verification Test, Analysis, or Similarity Plan.

Test, analysis, and similarity are all acceptable methods for showing HIRF compliance. The applicant should choose the method most appropriate for its project. See paragraphs 10 and 11 of this AC and SAE ARP5583A, for additional guidance on selecting the appropriate method. Specific HIRF test, analysis, or similarity plans should be prepared to describe specific verification activities. One or more verification plans may be necessary. For example, there may be several systems or equipment laboratory test plans, an aircraft test plan, or a similarity plan for selected systems on an aircraft.

9.2.1 **HIRF Test Plan**.

A HIRF compliance test plan should include the equipment, system, and aircraft test objectives for the acquisition of data to support HIRF compliance verification. The test plan should provide an overview of the factors being addressed for each system test requirement. The test plan should describe the appropriate aspects of the systems to be tested and their installation. Additionally, the test plan should reflect the results of any analysis performed in the overall process of the HIRF compliance evaluation. The test plan should include:

- Purpose of the test;
- Description of the aircraft and/or system being tested;
- System configuration drawings;
- Proposed test setup and methods;
- Intended test levels, modulations, and frequency bands;
- Pass/fail criteria; and
- Test schedule and test location.

The test plan should cover HCL A, B, and C systems and equipment, as appropriate. HCL A systems may need both laboratory integrated systems tests and aircraft tests. HCL B and C systems and equipment need only equipment laboratory testing.

9.2.2 **Analysis Plan**.

A HIRF compliance analysis plan should include the objectives, both at the system and equipment level, for generating data to support HIRF compliance verification. Comprehensive modeling and analysis for RF field coupling to aircraft systems and structures is an emerging technology; therefore, the analysis plan should be coordinated with the FAA to determine an acceptable scope for the analysis. The analysis plan should include:

- Purpose and scope of the analysis;
- Description of the aircraft and/or system addressed by the analysis;
- System configuration descriptions;

- Proposed analysis methods;
- Approach for validating the analysis results;
- Pass/fail criteria; and
- Margins (if necessary).

**Note:** When data have limited substantiation, the analysis plan should also include a description and justification for margins to account for analysis uncertainty. See paragraph 8 for additional information on margins.

#### 9.2.3 **Similarity Plan**.

A similarity plan should describe the approach undertaken to use the certification data from previously certified systems, equipment, and aircraft in the proposed HIRF compliance program. The similarity plan should include:

- Purpose and scope of the similarity assessment;
- Specific systems addressed by the similarity assessment;
- Data used from the previously certified systems, equipment, and aircraft;
- Details on differences between the aircraft and system being certified and the similar aircraft and system from which the data will be used; and
- Margins (if necessary).

**Note:** When data have limited substantiation, the similarity plan should also include a description and justification for margins to account for similarity uncertainty. See paragraph 8 for additional information on margins.

### 9.3 Compliance Reports.

One or more compliance reports may be necessary to document the results of your test, analysis, or similarity assessments. For new or significantly modified aircraft, HIRF compliance reports include many system and equipment test reports, aircraft test reports, and HIRF vulnerability analysis reports. For these types of HIRF certification programs, a compliance summary report may be useful to summarize the results of tests and analysis. For HIRF certification programs of relatively simple systems, a single compliance report is adequate.

#### 9.3.1 **Test Reports.**

Comprehensive test reports should be produced at the conclusion of HIRF compliance testing. The test reports should include descriptions of the salient aspects of equipment or system performance during the test, details of any area of noncompliance with HIRF requirements, actions taken to correct the noncompliance, and any similarity declarations. You should also provide supporting rationale for any deviations from system performance observed during testing.

9.3.2 **Analysis Reports.**

Analysis reports should describe the details of the analytical model, the methods used to perform the analysis, and the results of the analysis. If applicable, these reports should identify any modeling uncertainty and verify that the margins established in the analysis plan were met.

9.3.3 **Similarity Reports**.

Similarity reports should document the significant aircraft, system, equipment, and installation features common between the aircraft or system that is the subject of the similarity analysis and the aircraft or system that previously was certified for HIRF. You should identify all significant differences encountered, along with the assessment of the impact of these differences on HIRF compliance. If applicable, these reports should identify any similarity uncertainty and verify that the margins established in the similarity plan were met.

9.4 Methods of Compliance Verification.

9.4.1 Various methods are available to aid in demonstrating HIRF compliance. Paragraphs 10 and 11 of this AC describe methods acceptable to the FAA. Figures 1 and 2 below outline the steps to HIRF compliance for systems requiring System HCL A. Figure 3 below outlines the steps to HIRF compliance for systems requiring System HCL B or C. The steps in these figures are not necessarily accomplished sequentially. Wherever a decision point is indicated on these figures, you should complete the steps in that path as described in paragraphs 10 and 11 of this AC.

9.4.2 You may use other HIRF compliance techniques to demonstrate system performance in the HIRF environment. However, the FAA should approve those techniques before you use them.

**Figure 1. Routes to HIRF Compliance – Level A Systems**

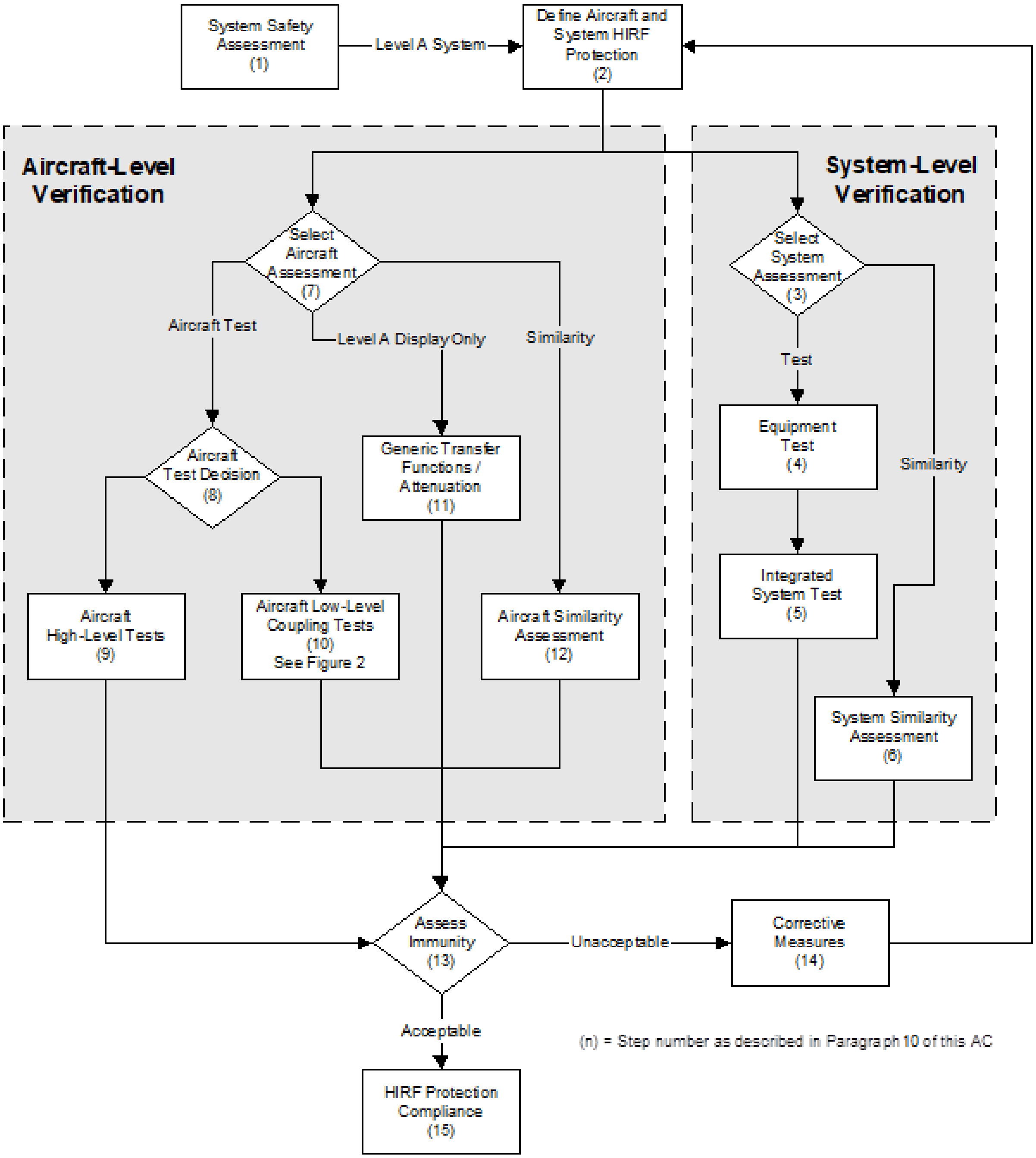
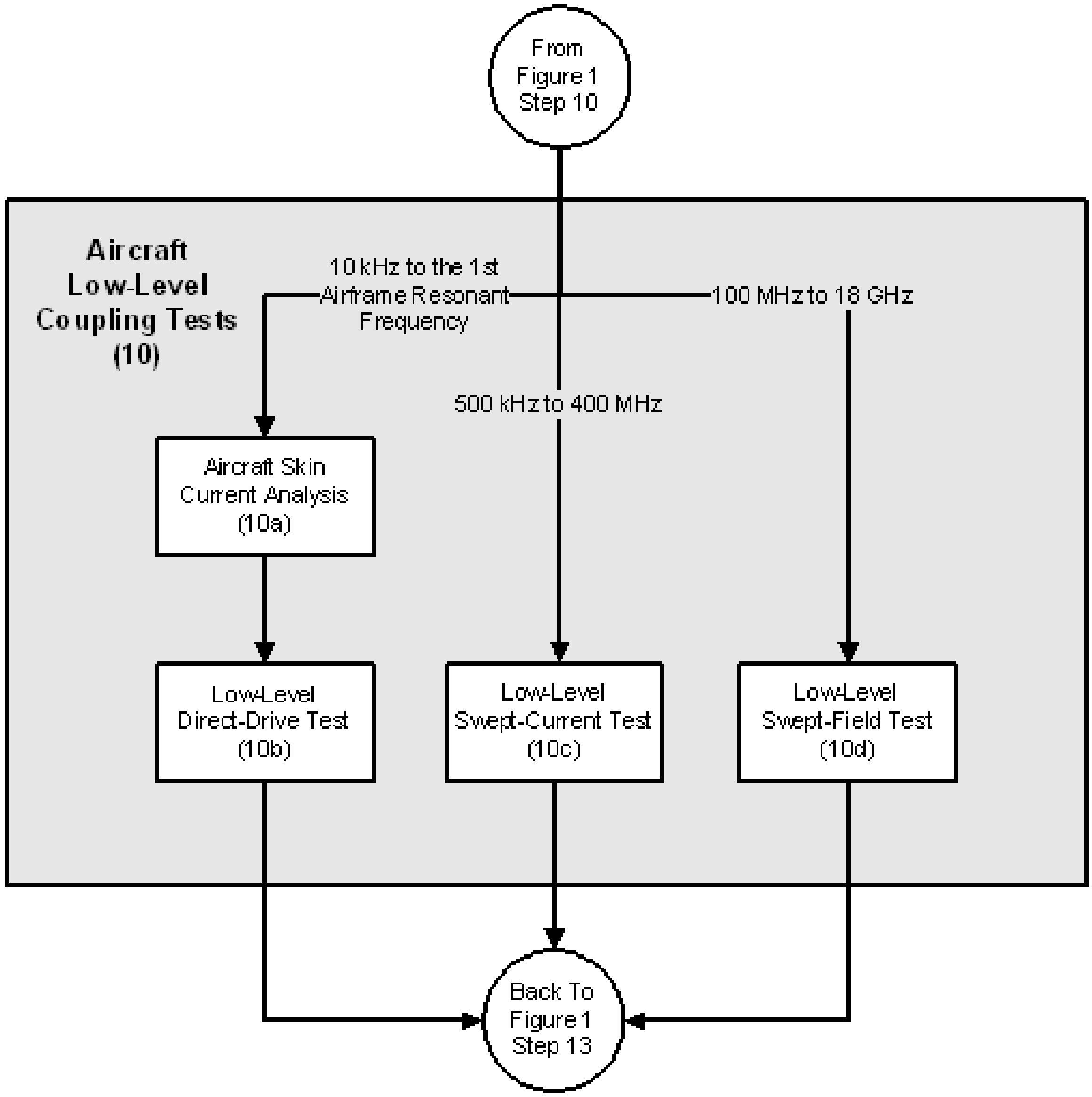
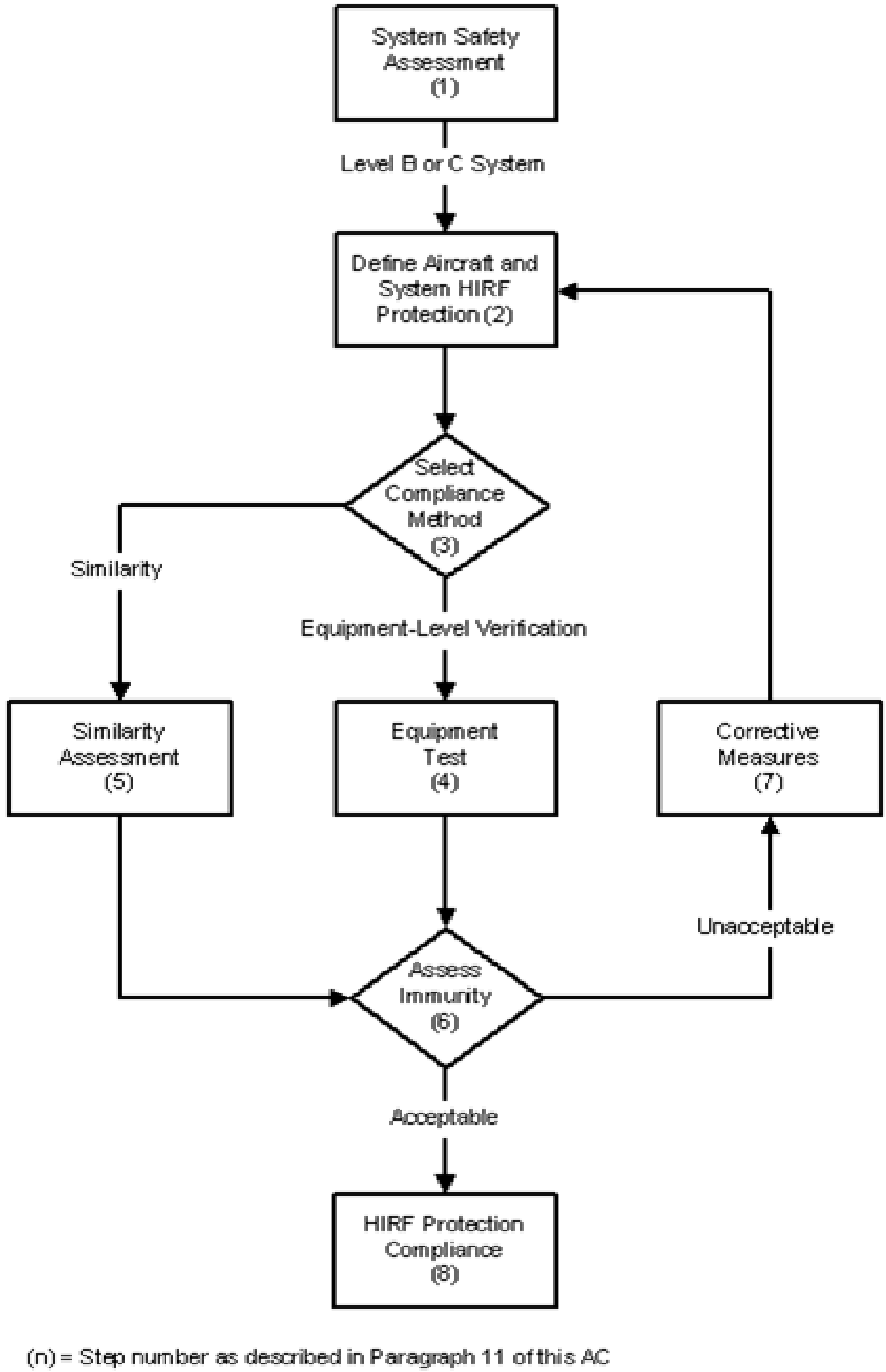


**Figure 2. Aircraft Low-Level Coupling Tests – Level A Systems**




(n) = Step number as described in Paragraph 10 of this AC

**Figure 3. Routes to HIRF Compliance – Level B and C Systems**



# 10 STEPS TO LEVEL A SYSTEM HIRF COMPLIANCE

Steps 1 through 15 listed below for HCL A system HIRF compliance may be used to show compliance with §§ 25.1317(a), 27.1317(a), or § 29.1317(a). Airplanes certificated under part 23 may use steps 1 through 15 to show compliance with § 23.1308(a) or § 23.2520(a), but acceptable compliance for HCL A systems on level 1, 2, 3, and 4 airplanes certificated under part 23 may also be shown using the method in paragraph 10.16 below.

## 10.1 Step 1 — HIRF Safety Assessment.

10.1.1 Determine the system failure condition classification for the systems being certified on your aircraft, using a system safety assessment as discussed in paragraphs 7.2 and 7.3. For systems classified with catastrophic failure conditions (HCL A systems), follow compliance steps 2 through 15 listed below, as appropriate. Figures 1 and 2 of this AC also depict these compliance steps, which are not necessarily accomplished sequentially. Systems classified with hazardous or major failure conditions (HCL B and C systems) should follow the compliance steps outlined in paragraph 11.

10.1.2 When showing compliance with §§ 23.1308(a), 23.2520(a), 25.1317(a), 27.1317(a), or § 29.1317(a), the level A electrical and electronic system includes all electrical and electronic equipment, components, and electrical interconnections required to perform the function whose failure would prevent continued safe flight and landing. This electrical and electronic system must also recover normal operation of the level A functions in a timely manner to comply with §§ 23.1308(a)(2), 23.2520(a)(2), 25.1317(a)(2), 27.1317(a)(2), or § 29.1317(a)(2). The level A electrical and electronic system is not required to include:

- Equipment, components, and electrical interconnections required only for non-normal situations; or
- Equipment, components, and electrical interconnections required only for dispatch under a minimum equipment list.

10.1.3 Some systems include mechanical, hydraulic, and/or pneumatic channels as well as electrical and electronic elements or channels that perform functions whose failure would prevent continued safe flight and landing. The HIRF safety assessment for §§ 23.1308(a), 23.2520(a), 25.1317(a), 27.1317(a), or § 29.1317(a) only applies to functions performed by electrical and electronic systems. The HIRF safety assessment should consider electrical or electronic failures that would adversely affect the function of the mechanical, hydraulic, and/or pneumatic channels. If electrical or electronic equipment, components, and electrical interconnections are used to assist, augment, or monitor for control loop feedback, the mechanical, hydraulic, and/or pneumatic channels in performing functions with failures that would prevent continued safe flight and landing during normal operation, then the electrical and electronic channel(s) must comply with §§ 23.1308(a), 23.2520(a), 25.1317(a), 27.1317(a), or § 29.1317(a).

10.1.4 Sections 23.1308(a), 23.2520(a), 25.1317(a), 27.1317(a), and 29.1317(a) do not require you to assume preexisting failure conditions when classifying the functional failure conditions and the scope of the level A systems. You should consider total losses, partial losses, and malfunctions of the systems, including hazardously misleading information presented to the flightcrew during and after the aircraft is exposed to HIRF.

10.1.5 Sections 23.1308(a)(2), 25.1317(a)(2), 27.1317(a)(2), and 29.1317(a)(2) require that the level A systems automatically recover normal operation of the function in a timely manner after exposure to HIRF Environment I. Section 23.2520(a)(2) requires that the level A systems recover normal operation of the function in a timely manner after exposure to the HIRF environment. Automatic or manual recovery applies to all redundant active channels of the level A system required for normal operation unless the recovery conflicts with other operational or functional requirements of the system. The exception for recovery conflicts should be based on aircraft operational or functional requirements independent of HIRF exposure. The exception should not be a mitigation for level A system effects observed after exposure to HIRF Environment I.

10.1.6 Appendix B provides examples of system scope for transport category airplanes based on the guidance above. The HIRF safety assessment examples for level A systems contained in appendix B may also be applicable to normal category airplanes and to rotorcraft.

10.2 Step 2 — Define Aircraft and System HIRF Protection.

Define the HIRF protection features to be incorporated into the aircraft and system designs, based on the HIRF environments that are applicable to your aircraft and its level A systems. Equipment, system, and aircraft HIRF protection design may occur before you perform aircraft-level tests, and before you determine the actual internal HIRF environment. Therefore, you should base the equipment, system, and aircraft HIRF protection design on an estimate of the expected internal HIRF environment. You should consider all aircraft configurations that may affect HIRF protection, such as open landing gear doors (see step 7).

10.3 Step 3 — System Assessment Decision.

Determine if you will perform integrated system HIRF tests on the level A system, or if you will base the system verification on previous integrated system HIRF tests performed on a similar system. Aircraft and system tests and assessments need not be performed for the HIRF environments above 18 GHz if data and design analysis show the integrated system tests results (see step 5) satisfy the pass criteria from 12 GHz to 18 GHz, and the systems have no circuits that operate in the 18 GHz to 40 GHz frequency range.

10.4 Step 4 — Equipment Test.

10.4.1 Radiated and conducted RF susceptibility laboratory tests of RTCA/DO-160E, section 20 (as specified in AC 21-16), may be used to build confidence in the equipment's HIRF immunity before conducting laboratory integrated system tests in step 5. The equipment should be tested in accordance with the test levels (wire bundle currents and RF field strengths) of RTCA/DO-160E, section 20, or to a level estimated for the aircraft and equipment installation using the applicable external HIRF environment.

10.4.2 Equipment HIRF tests may be used to augment the integrated system HIRF tests where appropriate. For equipment whose HIRF immunity is evaluated as part of the integrated system-level HIRF tests discussed in step 5, the individual equipment's HIRF testing described in this step is optional.

10.5 Step 5 — Integrated System Test.

10.5.1 Radiated and conducted RF susceptibility laboratory tests on an integrated system should be performed for level A systems. The HIRF field strengths and wire bundle currents selected for this test should be based on the attenuated external HIRF environment determined in the aircraft assessment (see steps 10, 11, or 12). In many cases, the integrated system test is performed before the aircraft assessment is complete. In these cases, the integrated system test field strengths and currents should be selected based on the expected aircraft attenuation or transfer function.

10.5.2 The installation details for the laboratory integrated system tests should be similar to the installation in the aircraft. For example, the bonding and grounding of the system, wire size, routing, arrangement (whether parallel or twisted wires), connector types, wire shields, and shield terminations, and the relative position of the elements to each other and the ground plane in the laboratory should closely match the system installation on the aircraft to be certificated. In addition, the laboratory integrated system rig should have an FAA conformity inspection prior to conducting any FAA certification credit testing.

10.5.3 For integrated system test of an engine and engine control system, you should also refer to the guidance provided in AC 33.28-3. When the engine certification occurs prior to a known specific aircraft installation, the engine manufacturer should make reasonable installation assumptions for engine-to-aircraft electrical interfaces. The engine installation manual or operating instructions should specify wire characteristics, shielding, connector types, shield terminations, and electrical bonding features for HIRF protection that are required when the engine is installed. Systems that are part of the engine certification must be installed in accordance with the engine manufacturer's requirements. The applicant should perform the required HIRF tests with the same wiring, shielding, and electrical bonding configuration as specified in the engine installation manual or operating instructions.

10.5.4 The integrated system should be tested with the system operating, to include connected displays, sensors, actuators, and other equipment. Place the system in various operating modes to ensure the integrated system is tested when operating at its maximum sensitivity. If the connected equipment is not related to the functions with catastrophic failures, these items may be simulated by test sets, if the test sets accurately represent the terminating circuit impedance of the sensor. However, the connected equipment should meet the appropriate HIRF requirements for their failure condition classification.

10.5.5 The test levels should be selected based on the expected aircraft internal HIRF environment determined through aircraft tests (see step 10), generic transfer functions “for level A display systems only” and attenuation (see step 11), or aircraft similarity assessment (see step 12), using the applicable external HIRF environment. Integrated system test procedures are described in detail in the user’s guide.

10.5.6 Wire bundle current injection should be used for frequencies from 10 kHz to 400 megahertz (MHz). RF currents are injected into the integrated system wiring via a current transformer. Each wire bundle in the system should be injected and the induced wire bundle current measured. If a system wire bundle branches, then each wire bundle branch should also be tested. Simultaneous multi-bundle current injection may be necessary on systems with redundant or multi-channel architectures.

10.5.7 High-level radiated susceptibility tests should be used at frequencies greater than 100 MHz. The radiating antenna should be far enough away to ensure the total volume of the equipment and at least half a wavelength of the wiring is simultaneously and uniformly illuminated during the test.

10.5.8 Define appropriate pass/fail criteria for the system, based on the system safety assessment and the appropriate HIRF regulation. Any system susceptibility, including system malfunctions such as displaying hazardously misleading information, upset, or damage should be recorded and evaluated based on these previously defined pass/fail criteria.

10.5.9 Using only the modulation to which the system under evaluation is most sensitive may minimize the test time. The user’s guide provides guidance on modulation selection and suggested default modulations and dwell times.

10.5.10 The equipment tests in step 4, using the techniques in RTCA/DO-160E, section 20 (refer to AC 21-16), are not normally sufficient to show HIRF compliance for step 5. However, these standard RTCA/DO-160E, section 20 tests may be sufficient if paragraphs 10.5.2 through 10.5.4 of this step are met.

10.5.11 If the level A system consists of multiple similar channels, you may propose using one or more channels in the laboratory test setup for the integrated system, instead of all similar channels. You should demonstrate that the laboratory test setup adequately performs the functions to demonstrate compliance with §§ 23.1308(a), 23.2520(a), 25.1317(a), 27.1317(a), or § 29.1317(a). Ensure that the laboratory test setup represents and monitors any cross-channel interactions, such as cross-channel data links, redundancy management, and system health monitoring.

**Note:** If pin programming or software is used to identify or configure equipment of similar elements or channels, you should assess whether these differences impact the functions performed.

10.6 Step 6 — System Similarity Assessment.

10.6.1 The integrated system HIRF tests performed for a system previously certified on one aircraft model may be used to demonstrate system verification for a similar system. Each system considered under the similarity approach needs to be assessed independently even if it may use equipment and installation techniques from previous certification projects.

10.6.2 The system used as the basis for similarity must have successfully completed integrated system HIRF tests. Similarity assessment requires comparison of both equipment and installation differences that could adversely affect HIRF immunity. The assessment should evaluate the differences between the previously HIRF-certified system and the equipment circuit interfaces, wiring, grounding, bonding, connectors, and wire-shielding practices of the equipment that comprise the new system.

10.6.3 If the assessment finds negligible differences, with respect to HIRF aspects, between the previously certified system and the new system to be certified, similarity may be used as the basis for system-level verification without the need for additional integrated system tests, providing there are no unresolved in-service HIRF problems related to the previously certified system. If there is uncertainty about the effects of the differences, additional tests and analysis should be conducted as necessary and appropriate to resolve the uncertainty. The amount of additional testing should be commensurate with the degree of difference identified between the new system and the system previously certified. If significant differences are found, similarity should not be used as the basis for system-level verification.

10.7 Step 7 — Aircraft Assessment Decision.

10.7.1 Level A systems require an aircraft assessment to support compliance with §§ 23.1308(a), 23.2520(a), 25.1317(a), 27.1317(a), and 29.1317(a). The aircraft assessment should determine the actual internal HIRF environment where the level A systems are installed in the aircraft. You should choose whether you will use either aircraft tests or previous coupling/attenuation data from similar aircraft types (similarity). For level A display systems only, you may use the generic transfer functions and attenuation in appendix A to this AC. Alternatively, the aircraft assessment may be a test that exposes the entire aircraft with operating level A systems to external HIRF environments I, II, or III (tables 2, 3, and 4, respectively), as appropriate, to demonstrate acceptable level A system performance.

10.7.2 Level A display systems include the display equipment, control panels, and the sensors that provide information to the displays. These sensors could also provide information to level A non-display systems, and in that case, you should determine the real transfer function and attenuation curves of these sensors when demonstrating compliance for this level A non-display system. For example, for air data system and inertial reference system, which sends information to the electronic flight instrument system and flight controls, the transfer function and attenuation should be determined by the aircraft low-level coupling test or the aircraft similarity assessment as defined in steps 10 and 12.

10.7.3 Other methods for aircraft HIRF assessment, such as analysis, may be acceptable. However, comprehensive modeling and analysis for RF field coupling to the aircraft structure is an emerging technology. Therefore, analysis alone is currently not adequate to show HIRF compliance for level A systems and should be augmented by testing.

10.7.4 If analysis is used to determine aircraft attenuation and transfer function characteristics, you should provide test data to support this analysis. Any analysis results should take into account the quality and accuracy of the analysis. Comprehensive testing, including aircraft level testing, is required to support the analysis.

10.7.5 Aircraft and system tests and assessments need not be performed for the HIRF environments above 18 GHz if data and design analysis show the integrated system tests results (see step 5) satisfy the pass criteria from 12 GHz to 18 GHz, and the systems have no circuits operating in the 18 GHz to 40 GHz frequency range.

10.8 Step 8 — Aircraft Test Decision.

10.8.1 Various aircraft test procedures are available and accepted for collecting data for aircraft HIRF verification. The two main approaches to aircraft testing are the aircraft high-level test (see step 9) and the aircraft low-level coupling test (see step 10). The aircraft high-level field-illumination test involves radiating the aircraft at test levels equal to the applicable external HIRF environment as described in paragraph 7.4. Aircraft low-level coupling tests involve measuring the airframe attenuation and transfer functions, so that the internal HIRF electric fields and currents can be compared to the integrated system test levels.

10.8.2 Some test procedures may be more appropriate than others because of the size of the aircraft and the practicality of illuminating the entire aircraft with the appropriate external HIRF environment. The aircraft low-level coupling tests (see step 10) may be more suitable for testing large aircraft than the high-level field-illumination test in step 9, which requires illumination of the entire aircraft with the external HIRF environment.

10.9 Step 9 — Aircraft High-Level Tests.

10.9.1 The aircraft high-level field-illumination test requires generating RF fields external to an aircraft at a level equal to the applicable external HIRF environment.

10.9.2 At frequencies below 400 MHz, the distance between the aircraft and the transmitting antenna should be sufficient to ensure the aircraft is illuminated uniformly by the external HIRF environment. The transmit antenna should be placed in at least four positions around the aircraft. For airplanes, the antenna is typically placed to illuminate the nose, tail, and each wingtip. For rotorcraft, the antenna is typically placed to illuminate the nose, tail, and each side. The aircraft should be illuminated by the antenna at each position while sweeping the frequency range. Perform separate frequency sweeps with the transmit antenna oriented for horizontal and vertical polarization. The RF field should be calibrated by measuring the RF field strength in the center of the test volume before the aircraft is placed there.

10.9.3 At frequencies above 400 MHz, the RF illumination should be localized to the system under test, provided all parts of the system and at least one wavelength of any associated wiring (or the total length if less than one wavelength) are illuminated uniformly by the RF field. You may need reflection planes to illuminate relevant apertures on the bottom and top of the aircraft.

10.9.4 To ensure the systems are tested when operating at their maximum sensitivity, level A systems should be fully operational, and the aircraft should be placed in various simulated operating modes.

10.9.5 The test time can be minimized by using only the modulation to which the system under evaluation is most sensitive. If you do this, the rationale used to select the most sensitive modulation should be documented in the HIRF test plan as discussed in paragraph 9.2.1. The user’s guide provides guidance on modulation selection and suggested default modulations and dwell times.

10.9.6 As an alternative to testing at frequencies below the first airframe resonant frequency, it is possible to inject high-level currents directly into the airframe using aircraft high-level direct-drive test methods. Aircraft skin current analysis should be performed as described in the user's guide, or low-level swept-current measurements should be made to determine the skin current distribution that will exist for different RF field polarizations and aircraft illumination angles so that these can be simulated accurately during this test. Aircraft high-level direct-drive testing, although applicable only from 10 kHz to the first airframe resonant frequency, is advantageous because it is possible to test all systems simultaneously.

10.10 Step 10 — Aircraft Low-Level Coupling Tests.

10.10.1 **Low-Level Coupling Tests.**

The aircraft low-level coupling tests include three different tests that cover the frequency range of 10 kHz to 18 GHz (see figure 2). Detailed descriptions are available in the user's guide. Other techniques may be valid but must be discussed with and approved by the FAA before being used.

10.10.2 **Low-Level Direct-Drive Test and Low-Level Swept-Current Test.**

The low-level direct-drive test (see step 10b, figure 2) and the low-level swept-current test (see Step 10c) are used for frequencies at or below 400 MHz. The low-level swept-field test (see Step 10d) is used for frequencies at and above 100 MHz. There is an overlap of test frequencies from 100 MHz to 400 MHz in the low-level swept-current test and the low-level swept-field test. The division at 400 MHz is not absolute but rather depends on when HIRF penetration of the equipment case becomes a significant factor.

### 10.10.3 Steps 10a and 10b - Aircraft Skin Current Analysis and Low-Level Direct-Drive Test.

Low level direct-drive tests in conjunction with skin current analysis should be used to determine the transfer function between the skin current and individual equipment wire bundle currents. The low-level direct-drive test is typically used for frequencies from 10 kHz to the first airframe resonant frequency. For the low-level direct-drive test to be applied successfully, a three dimensional model of the aircraft should be derived using aircraft skin current analysis. The three dimensional model can then be used to derive the aircraft's skin current pattern for the applicable external HIRF environment. Guidance on skin current analysis is in the user's guide. If the relationship between the external HIRF environment and the skin current is known for all illumination angles and polarization, either because of aircraft skin current analysis or the use of the low-level swept-current test, the skin current can be set up by direct injection into the airframe. The resultant currents on the system wire bundles are measured with a current probe and normalized to 1 V/m electric field strength so they can be scaled to the appropriate external HIRF environment. The low-level direct-drive test is more effective than low-level swept-current tests for frequencies from 10 kHz to the first airframe resonant frequency and may be necessary for small aircraft or aircraft with high levels of airframe shielding.

### 10.10.4 Step 10c — Low-Level Swept-Current Test.

The low-level swept-current test involves illuminating the aircraft with a low-level external HIRF field to measure the transfer function between the external field and the aircraft and equipment wire bundle currents. This test is typically used in the frequency range of 500 kHz to 400 MHz. The transfer function is resonant in nature and is dependent on both the aircraft structure and the system installation. Because the transfer function relates wire bundle currents to the external field, the induced bulk current injection test levels can be related to an external HIRF environment.

10.10.4.1 The transmit antenna should be placed in at least four positions around the aircraft, with the distance between the aircraft and the transmitting antenna sufficient to ensure the aircraft is illuminated uniformly.

- For airplanes, the antenna is typically placed to illuminate the nose, tail, and each wingtip.
- For rotorcraft, the antenna is typically placed to illuminate the nose, tail, and each side.

The aircraft should be illuminated by the antenna at each position while sweeping the frequencies in the range of 500 kHz to 400 MHz. Perform separate frequency sweeps with the transmit antenna oriented for horizontal and vertical polarization. Measure the currents induced on the aircraft wire bundles.

10.10.4.2 Calculate the ratio between the induced wire bundle current and the illuminating antenna field strength and normalize this ratio to 1 V/m. This provides the transfer function in terms of induced current per unit external field strength. Then the current induced by the applicable external HIRF environment can be calculated by multiplying the transfer function by the external HIRF field strength. The calculated HIRF currents for all transmit antenna positions for each aircraft wire bundle being assessed should be overlaid to produce worst-case induced current for each wire bundle. These worst-case induced currents can be compared with the current used during the integrated system test in step 5.

10.10.5 **Step 10d — Low-Level Swept-Field Test.**

Low-level swept-field testing is typically used from 100 MHz to 18 GHz. The test procedures for the low-level swept-field test are similar to those used for the low-level swept-current test; however, in the low-level swept- field test, the internal RF fields in the vicinity of the equipment are measured instead of the wire bundle currents. Various techniques can be used to ensure the maximum internal field in the vicinity of the equipment is measured. Depending on the size of the aircraft and the size of the aircraft cabin, flight deck, and equipment bays, multipoint measurement, or mode stirring can be used to maximize the internal field in the vicinity of the equipment. See the user's guide for detailed low-level swept-field test procedures.

10.11 Step 11 — Generic Transfer Functions and Attenuation - Display Systems Only.

10.11.1 Level A displays involve functions for which system information is displayed directly to the pilot. For level A display systems, the aircraft attenuation data may be determined using generic attenuation and transfer function data. This approach should not be used for other level A systems, such as control systems, because failures and malfunctions of those systems can more directly and abruptly contribute to a catastrophic failure event than display system failures and malfunctions; therefore, other level A systems should have a more rigorous HIRF compliance verification program.

10.11.2 The integrated system test levels specified in step 5 may be derived from the generic transfer functions and attenuation for different types of aircraft. Acceptable transfer functions for calculating the test levels are given in appendix A to this AC. Appendix A to this AC also contains guidelines for selecting the proper generic attenuation. The generic transfer functions show the envelope of the currents that might be expected to be induced in the types of aircraft in an external HIRF environment of 1 V/m. The current levels should be multiplied linearly by HIRF environment I, II, or III, as appropriate, to determine the integrated system test levels.

10.11.3 The internal HIRF electric field levels are the external HIRF environment divided by the appropriate attenuation, in linear units. For example, 20 dB or a 10:1 attenuation means the test level is the applicable external HIRF environment electric field strength reduced by a factor of 10.

10.11.4 The internal HIRF environments for level A display systems can also be measured using on-aircraft low-level coupling measurements of the actual system installation (see step 10). This procedure should provide more accurate information to the user, and the test levels may be lower than the generic transfer functions or attenuation, which are worst-case estimates.

10.12 Step 12 — Aircraft Similarity Assessment.

10.12.1 The aircraft attenuation and transfer functions tests performed for a previously certified aircraft may be used to support aircraft-level verification for a similar aircraft model. To use this assessment, the aircraft used as the basis for similarity must have been previously certified for HIRF compliance, using HIRF attenuation and transfer functions determined by tests on that aircraft.

10.12.2 The similarity assessment for the new aircraft should consider the aircraft differences that could impact the internal HIRF environment affecting the level A systems and associated wiring. The comparison should consider equipment and wiring installation locations, airframe materials, construction, and apertures that could affect attenuation for the external HIRF environment.

10.12.3 If the assessment finds negligible differences, with respect to HIRF aspects, between the previously certified aircraft and the new aircraft to be certified, similarity may be used to determine aircraft attenuation and transfer functions without the need for additional aircraft tests, providing there are no unresolved in-service HIRF problems related to the existing aircraft. If there is uncertainty about the effects of the differences, additional tests and analysis should be conducted as necessary and appropriate to resolve the uncertainty. The amount of additional testing should be commensurate with the degree of difference identified between the new aircraft and the aircraft previously certified. If significant differences are found, similarity should not be used as the basis for aircraft-level verification.

10.13 Step 13 — Assess Immunity.

10.13.1 Compare the test levels used for the integrated system test of step 5 with the internal RF current or RF fields determined by the aircraft low-level coupling tests (see step 10), the generic transfer functions and attenuation (see step 11), or the aircraft similarity assessment (see step 12). The actual aircraft internal RF currents and RF fields should be lower than the integrated system test levels. You should include your comparison method in the HIRF compliance plan. The method should enable a direct comparison between the system test level and the aircraft internal HIRF environment at the equipment or system location, using current for frequencies from 10 kHz through 400 MHz, and using electric field strength for frequencies from 100 MHz through 18 GHz.

10.13.2 If the conducted RF susceptibility test levels used for the integrated system test (see step 5) were too low when compared with the aircraft-induced currents determined in step 10b, 10c, 11, or 12, then corrective measures are needed (see step 14). If the radiated RF susceptibility test levels used for integrated system tests (see step 5) were too low when compared with the aircraft internal fields determined in step 10d, 11, or 12, then corrective measures are needed (see step 14).

10.13.3 When comparing the current measured during low-level swept-current tests in step 10c with the current used during the integrated system tests in step 5, there may be differences. These differences may be due to variations between the actual aircraft installation and the laboratory integrated system test installation, such as wire bundle lengths, shielding and bonding, and wire bundle composition. The worst-case current signature for a particular wire bundle should be compared to the current induced at the particular test level or equipment malfunction over discrete frequency ranges such as 50 kHz to 500 kHz, 500 kHz to 30 MHz, and 30 MHz to 100 MHz. This comparison should be broken into discrete frequency ranges because the resonant frequencies may differ between the integrated system tests and the aircraft tests.

If you used aircraft high-level tests (see step 9) for aircraft HIRF verification, you should determine if there were any level A system susceptibilities. Any level A system susceptibilities should be evaluated based on the pass/fail criteria as established in the HIRF test plan (see paragraph 9.2.1). If the HIRF susceptibilities are not acceptable, then corrective measures may be needed (see step 14).

10.13.4 HIRF susceptibilities that were not anticipated or defined in the test plan pass/fail criteria may be observed during aircraft high-level tests or laboratory integrated system tests.

10.13.5 The pass/fail criteria may be modified if the effects neither cause nor contribute to conditions that adversely affect the aircraft functions or systems in the HIRF regulations. You should provide an assessment and supporting rationale for any modifications to the pass/fail criteria to the FAA for approval. If the HIRF susceptibilities are not acceptable, then corrective measures may be needed (see step 14).

10.13.6 If the level A systems show no adverse effects when tested to levels derived from the applicable HIRF environment I or III, this also demonstrates compliance of the system with HIRF environment II.

10.13.7 If the integrated system tests results (see step 5) satisfy the pass criteria from 12 GHz to 18 GHz, and design analysis shows the system has no circuits operating in the 18 GHz to 40 GHz frequency range, this demonstrates by analysis the system is not adversely affected when exposed to HIRF environments above 18 GHz. If these conditions are satisfied, further aircraft and system tests and assessments above 18 GHz are not necessary.

10.13.8 Review the actual system installation in the aircraft and the system configuration used for the integrated system test (see step 5). If significant configuration differences are identified, corrective measures may be needed (see step 14).

10.13.9 Certain RF receivers with antennas connected should not be expected to perform without effects during exposure to the HIRF environments, particularly in the RF receiver operating band. Because the definition of adverse effects and the RF response at portions of the spectrum depends on the RF receiver system function, refer to the individual RF receiver minimum performance standards for additional guidance. However, because many RF receiver minimum performance standards were prepared before implementation of HIRF requirements, the RF receiver pass/fail criteria should be coordinated with the FAA.

10.13.10 You should provide the similarity assessment and supporting rationale to the FAA for approval.

10.14 Step 14 — Corrective Measures.

Take corrective measures if the system fails to satisfy the HIRF immunity assessment of step 13. If changes or modifications to the aircraft, equipment, system, or system installation are required, then additional tests may be necessary to verify the effectiveness of the changes. RTCA/DO-160E, section 20 (as specified in AC 21-16) equipment tests, integrated system tests, and aircraft tests, in whole or in part, may need to be repeated to show HIRF compliance.

10.15 Step 15 — HIRF Protection Compliance.

Submit the test results and compliance report to the cognizant AIR certification branch for approval as part of the overall aircraft type certification or supplemental type certification process.

10.16 Compliance for HCL A Systems on Level 1, 2, 3, and 4 Airplanes Certificated Under Part 23.

Airplane certification levels 1, 2, 3, and 4 are defined in 14 CFR 23.2005 (established by Amendment 23-64). Airplane certification classes I, II, III, and IV are defined in AC 23.1309-1. The following test levels may be used for HCL A integrated systems on normal category level 1, 2, 3, and 4 airplanes (certification class I, II, III, and IV). Equipment testing is acceptable if you show that equipment in the HCL A systems can be operated and tested independently and effectively monitored to verify no adverse effects to the system and function. Otherwise, you should perform integrated system HIRF tests as discussed in step 5 (refer to paragraph 10.5). The system should comprise all equipment and wiring needed to perform the function. One or more of these systems with redundant channels may perform the same function. When there are multiple systems with redundant channels performing the same function, it is only necessary for one of the multiple systems' redundant channels to meet the requirements in § 23.1308(a) or § 23.2520(a). Level 1 airplanes certificated under part 23 meet the same requirements for HIRF as shown in paragraph 10.16.1 below. Level 2 and 3 airplanes certificated under part 23 meet the requirements for HIRF as shown in paragraph

10.16.2 below. Level 4 airplanes certified under part 23 meet the requirements for HIRF as shown in paragraph 10.5 (Step 5 - Integrated System Test).

**Note:** The applicant may also use a means of compliance, which may include ASTM consensus standards, accepted by the Administrator under § 23.2010. (See paragraph 4.4).

10.16.1 For level 1 airplane HCL A systems, you may perform integrated system conducted and radiated susceptibility tests using RTCA/DO-160E (refer to AC 21-16), section 20, category R.

10.16.2 For level 2 and 3 airplane HCL A systems, you may perform integrated system conducted susceptibility tests per the Generic Conductive Curve — < 25 meters extrapolated to Environment I and using the applicable levels defined in RTCA/DO-160G (refer to AC 21-16), section 20, category M.

**Note:** RTCA/DO-160E, section 20, category A is also acceptable.

10.16.3 For level 2 and 3 airplane HCL A systems, you may perform integrated system radiated susceptibility tests per the Aircraft Generic Attenuation Curves applied to Environment I and using the applicable levels described below (RTCA/DO-160G, refer to AC 21-16).

- 0 dB: 100 MHz – 400 MHz (using RTCA/DO-160G, section 20, category G)
- -6 dB: 400 MHz – 1 GHz (using RTCA/DO-160G, section 20, category F)
- -12 dB: 1 GHz – 18 GHz (using RTCA/DO-160G, section 20, category D)

10.16.4 You may design and install the engine control systems using the guidance provided in AC 33.28-3. You may develop and install appropriate electrical bonding features for the engine control systems using the guidance in AC 33.28-3.

10.16.5 Electrical bonding specifications and verifications should be developed and implemented on the production drawings and instructions for continued airworthiness.

## 11 STEPS TO LEVEL B AND C SYSTEM HIRF COMPLIANCE

Steps 1 through 8 listed below for HCL B and C systems HIRF compliance may be used to show compliance with §§ 23.1308(b) and (c), 23.2520(b), 25.1317(b) and (c), 27.1317(b) and (c), or § 29.1317(b) and (c).

11.1 Step 1 — System Safety Assessment.

Determine the system failure condition classification for the systems being certified on your aircraft, using a system safety assessment as discussed in paragraph 7.3. For systems classified with hazardous or major failure conditions (level B and C systems), follow compliance steps 2 through 8 listed below, as appropriate. These compliance steps are also depicted in figure 3 of this AC and are not necessarily accomplished sequentially. Systems classified with catastrophic failure conditions (level A systems) should follow the compliance steps outlined in paragraph 10.

11.2 Step 2 — Define Aircraft and System HIRF Protection.

Define the HIRF protection features incorporated into the aircraft and system designs, based on the HIRF test levels applicable to your aircraft and its level B and C systems. Equipment, system, and aircraft HIRF protection design may occur before you perform aircraft-level tests, and before you determine the actual internal HIRF environment. Therefore, you should base the equipment, system, and aircraft HIRF protection design on an estimate of the expected internal HIRF environment.

11.3 Step 3 — Select Compliance Method.

Determine if you will perform equipment HIRF tests on the level B and C systems, or if you will base the compliance on previous equipment tests performed for a similar system.

11.4 Step 4 — Equipment Test.

Level B and C systems do not require the same degree of HIRF compliance testing as level A systems, and therefore do not require aircraft-level testing. You should follow RTCA/DO-160E, section 20 (as specified in AC 21-16) laboratory test procedures, using the equipment test levels defined in the regulations. The test levels used depend on whether the system is categorized as level B or C. Equipment HIRF test level 1 or 2, as applicable, should be used for level B systems. RTCA/DO-160E, section 20, Category RR, satisfies the requirements of equipment HIRF test level 1. For equipment HIRF test level 2, you may use the approach in paragraph 10.11 of this AC to determine acceptable aircraft transfer function and attenuation curves for your level B system. Equipment HIRF test level 3 should only be used for level C systems. RTCA/DO-160E, section 20, category TT, satisfies the requirements of equipment HIRF test level 3. When applying modulated signals, the test levels are given in terms of the peak of the test signal as measured by a root-mean-square (rms) indicating spectrum analyzer's peak detector. See the user’s guide for more details on modulation.

11.4.1 Define appropriate pass/fail criteria for the system, based on the system safety assessment and the appropriate HIRF regulation (see paragraph 7.3). Any susceptibility noted during the equipment tests, including equipment malfunctions, upset, or damage, should be recorded and evaluated based on the defined pass/fail criteria.

11.5 Step 5 — Similarity Assessment.

11.5.1 The equipment HIRF tests performed for a system previously certified on one aircraft model may be used to show compliance for a similar system. Each system considered for similarity needs to be assessed independently even if it used equipment and installation techniques from a previous certification.

11.5.2 The system used as the basis for certification by similarity must have successfully completed equipment HIRF tests and previously certified for HIRF compliance on another aircraft model. Similarity assessment requires comparison of both equipment and installation differences that could adversely affect HIRF immunity. An assessment of a new system should consider the differences in the equipment circuit interfaces, wiring, grounding, bonding, connectors, and wire-shielding practices.

11.5.3 If the assessment finds only minimal differences between the previously certified system and the new system to be certified, similarity may be used for HIRF compliance without the need for additional equipment HIRF tests, provided there are no unresolved in-service HIRF problems related to the previously certified system. If there is uncertainty about the effects of the differences, you should conduct additional tests and analysis as necessary and appropriate to resolve the uncertainty. The amount of additional testing should be commensurate with the degree of difference identified between the new system and the system previously certified. If significant differences are found, similarity should not be used as the basis for HIRF compliance.

11.6 Step 6 — Assess Immunity.

Review the results of the equipment test to determine if the pass/fail criteria are satisfied. HIRF susceptibilities not anticipated or defined in the test plan pass/fail criteria may be observed during equipment HIRF tests. The pass/fail criteria may be modified if the effects neither cause nor contribute to conditions that adversely affect the aircraft functions or systems, as applicable, in the HIRF regulations. You should provide an assessment and supporting rationale for any pass/fail criteria modifications to the FAA for approval. If the HIRF susceptibilities are not acceptable, then corrective measures may be needed (see step 7).

11.6.1 Review the actual system installation in the aircraft and the configuration used for the equipment tests (see step 4). If significant differences in grounding, shielding, connectors, or wiring are identified, corrective measures may be needed (see step 7).

11.6.2 Certain RF receivers with antennas connected should not be expected to perform without effects during exposure to the HIRF environments, particularly in the RF receiver operating band. Because the definition of adverse effects and the RF response at particular portions of the spectrum depends on the RF receiver system function, refer to the individual RF receiver minimum performance standards for additional guidance. However, because many RF receiver minimum performance standards were prepared before implementation of HIRF requirements, the RF receiver pass/fail criteria should be coordinated with the FAA. Future modifications of the minimum performance standards should reflect HIRF performance requirements.

11.7 Step 7 — Corrective Measures.

Take corrective measures if the system fails to satisfy the HIRF immunity assessment of step 6. If changes or modifications to the equipment, system, or system installation are needed, then additional tests may be necessary to verify the effectiveness of the changes. The RTCA/DO-160E, section 20 (refer to AC 21-16) equipment tests, in whole or in part, may need to be repeated to show HIRF compliance.

11.8 Step 8 — HIRF Protection Compliance.

Submit the test results and compliance report to the cognizant AIR certification branch for approval as part of the overall aircraft type certification or supplemental type certification process.

## 12 MAINTENANCE, PROTECTION ASSURANCE, AND MODIFICATIONS

12.1 The minimum maintenance necessary to support HIRF certification must be identified in instructions for continued airworthiness as required by §§ 23.1529, 25.1529, 25.1729, 26.11, 27.1529, or § 29.1529.

12.2 Dedicated devices or specific features may be needed to provide HIRF protection for an equipment or system installation. You should define appropriate maintenance procedures for these devices and features to ensure in-service protection integrity. A HIRF protection assurance program may be necessary to verify that the maintenance procedures are adequate. This assurance program may propose a surveillance program based on a sampling of the fleet for monitoring the effectiveness of the protection features and/or maintenance procedures. The user’s guide provides further information on these topics.

12.3 The maintenance procedures should address the effects of corrosion, fretting, flexing cycles, or other causes that could degrade these HIRF protection devices. Whenever applicable, you should identify specific replacement times of these devices and features.

12.4 Aircraft or system modifications should be assessed for the impact any changes will have on the HIRF protection. You should base this assessment on analysis and/or measurement.

# Appendix A. Generic Transfer Functions and Attenuation

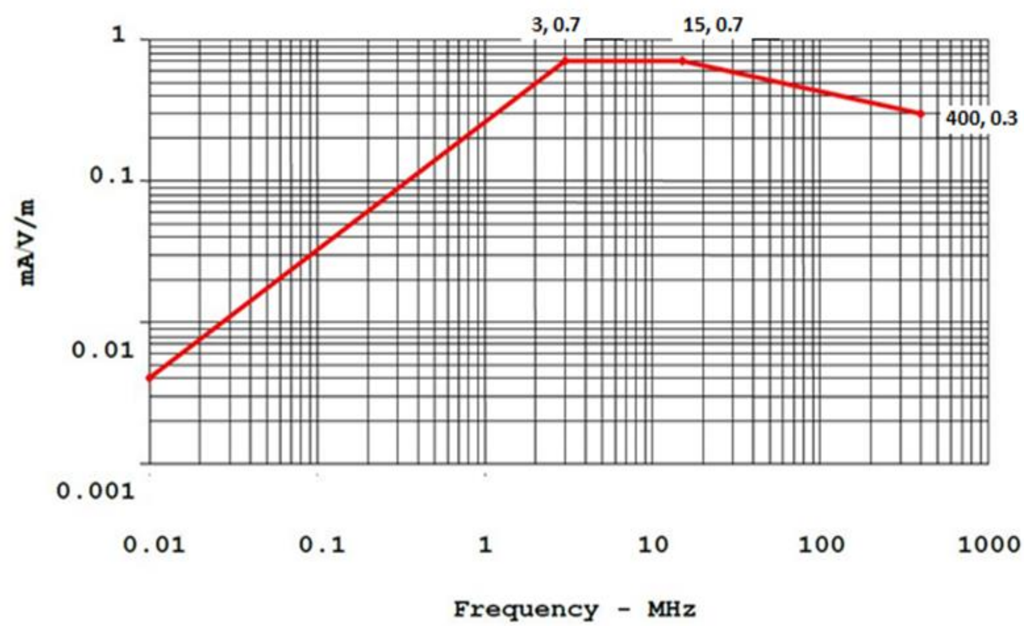
## A.1 GENERIC TRANSFER FUNCTIONS.

A.1.1 Suitable transfer functions for calculating the bulk current injection test levels for level A display systems (see paragraph 10.11) are given in figures A-1 through A-5. These are derived generic transfer functions acquired from test results obtained from a significant number of aircraft. The test results were processed to establish a 95 percent population probability.

A.1.2 The transfer functions are normalized to a 1 V/m HIRF environment and may be multiplied linearly by the external HIRF environment to establish the bulk current injection test level requirements in the frequency range from 10 kHz up to 400 MHz. For example, if the HIRF environment is 100 V/m at 3 MHz, then using figure A-1, multiply 0.7 mA/V/m by 100 V/m to establish a test level of 70 milliamperes (mA).

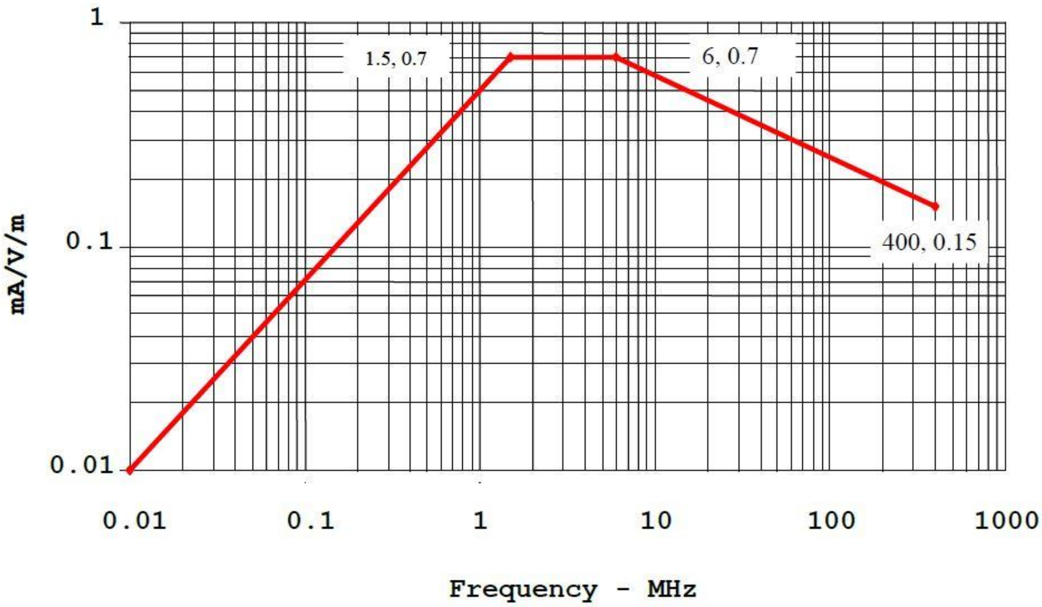
A.1.3 Consult the user's guide for details on the use of generic transfer functions.

**Figure A-1. Generic Transfer Function—Airplane**



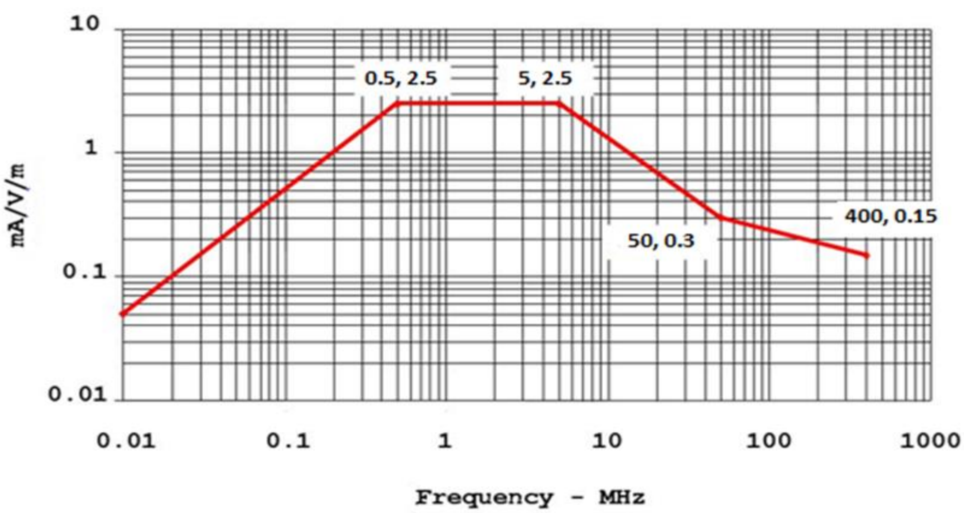

**Note:** Generic transfer function normalized to 1 V/m for an airplane with a fuselage length of $\leq$ 25m.

**Figure A-2. Generic Transfer Function—Airplane**



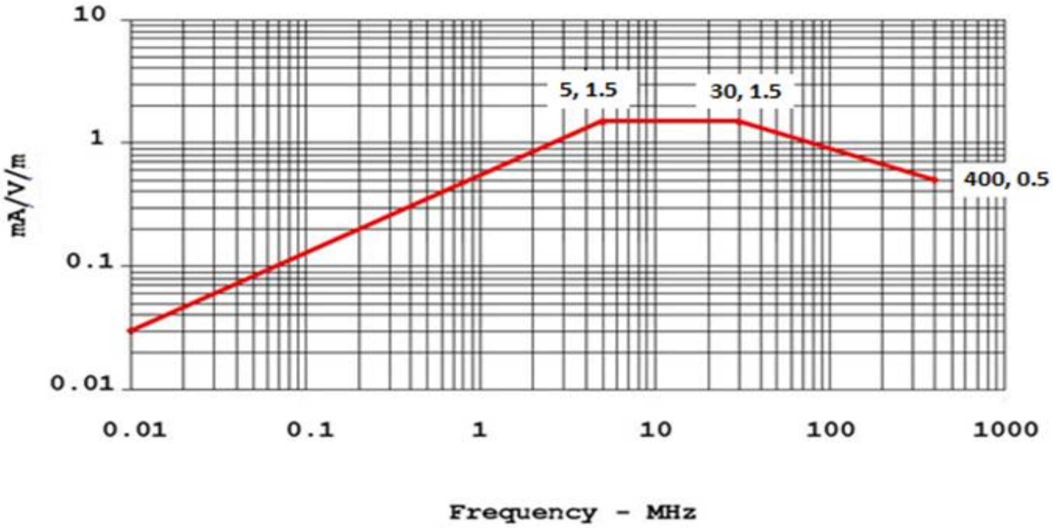

**Note:** Generic transfer function normalized to 1 V/m for an airplane with a fuselage length of > 25m and ≤ 50m.

**Figure A-3 — Generic Transfer Function – Airplane**



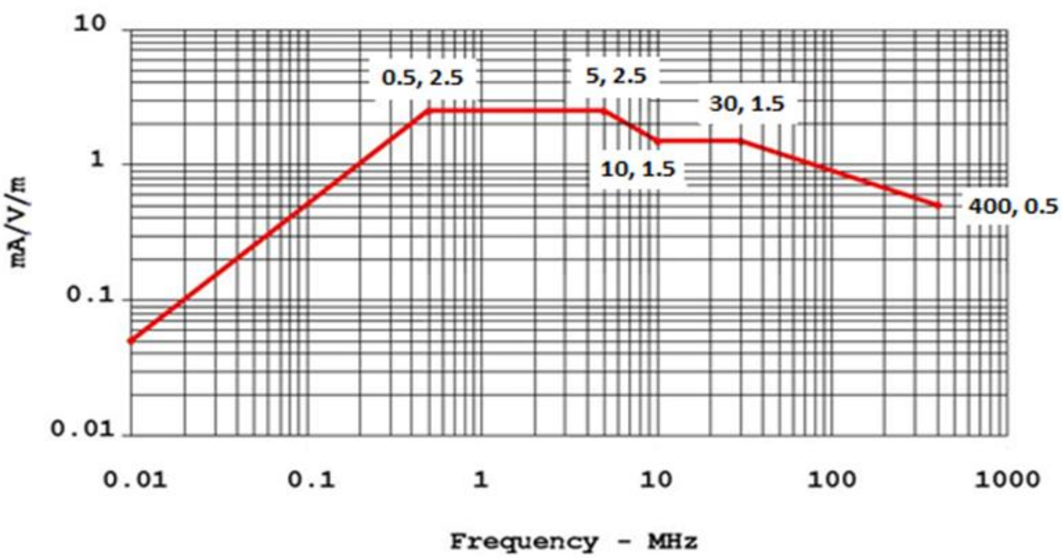

**Note:** Generic transfer function normalized to 1 V/m for an airplane with a fuselage length of > 50m.

**Figure A-4 Generic Transfer Function – Rotorcraft**




**Note:** Generic transfer function normalized to 1 V/m for a rotorcraft.

**Figure A-5 Generic Transfer Function – All Aircraft**




**Note:** Generic transfer function normalized to 1 V/m for all aircraft.

## A.2 GENERIC ATTENUATION.

A.2.1 Figure A-6 shows the generic attenuation for frequencies from 100 MHz to 18 GHz that can be used for determining the internal HIRF environment where equipment and associated wiring for level A display systems (see paragraph 10.11) are installed. This internal HIRF environment provides the radiated susceptibility test level for the laboratory integrated system test. The external HIRF environment should be divided by the appropriate attenuation, in linear units, to determine the internal HIRF environment. For example, 12 dB or a 4:1 attenuation means the test level is the applicable external HIRF environment electric field strength reduced by a factor of 4.

A.2.2 Guidance on the use of the generic attenuation is given below:

A.2.2.1 No Attenuation.

No attenuation credit can be used when the level A display equipment and associated wiring are located in aircraft areas with no HIRF shielding, such as areas with unprotected nonconductive composite structures, areas where there is no guarantee of structural bonding, or other open areas where no shielding is provided. You may choose to use no attenuation for equipment that may be installed in a broad range of aircraft areas.

A.2.2.2 6 dB Attenuation.

This attenuation is appropriate when the level A display equipment and associated wiring are located in aircraft areas with minimal HIRF shielding, such as a cockpit in a nonconductive composite fuselage with minimal additional shielding, or areas on the wing leading or trailing edges, or in wheel wells.

A.2.2.3 12 dB Attenuation.

This attenuation is appropriate when the level A display equipment and associated wiring are located entirely within aircraft areas with some HIRF shielding, in aircraft with a metal fuselage or a composite fuselage with shielding effectiveness equivalent to metal. Examples of such areas are avionics bays not enclosed by bulkheads, cockpits, and areas near windows, access panels, and doors without EMI gaskets. Current-carrying conductors in this area, such as hydraulic tubing, control cables, wire bundles, and metal wire trays, are not all electrically bonded to bulkheads they pass through.

A.2.2.4 20 dB Attenuation.

This attenuation is appropriate when the level A display equipment and associated wiring are located entirely within aircraft areas with moderate HIRF shielding, in aircraft with a metal fuselage or a composite fuselage with shielding effectiveness equivalent to metal. In addition, wire bundles passing through bulkheads in these areas have shields electrically bonded to the bulkheads. Wire bundles are installed close to metal structure and take advantage of other inherent shielding characteristics provided by metal structure. Current-carrying conductors, such as hydraulic tubing, cables, and metal wire trays are electrically bonded to all bulkheads they pass through.

A.2.2.5 32 dB Attenuation.

This attenuation is appropriate when the level A display equipment and all associated wiring to and from equipment are located entirely within areas with very effective HIRF shielding to form an electromagnetic enclosure.

A.2.2.6 Generic Attenuation for Rotorcraft.

Display units installed in rotorcraft typically have minimal attenuation unless specific shielding is provided in the bulkhead, glare shield, panel, and doors.

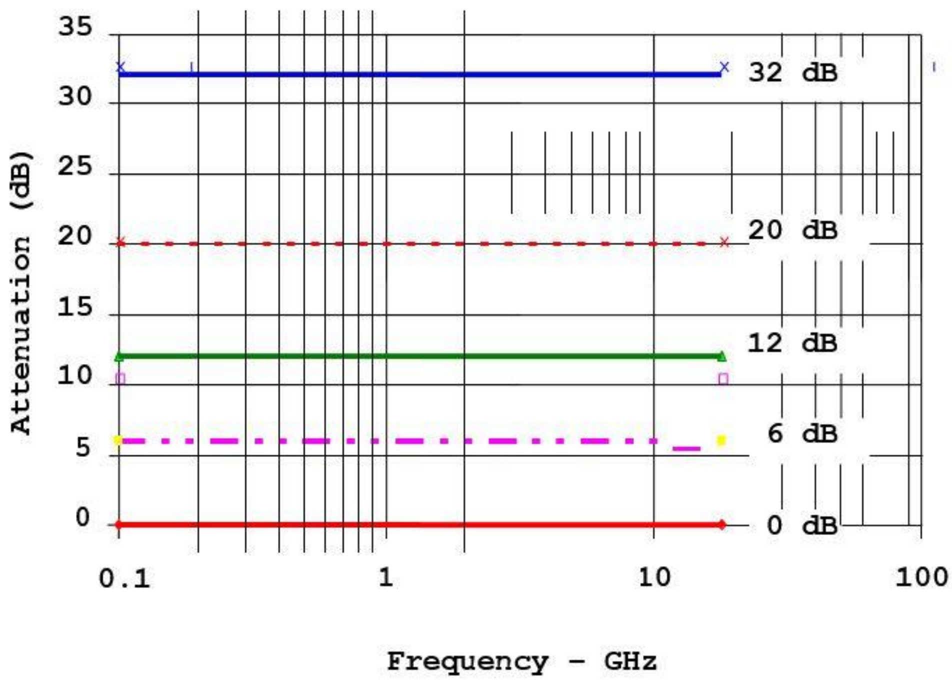
A.2.3 Different attenuation values may be appropriate for different frequency ranges. For example, 0 dB attenuation may be used for the frequency range of 100 MHz to 400 MHz, 6 dB attenuation for the frequency range of 400 MHz to 1 GHz, and 12 dB attenuation for the frequency range of 1 GHz to 18 GHz. If you intend to use different attenuation values for various frequency ranges, then you should also provide the supporting rationale.

A.2.4 Consult the user’s guide for details on the use of generic attenuation.

## A.3 MEASURED TRANSFER FUNCTIONS OR ATTENUATION.

You can produce your own generic transfer functions and attenuation for your level A display systems (see paragraph 10.11) based on actual measurements on your aircraft models. These transfer functions and attenuation can then be used in your HIRF compliance submission in place of the generic transfer functions and attenuation specified in this appendix. The FAA encourages this approach because it provides a more accurate reflection of the true internal HIRF environment for your aircraft models. However, if you intend to produce your own generic transfer functions and attenuation, then this approach should also be addressed in the HIRF compliance plan (see paragraph 9.1) that is submitted to the FAA for approval.

**Figure A-6 Generic Attenuation Values – All Aircraft 100 MHz to 18 GHz**



# Appendix B. Examples of HIRF Safety Assessment Considerations - Level A Systems on Transport Category Airplanes

## B.1 EXAMPLES OF HIRF SAFETY ASSESSMENT CONSIDERATIONS.

B.1.1 This appendix contains examples of HIRF safety assessment considerations for level A systems of transport category airplanes. These HIRF safety assessment considerations for level A systems may be applicable to normal category airplanes and rotorcraft. Establishing appropriate pass/fail criteria for complying with § 25.1317(a) should be achieved through a comprehensive review of the system design using an acceptable HIRF functional hazard assessment process to determine the system's HCL. The following paragraphs summarize approaches whereby pass/fail criteria for compliance with § 25.1317(a) may depend on the specific system architecture attributes (for example, system with similar redundant channels, dissimilar redundant channels, combination of similar and dissimilar redundant channels). For evaluation of the examples in paragraph B.1.2 of this appendix, consider the specific system architecture attributes. Channel modes as used in this appendix mean the following:

- Active mode means the channel is performing the aircraft function during normal operation.
- Active-backup mode means the channel is operational (in the ready state), but not used to perform the aircraft function until switched to active mode, either automatically or by flightcrew action.
- Passive-backup mode means the channel is not operational (not in the ready state). Switching to active mode is either automatic or by flightcrew action upon failure recognition.

Systems are typically categorized with the following architectures:

B.1.1.1 Similar Redundant Channels.

The multiple channels consist of equipment, components, electrical interconnections, and configurations that are similar, typically with equipment that have identical part numbers. The channels should be independent. They may be configured in active, active-backup, and passive-backup modes.

B.1.1.2 Dissimilar Redundant Channels.

Each channel is unique (comprises different equipment, components, electrical interconnections, and configurations) and independent of the others. They may be configured in active, active-backup, and passive-backup modes.

B.1.1.3 Combination of Similar and Dissimilar Redundant Channels.

The combination of similar redundant channels and dissimilar redundant channels, as defined above, with independence between channels. They may be configured in active, active-backup, and passive-backup modes.

B.1.1.4 Combination of Electrical and Electronic and Mechanical, Hydraulic, and/or Pneumatic Channels.

Certain architectures combine electrical and electronic channels with mechanical, hydraulic, and/or pneumatic channels. These combinations of channels may be configured in active, active-backup, and passive-backup modes.

**Note:** The examples in paragraph B.1.2 of this appendix are theoretical and do not account for all possible configurations but instead represent common system architectures or those that present unique challenges.

B.1.2 The following examples (B-1 through B-8) describe aircraft systems with multiple independent and redundant channels performing a function whose failure would prevent continued safe flight and landing of the aircraft.

### Example B-1 Information Essential to Continued Safe Flight and Landing

| Function | System Channel | System Channel | System Channel |
|---|---|---|---|
| Display of attitude, altitude, and airspeed information to the pilots during operation under IFR (e.g., primary display system and associated sensors, with dissimilar standby display system and sensors). | Active<br>(pilot displays and associated sensors). | Active<br>(co-pilot displays and associated sensors). | Active-backup<br>(dissimilar standby display and associated sensors). |
| Applicable paragraph in § 25.1317 | (a)(1), (2), and (3) | (a)(1), (2), and (3) | (b) |

**Discussion:**

This example illustrates the requirement in § 25.1333 for the instruments at each pilot station to independently display information essential to the safety of flight. The standby display is necessary for the system to comply with § 25.1309. Either the pilot or co-pilot can be the pilot flying or pilot monitoring during normal operations, so both the pilot and co-pilot display system could be the active system.

Compliance with § 25.1317(a)(1), (2), and (3) should demonstrate that each pilot instrument display of aircraft attitude, altitude, and airspeed is not adversely affected when the aircraft is exposed to HIRF environments I and II and recovers normal operation after the aircraft is exposed to HIRF environment I. The dissimilar standby display should comply with § 25.1317(b) based on the functional failure condition of hazardous. Adverse effects include both loss of, and hazardously misleading, attitude, altitude, and airspeed information.

## Example B-2 Electronic Flight Control System

| Function | System Channel | System Channel | System Channel |
|---|---|---|---|
| Full authority control of pitch, yaw, and roll using electrical and electronic flight control systems | Active or active-backup (flight control system #1) | Active or active-backup (flight control system #2) | Active or active-backup (flight control system #3) |
| Applicable paragraph in § 25.1317 | (a)(1), (2), and (3) | (a)(1), (2), and (3) | (a)(1), (2), and (3) |

**Discussion:**

This example illustrates an electronic flight control system comprising three independent channels to comply with § 25.1309. At any time, any one of the three channels can operate as the active channel. This may be necessary to achieve the safety intent or maintain reliability, priority scheme, voting logic, etc.

Only one channel operates in active mode while others are in active-backup mode. Any channel can perform the control function at any one time; therefore, all channels must comply with § 25.1317(a)(1), (2), and (3).

### Example B-3 Engine Over-Speed Protection

| Function | System Channel | System Channel | System Channel |
|---|---|---|---|
| Provide engine over-speed protection. | Active<br>(electronic engine control system)<br>(normal speed control) | Active or active-backup<br>(electronic engine control system)<br>(over-speed protection) | Active<br>(independent mechanical over-speed protection) |
| Applicable paragraph in § 25.1317 | (b) | (b) | None |

**Discussion:**

This example illustrates the function of engine over-speed protection performed by a combination of active electrical and electronic control and mechanical system control. The mechanical channel must provide over-speed protection during normal operations and be independent of the active electronic control channels. The mechanical channel must not rely on electrical or electronic components to assist, augment, or monitor the over-speed protection. If the mechanical channel is independent of the electronic engine control speed control and over-speed protection, and has no electrical or electronic components, then the engine over-speed protection function is not adversely affected when the aircraft is exposed to HIRF environments I and II. The system therefore is not subject to § 25.1317(a). The electronic engine control channels should comply with § 25.1317(b) based on the functional failure condition of hazardous.

This example only addresses the over-speed protection feature implemented by the system. Other functions whose failure may be classified as catastrophic, like the loss of thrust control where the function may be implemented by electronic control channels, should comply with § 25.1317(a).

### Example B-4 Electrical Power Generation System including Ram Air Turbine (RAT)

| Function | System Channel | System Channel | System Channel |
|---|---|---|---|
| Provide electrical power for electrical and electronic systems including those with catastrophic failure conditions. | Active<br>(left engine generator system) | Active<br>(right engine generator system) | Passive-backup<br>(emergency power supply system driven by ram air turbine) |
| Applicable paragraph in § 25.1317 | (a)(1), (2), and (3) | (a)(1), (2), and (3) | (b) |

**Discussion:**

This example illustrates a typical transport category airplane electrical system on a two-engine airplane where two or more independent sources of electrical power are required by § 25.1307(b) and a ram air turbine is necessary to comply with the requirements in §§ 25.1309 and 25.1351(d).

For this example, the electrical system consists of two active channels provided by a single main engine driven generator on each engine with the associated distribution and controls, and a third passive-backup channel provided by a ram air turbine electrical power system. The ram air turbine electrical power system is stowed during normal operation and deployed either automatically or manually when power from the two main engine driven generators is lost.

The active engine generator system channels must not be adversely affected when the aircraft is exposed to HIRF environments I and II and must comply with § 25.1317(a)(1), (2), and (3). The passive-backup ram air turbine electrical power system does not mitigate adverse effects for compliance with § 25.1317(a). The ram air turbine electrical power system must comply with § 25.1317(b) based on the functional failure condition of hazardous.

### Example B-5 Electrical Power Generation System including Auxiliary Power Unit (APU) and RAT

| Function | System Channel | System Channel | System Channel | System Channel |
|---|---|---|---|---|
| Provide electrical power for electrical and electronic systems including those with catastrophic failure conditions. | Active<br>(left engine generator system). | Active<br>(right engine generator system). | Active-Backup<br>(APU driven generator system required for extended operations (ETOPS) flight beyond 180 minutes). | Passive-Backup<br>(emergency power supply system driven by ram air turbine). |
| Applicable paragraph in § 25.1317 | (a)(1), (2), and (3) | (a)(1), (2), and (3) | Based on specific aircraft safety assessment. | (b) |

**Discussion:**

This example illustrates a two-engine transport category airplane electrical system where two or more independent sources of electrical power are required by § 25.1307(b) and an alternate source (driven by ram air turbine) is necessary to comply with §§ 25.1309 and 25.1351(d). This configuration includes a third electrical power source driven by an APU. This third source (active-backup channel) is required for ETOPS beyond 180 minutes. As in example 4, the emergency power source is a passive-backup channel provided by a ram air turbine that remains stowed during normal flight and deployed either automatically or manually when power from all other channels is lost.

All active electrical power generation channels should comply with § 25.1317(a)(1), (2), and (3). The active-backup electrical power generation channel HCL should be determined based on the specific aircraft safety assessment. The passive-backup electrical power generation channel does not mitigate adverse effects due to HIRF exposure to meet the intent of the HIRF rule. The passive backup channel must be evaluated under § 25.1317(b) based on the functional failure condition of hazardous.

**Note**: For airplanes without ETOPS type design approval or with ETOPS type design approval for up to 180 minutes, the APU HCL should be defined based on a specific aircraft safety assessment.

### Example B-6 Independent Systems Performing an Aircraft Function

| Function | System Channel | System Channel | System Channel | System Channel |
|---|---|---|---|---|
| Reduce aircraft speed on ground in a controlled manner using thrust reverser control system, spoiler deployment system, wheel braking system. | Active<br>main brake system (electro-mechanical) | Active<br>(electronic engine thrust reverse control with associated sensors) | Active<br>(electronic spoiler deployment control with associated sensors) | Active<br>(independent mechanical wheel braking) |
| Applicable paragraph in § 25.1317 | (a)(1), (2), and (3) | Based on specific aircraft safety assessment. | Based on specific aircraft safety assessment. | None |

**Discussion:**

This example illustrates an aircraft level function that is performed by a combination of independent systems, each contributing to the function in part during a specific phase of flight. Each system implements a very distinct aircraft level function that serves in a complementary manner to decelerate the aircraft during the landing roll. The mechanical wheel braking system is assumed to be independent of the other channels, with no associated electrical or electronic equipment to assist, augment, or monitor the mechanical wheel braking system.

In this example, it is assumed that the main brake system includes failure conditions that are catastrophic. For the electronic engine thrust reverser control and the electronic spoiler control systems, the applicable paragraphs in § 25.1317 would depend on the specific failure conditions. The effectiveness, authority, and malfunctions associated with each system should be addressed. Additionally, the interaction between the systems should be addressed. Issues such as unsymmetrical thrust reverser activation or spoiler deployment could adversely affect the main brake and mechanical wheel braking functions and could affect the safety classification for the thrust reverser and spoiler controls.

An aircraft safety assessment should be conducted for each of these systems performing a specific aircraft level function to identify and classify their failure conditions. The failure hazard classifications and the decomposition of each system into the constituent channels would then dictate which paragraphs of § 25.1317 must be complied with.

## Example B-7 Altitude Information from Multiple Sources

| Function | System Channel | System Channel | System Channel |
|---|---|---|---|
| Provide altitude information to display in IFR using air data computer connected to the primary flight display, and pneumatic standby instrument with alternate static port. | Active (air data computer 1 with static port) | Active (air data computer 2 with static port) | Active-backup (pneumatic standby altimeter with alternate static port) |
| Applicable paragraph in § 25.1317 | (a)(1), (2), and (3) | (a)(1), (2), and (3) | None |

**Discussion:**

This example illustrates the function of providing altitude information. The main sources are obtained from two air data computers coupled to static ports and a backup source from a standby pneumatic altimeter coupled to an alternate static port independent from the main static ports. The pneumatic standby altimeter (active-backup channel) has no associated electrical or electronic equipment to assist, augment, or monitor the pneumatic standby altimeter system.

In this example, the standby altimeter does not mitigate the hazardously misleading altitude information from the active air data computer channels to comply with § 25.1317(a).

### Example B-8 HCL Comparison to Development Assurance Level (DAL) Function

| Function | System Channel | System Channel | System Channel | |
|---|---|---|---|---|
| Control and protection of the aircraft pneumatic (bleed) system (top-level failure condition classification: catastrophic). | Active (pneumatic system controller #1)<br>Functional DAL (FDAL) B | Active (pneumatic system controller #2)<br>FDAL B | Passive Back-up (high pressure switch + valve)<br>FDAL C | |
| Applicable paragraph in § 25.1317 | (a)(1), (2), and (3) | (a)(1), (2), and (3) | (b) | |

**Discussion:**

This is a generic example to show that the HCL of a given system may be different from the FDAL and item development assurance level (IDAL), as defined in SAE ARP4754A. Therefore, it is important to use the proper nomenclature and avoid using ARP4754A "DAL" or similar terms when referring to the HCL.

In this example, the pneumatic control system is composed of two main active controllers and a simpler passive back-up channel that can perform the function, preventing a catastrophic event should both controllers fail.

The FDAL for each channel or member (ARP4754A nomenclature) in this example was determined for a catastrophic top-level failure condition based on the "Option 2" column of Table 3 "DEVELOPMENT ASSURANCE LEVEL ASSIGNMENT TO MEMBERS OF A FUNCTIONAL FAILURE SET" in ARP4754A, which allows the combination of FDAL B+B+C for independent channels. In contrast, the respective HCLs would be A+A+B.

Considering that HIRF can simultaneously affect all channels, the considerations used for FDAL assignment are not sufficient. Compliance with § 25.1317(a) is required for both active channels performing a function with a catastrophic top-level failure condition.

The FDAL for the passive back-up channel may be C in this example. However, for HIRF, the applicable paragraph in § 25.1317 is (b) based on the functional failure condition of hazardous.

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