Australian Government
Civil Aviation Safety Authority

ADVISORY CIRCULAR

AC 21-53
Electromagnetic compatibility

v1.0 – December 2015

Advisory Circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.

Advisory Circulars should always be read in conjunction with the relevant regulations.

Audience

This Advisory Circular (AC) applies to:

- Subpart 21.J - Approved design organisations
- Subpart 21.M - Authorised persons.

Purpose

The purpose of this AC is to provide guidance on aircraft electromagnetic interference, electromagnetic compatibility, lightning protection and high-intensity radiated fields.

For further information

For further information on this AC, contact Civil Aviation Safety Authority's (CASA's) Airworthiness and Engineering Standards Branch (telephone 131 757).

Status

This version of the AC is approved by the Executive Manager, Standards Division.

Version	Date	Details
1.0	December 2015	Initial version

Unless specified otherwise, all subregulations, regulations, divisions, subparts and parts referenced in this AC are references to the *Civil Aviation Safety Regulations 1998 (CASR)*.

Contents

1 Reference material

1.1 Acronyms

The acronyms and abbreviations used in this AC are listed in the table below.

Acronym	Description
AC	Advisory Circular
ADO	Approved Design Organisation
AIP	Aeronautical Information Publication
ACMA	Australian Communication and Media Authority
AMC	Acceptable Means of Compliance
APU	Auxiliary Power Unit
ATL	Actual Transient Level
ATSB	Australian Transport Safety Bureau
CAAP	Civil Aviation Advisory Publication
CAO	Civil Aviation Order
CAR	*Civil Aviation Regulations 1988*
CASA	Civil Aviation Safety Authority
CASR	*Civil Aviation Safety Regulations 1998*
CS	Certification Specifications
DOT	Department of Transportation (United States of America)
EASA	European Aviation Safety Agency
EMC	Electro Magnetic Compatibility
EMI	Electro Magnetic Interference
ETDL	Equipment Transient Design Level
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration (of the USA)
FAR	Federal Aviation Regulation (of the USA)
GM	Guidance Material
GNSS	Global Navigation Satellite System
HEC	Human External Cargo
HID	High Intensity Discharge
HIRF	High Intensity Radiated Fields
IPL	Interference Path Loss
JAA	Joint Aviation Authorities (of Europe)

Acronym	Description
JAR	Joint Aviation Requirements (of Europe)
RF	Radio Frequency
OEM	Original Equipment Manufacturer
PED	Portable Electronic Device
RFID	Radio Frequency Identification
RTCA	Radio Technical Commission for Aeronautics
SC	Special Conditions
TCDS	Type Certificate Data Sheet
TGA	Australian Therapeutic Goods Administration

1.2 Definitions

Terms that have specific meaning within this AC are defined in the table below.

Term	Definition
Actual Transient Level	The level of transient voltage and/or current that appears at the equipment interfaces as a result of the external lightning environment.
Airworthy	An aircraft is airworthy if it is in a state that conforms with its approved design and is in a condition for safe operation as per subregulation 42.015 (2).
Aperture	An electromagnetically transparent opening.
Approved Design	The type design for the aircraft or aircraft engine and any changes to the type design made in accordance with a Part 21 approval as per regulation 42.015.
Attachment Point	A point of contact of the lightning flash with the aircraft.
Back Door Coupling	Radio frequency transmissions that are radiated within the aircraft and received by aircraft electronic systems through their interconnecting wires or electronic equipment enclosures.
Breakdown	The production of a conductive ionised channel in a dielectric medium resulting in the collapse of a high electric field.
Coupling	Process whereby electromagnetic energy is induced in a system by radiation produced by a radio frequency source.
Dwell Point	A lightning attachment point.
Dwell Time	The time that the lightning channel remains attached to a single spot on the aircraft.
Electromagnetic Compatibility	Ability of any electrical or electronic equipment to simultaneously operate without suffering or causing adverse degradation in performance attributed to the interaction with electromagnetic energy present in the intended operational environment.
Electromagnetic Interference (EMI)	Phenomenon occurring when electromagnetic energy present in the intended operational environment interacts with the electrical or electronic equipment causing unacceptable or undesirable responses, malfunctions, interruptions, or degradations in its performance.
EMI Source	Source of electromagnetic energy that has the potential to interfere with the normal operation of other electrical or electronic equipment.
EMI Victim	Electrical or electronic equipment identified as likely to be affected by electromagnetic energy generated by other electrical or electronic equipment.
Equipment Transient Design Level	The peak amplitude of transients to which the equipment is qualified.
External Environment	Characterisation of the natural lightning environment for design and certification purposes.
High-Intensity Radiated Fields	Electromagnetic environment that exists from the transmission of high power radio frequency energy into free space.
First Return Stroke	The high current surge that occurs when the leader completes the connection between two charge centres.
Flashover	When the arc, produced by a gap breakdown, passes over or close to a dielectric surface without puncture.

Term	Definition
Front door coupling	Radio frequency emissions that are radiated within the aircraft, propagating through aircraft windows and doors, and received by aircraft radio receivers through their antennae installed on the aircraft.
Indirect effects	Electrical transients induced by lightning in aircraft conductive components such as electric circuits.
Leader	The low luminosity, low current precursor of a lightning return stroke, accompanied by an intense electric field.
Lightning Channel	The ionised path through the air that the lightning current pulse follows.
Lightning Flash	The total lightning event. It may occur within a cloud, between clouds or between a cloud and the ground. It can consist of one or more return strokes, plus intermediate or continuing currents.
Lightning Strike	Any attachment of the lightning flash to the aircraft.
Lightning Strike Zones	Aircraft surface areas and structures classified according to the possibility of lightning attachment, dwell time and current conduction.
Pinch effect	Crumpling damage due to electromagnetic forces created by the interaction of magnetic fields generated by lightning electrical currents.
Portable Electronic Device	Any piece of lightweight, electrically-powered equipment. These devices are typically consumer electronics devices functionally capable of communications, data processing and/or utility.
Reattachment	The establishment of new attachment points on the surface of an aircraft due to the sweeping of the flash across the surface of the aircraft by the motion of the aircraft.
Restrike	A subsequent high current surge attachment. This normally follows the same path as the first return stroke, but may reattach to a new location further to the rear of the aircraft.
Shield	A conductor which is grounded to an equipment case or aircraft structure at both ends and is routed in parallel with and bond within a cable bundle.
Similarity	Applicable to systems similar in characteristics and usage to systems used on previously certified aircraft.
Slit effect	Pressure increases when lightning creeps through a narrow slit. This results in a higher voltage drop along the channel. As the current does not change the resultant power increases that cause's intense heating along the channel. This higher temperature produces higher pressures. If the pressure is high enough and/or the material is weakened, rigid materials can fracture.
Susceptibility	The minimum radio frequency interference level will degrade system performance requirements when in its most vulnerable state. Susceptibility is the lack of immunity.
Swept Leader	A lightning leader that has moved its position relative due to aircraft movement during leader propagation.
Swept Channel	The lightning channel relative to the aircraft that results in a series of successive attachments due to the sweeping of the flash across the moving aircraft.
System Redundancy	The practice of implementing two or more parallel systems that can take over for each other in the event that one has a failure.

Term	Definition
Zoning	The process of determining the location on an aircraft to which the components of the external environment are applied.

1.3 References

Regulations

Regulations and CASA instruments are available on the Federal Register of Legislation website http://www.comlaw.gov.au/Home

Document	Title
Radiocommunications Act 1992	Radiocommunications (Aircraft and Aeronautical Mobile Stations) Class Licence 2006
Part 8 of the *Civil Aviation Regulations 1988 (CAR)*	Radio systems for use in, or in connection with, aircraft
Part 21	Certification and airworthiness requirements for aircraft and parts
Part 23	Airworthiness standards for aeroplanes in the normal, utility, acrobatic or commuter category
Part 27	Airworthiness standards for rotorcraft in the normal category
Part 42	Continuing airworthiness requirements for aircraft and aeronautical products
Part 174A of CAR	Visual flight rules
Part 177 of CAR	Instrument flight rules
CASA Instrument EX102/14	Exemption – carriage of portable electronic devices during flight
CASA Instrument EX66/14	Exemption – use of mobile phones and other electronic devices when loading fuel

Advisory material

ACs are available at http://www.casa.gov.au/AC

Civil Aviation Advisory Publications (CAAP) are available at http://www.casa.gov.au/CAAP

European Aviation Safety Agency (EASA) Certification Specifications (CS) and acceptable means of compliance (AMC) / guidance material (GM) are available at http://easa.europa.eu/regulations

Federal Aviation Administration (FAA) ACs are available at http://www.faa.gov/regulations_policies/advisory_circulars/

New Zealand Civil Aviation Authority (NZCAA) ACs are available at https://www.caa.govt.nz/rules/ACs.htm

Directorate General Technical Airworthiness documents are available at http://www.defence.gov.au/dasp/

Military Standards are available at http://quicksearch.dla.mil/

SAE International publications are available at http://www.sae.org/aerospace/

RTCA Inc. publications are available at http://www.rtca.org/index.asp

European Organisation for Civil Aviation Equipment (EUROCAE) publications are available at EUROCAE - Driving the standard for aviation

Document	Title
CASA AC 21-99	Aircraft wiring and bonding
Appendix 1 to CASA AC 21-46	Existing avionics standards
Civil Aviation Order (CAO) 20.16.3	Air service operations – Carriage of persons
AAP 7001.054	Australian Air Publication 7001.054. Electronic Airworthiness Design Requirements Manual Section S2C4 - Electromagnetic environmental effects Section S5C6 - Role equipment and portable electronic devices
Aeronautical Information Publication (AIP)	Air Services Australia - Aeronautical Information Package
AIP GEN 1.5	Aircraft instruments, equipment and flight documents
AIP GEN 3.4	Communication Services
CAAP 232A-1	Administration of Aircraft & Related Ground Support Network Security Programs
FAA AC 20-168	Certification Guidance for Installation of Non-Essential, Non-Required Aircraft Cabin Systems & Equipment (CS&E)
FAA AC 43.13-1B	Acceptable Methods, Techniques, and Practices - Aircraft Inspection and Repair
FAA AC 43.13-2B	Acceptable Methods, Techniques, and Practices – Aircraft Alterations
FAA AC 21-16G	RTCA Document DO-160 versions D, E, F, and G, “Environmental Conditions and Test Procedures for Airborne Equipment
FAA AC 20-136B	Aircraft Electrical and Electronic System Lightning Protection
FAA AC 20-155A	Industry Documents To Support Aircraft Lightning Protection Certification
FAA AC 20-158A	The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-intensity Radiated Fields (HIRF) Environment

Document	Title
FAA 20-164	Designing and Demonstrating Aircraft Tolerance to Portable Electronic Devices
FAA AC 20-162	Airworthiness Approval and Operational Allowance of RFID Systems
FAA AC 20-164	Designing and Demonstrating Aircraft Tolerance to Portable Electronic Devices
FAA AC 23.1311-1C	Installation of Electronic Display in Part 23 Airplanes
FAA AC 23.1309-1E	System Safety Analysis and Assessment for Part 23 Airplanes
FAA AC 25.1309-1A	System Design and Analysis
FAA AC 23-17C	Systems and equipment guide for certification of part 23 airplanes and airships
FAA AC 27-1B	Certification of Normal Category Rotorcraft
FAA AC 29-2C	Certification of Transport Category Rotorcraft
FAA AC 33.4-3	Instructions for Continued Airworthiness; Aircraft Engine High Intensity Radiated Fields (HIRF) and Lightning Protection Features
FAA AC 25-7C	Flight Test Guide for Certification of Transport Category Airplanes
FAA AC 23-8C	Flight test guide for certification of part 23 airplanes
FAA AC 21-22	Injury Criteria for Human Exposure to Impact
FAA AC 43-206	Inspection, prevention, control and repair of corrosion on avionics equipment
FAA AC 91.21-1C	Use of Portable Electronic Devices Aboard Aircraft
FAA report	Accident overview on Pan American flight 214
PED.ARC.RR.20130930	A Report from the PED ARC to the FAA
UK CAP 756	Portable Electronic Device Generated Electro-magnetic Fields on board a Large Transport Aeroplane
UK CAP 1066	Flying with gadgets. The dos and don'ts of using mobile phones and electronic devices on board aircraft
Joint Aviation Requirement (JAR) TGL-29	Guidance concerning the use of portable electronic devices on board aircraft
Joint Aviation Authorities (JAA) INT POLs 23/1	JAA Interim Policy - Protection from the Effects of HIRF
JAA INT POLs 23/3	JAA Interim Policy - Lightning Protection; Indirect Effects for Small Aeroplanes
JAA INT POLs 25/2	JAA Interim Policy - Protection from the Effects of HIRF
JAA INT POLs 27&29/1	JAA Interim Policy - Protection from the Effects of HIRF for Small and Large Rotorcraft
TC AC 500-002	Electromagnetic Compatibility Testing of Electrical and Electronic Equipment
EASA AMC 20	General Acceptance Means of Compliance for Airworthiness of Products, Parts and Appliances

Document	Title
EASA Part-21/AMC/GM	AMC and GM to Part 21 Acceptable Means of Compliance and Guidance Material
EASA CS-27	EASA Certification Specification Small Rotorcraft
EASA CS-29	EASA Certification Specification Large Rotorcraft
NZCAA AC 91-5	Operation of Portable Electronic Devices (PEDs) During Flight Under IFR
Department of Transportation (DOT)/FAA/CT-89/22	Aircraft Lightning Protection Handbook
DOT/FAA/CT-86/40	Aircraft Electromagnetic Compatibility
A98H0003	Transportation Safety Board of Canada. Aviation Investigation Report: High-Intensity Radiated Fields
SAE ARP5412B EUROCAE/ED-84A	Aircraft Lightning Environment and Related Test Waveforms
SAE ARP5414B EUROCAE/ED-91	Aircraft Lightning Zoning
SAE ARP5415A	User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning
SAE ARP5416A EUROCAE/ED-105A	Aircraft Lightning Test Methods
SAE ARP 5583A/EUROCAE ED-107A	Guide to Certification of Aircraft in a High-Intensity Radiated Field (HIRF) Environment
SAE ARP5583A	Guide to Certification of Aircraft in a High-Intensity Radiated Field (HIRF) Environment
SAE ARP4242A	Electromagnetic Compatibility Control Requirements System
MSG-3/2011	Operator Manufacturer Scheduled Maintenance Development
AECTP-250	NATO Standard. Electrical and electromagnetic environmental conditions
MIL-STD-464C	Electromagnetic environmental effects requirements for systems
MIL-STD-461F	Requirements for the control of Electromagnetic Interference characteristics of subsystems and equipment
RTCA/DO-160G EUROCAE/ED-14G	Environmental Conditions and Test Procedures for Airborne Equipment
RTCA/DO-313	Certification Guidance for Installation of Non-essential, Non-required Aircraft Cabin Systems & Equipment
RTCA/DO-294	Guidance on Allowing Transmitting Portable Electronic Devices (T-PEDS) on Aircraft
EUROCAE/ED-130	Guidance for the use of Portable Electronic Devices (PEDs) on Board Aircraft
EUROCAE/ED-81 Amd 1	Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning
EUROCAE/ED-91 Amd 2	Aircraft Lightning Zoning Standard

Document	Title
EUROCAE/ED-107A	Guide to certification of Aircraft in a High Intensity Radiated Field (HIRF) Environment
IEEE 802.15.1	Wireless personal area networks
Appendix F of PED ARC Final Report	Recommendations on Expanding the Use of Portable Electronic Devices During Flight
Mobile Architecture Lab Technology & Research Labs report	Safety Evaluation of Bluetooth Class ISM Brand Transmitters on board Commercial Aircraft
Australian Transport Safety Bureau (ATSB) report 2004-2013	Aviation Occurrence Statistics
Bureau of Meteorology (BOM)	BOM website

2 Introduction

Aircraft rely on electrical and electronic equipment to provide various functions. Aircraft equipment and associated wiring may either generate, or be susceptible to, electromagnetic interference. This interference can couple into associated wiring and other apertures, causing unintended consequences.

Electromagnetic fields are produced by the generation, transmission and utilisation of electrical energy.

Electromagnetic compatibility is preserved by aircraft design specifications, equipment environmental categories and installation compliance.

Generators of electromagnetic interference to an aircraft can come from several sources, for example:

- lightning strikes
- high intensity radiated fields (HIRF)
- intentional transmitters installed on the aircraft
- aircraft power sources
- avionics and other electronic equipment
- power generation, regulation and switching circuits
- transients by switching on and off electrical equipment
- electrostatic discharge.

Aircraft wiring function is to transfer data or power, but in turn can act to transfer interference. Routing of wiring (whether through aircraft structure or shielded wiring) will have a dramatic effect on elimination of electromagnetic interference. Deterioration at wiring termination points can affect shields and grounds causing interference or degradation of performance.

2.1 Failure modes

2.1.1 Interference to avionic systems can cause varying function failures of the aircraft systems. These failures can occur in both required and non-required aircraft systems.[1]

2.2 Environmental testing

2.2.1 RTCA/DO-160 or EUROCAE/ED-14 testing qualifies equipment by a series of bench tests to meet a certain environmental category rating. This environmental testing does not qualify the equipment for automatic acceptance into any aircraft. Further verification and testing on the aircraft may be required to address any compatibility issues. The type of testing will depend on the aircraft design and complexity.

> **Note:** Compatibility of equipment takes into account other installed equipment, wiring and electrical bonding.

[1] For further information on the failures and their affects see FAA AC 23.1309-1E, 25.1309-1A, AC 27-1B, AC 29-2C; or EASA Part-21/AMC/GM, as appropriate to the aircraft type certification basis.

2.3 Equipment, systems and installations

2.3.1 Any equipment installed (whether required or non-required) must be designed to minimise hazards to the aircraft in the event of a probable malfunction or failure. This is a basic design requirement in accordance with:

- United States of America - Federal Aviation Regulations (FARs) 14CFR2X.1309
- European Aviation Safety Agency (EASA) - Certification Specification JAR/CS-2X.1309.[2]

Note: Compliance with these airworthiness design standards are mandated by Parts 23, 25, 27 and 29.

2.3.2 Whilst aircraft type certified prior to 1987 may not have verified radio frequency (RF) immunity on the type certification basis, there may be special conditions (SC) imposed, for example:

- 23-140-SC - Pilatus PC-12
- 25-147-SC - Boeing Model 737-300/-400/-500
- 25-ANM-66 - Saab 2000 Airplane
- 27-009-SC - Eurocopter EC130
- 29-007-SC - Eurocopter EC155.

2.4 Coupling paths

2.4.1 RF signals travelling from one point to another can be conducted on wires and radiated through space. Radiated emissions can couple to aircraft systems through apertures in aircraft equipment, induce currents on aircraft wires or be received by antennae providing a direct path into the aircraft radio receivers.

2.4.2 Aircraft electrical and electronic systems are protected against the effects of electromagnetic interference, particularly against HIRF and the effects of lightning. The system tolerance to RF fields depends on the system criticality and its location in the aircraft.

2.4.3 When an electromagnetic wave is reflected back on itself, the incident and reflected wave energy will combine to form deconstructive and constructive interference. This can result in a standing wave in which there is an intensification of the energy density compared to the original electromagnetic wave. A closed cavity, length of wire or perimeter of an aperture can allow multiple reflections to occur, resulting in peak amplitudes that are larger than the incident wave.

2.4.4 Front door coupling

2.4.4.1 RF energy radiates from a device and couples directly into the aircraft radio receiver antennae. Front door coupling applies only to aircraft radio receivers (Figure 1).

[2] For further information on the conduct of system safety analysis and assessment refer to FAA AC 23.1309-1E, 25.1309-1A, AC 27-1B, AC 29-2C; or EASA Part-21/AMC/GM, as appropriate to the aircraft type certification basis.

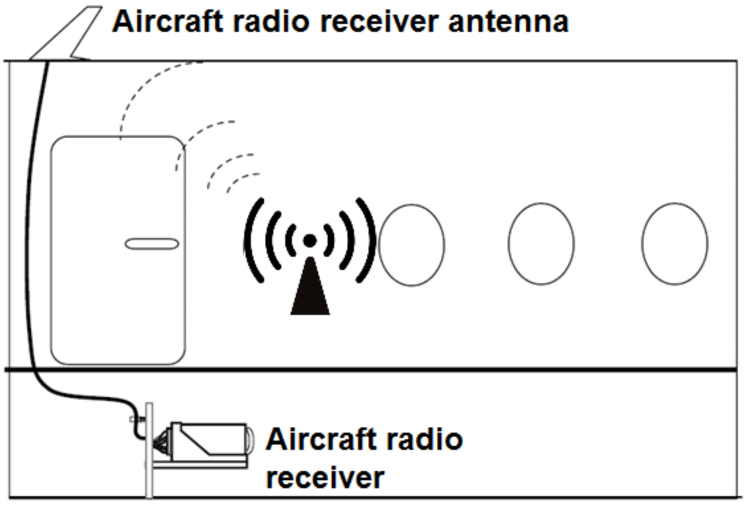

Figure 1: Front door coupling

2.4.4.2 A system's robustness to interference is verified through the qualification of the receiver (both in band frequencies and out of band frequencies) to the relevant minimum operational performance standard (Figure 2).

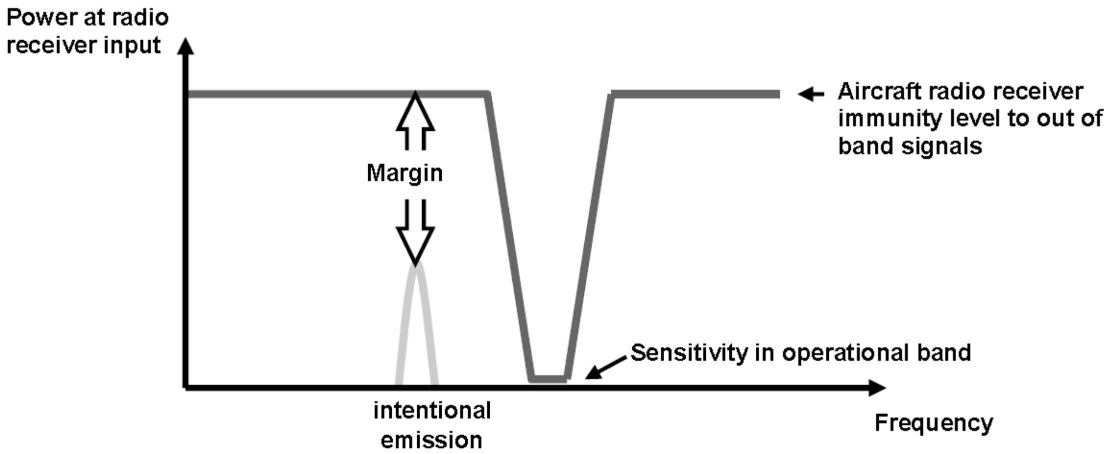

Figure 2: Front door coupling of intentional radiated emissions

2.4.4.3 Interference path loss (IPL) is the ratio of power measured at the aircraft radio receiver input to the power measured at the output of the transmitter reference antennae terminals (Figure 3). For most aircraft radio receivers, the IPL includes cable losses. IPL varies rapidly with frequency and position.

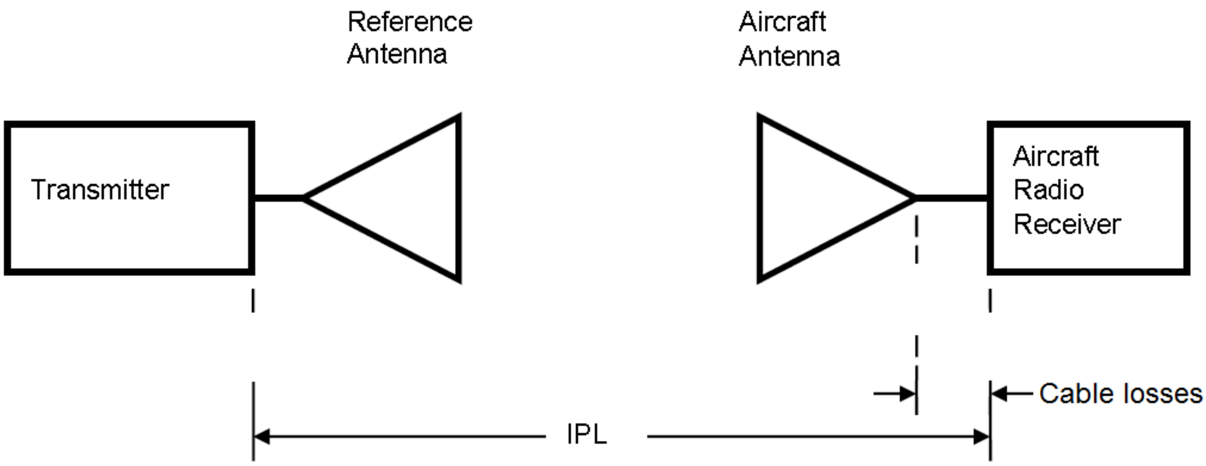

Figure 3: How IPL works

2.4.4.4 Changes to the aircraft structure can affect coupling paths and therefore have a significant impact on IPL values. IPL measurements are not required for frequencies operating outside the aircraft radio bands.

2.4.4.5 Assessments involving a number of individual aircrafts may be accepted by analysis if it can be shown that their configurations (including aircraft equipment, wiring, installation and interior configuration) are sufficiently similar.

2.4.5 Back door coupling

2.4.5.1 Aircraft communication, navigation and surveillance radio receivers are protected for backdoor coupling by environmental qualification testing using either RTCA/DO-160 or EUROCAE/ED-14.

2.4.5.2 RF energy radiates from a device and couples directly into the aircraft electrical and electronic equipment or into the wiring that connects to this equipment. Back door coupling can affect any aircraft's electrical and electronic equipment (Figure 4).

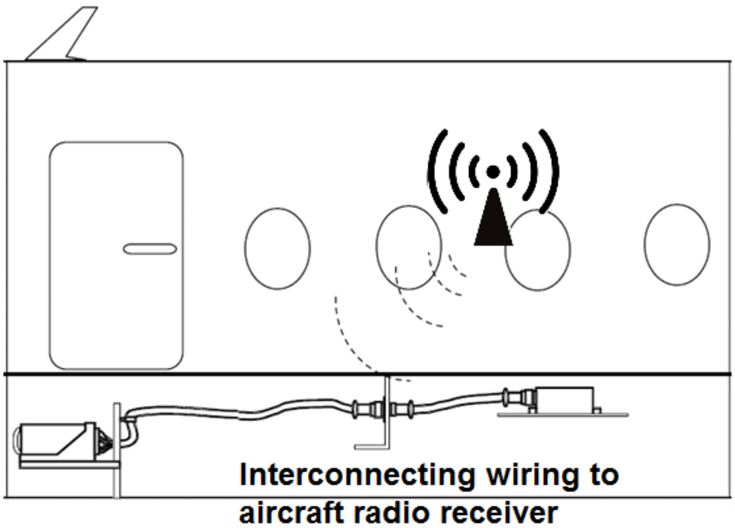

Figure 4: Back door coupling

2.4.5.3 The potential for interference depends on:

- the strength of the transmitting signal
- the design of the shielding
- the bonding/grounding policy for power supplies, electrical signals and associated filtering devices
- the aircraft system susceptibility at the specific frequency of the interfering transmission (Figure 5).

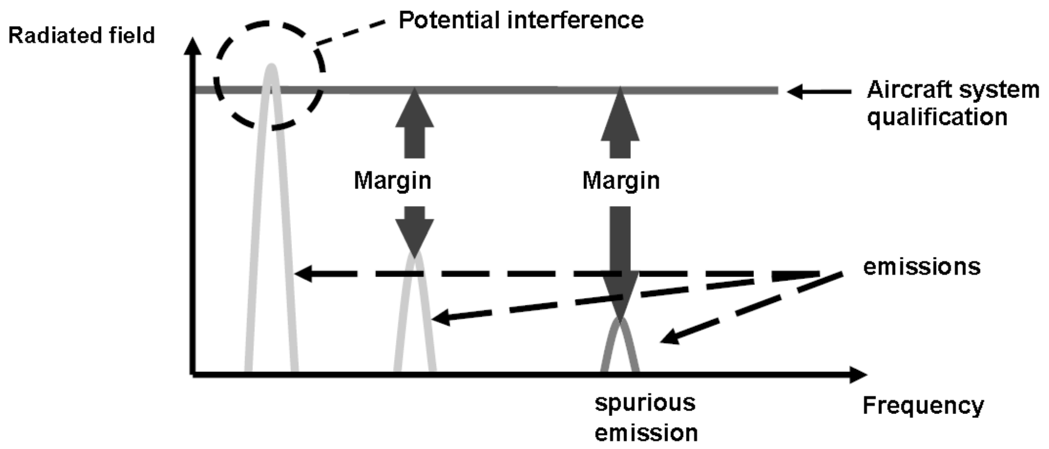

Figure 5: Backdoor coupling of radiated emissions

2.5 Aircraft RF spectrum

2.5.1 Aircraft radio communication, navigation and surveillance frequency bands are internationally harmonised through treaties. The Australian Communication and Media Authority (ACMA) oversights the RF spectrum usage in Australia. Table 1 summarises these operating frequency bands currently in use in aircraft.

Table 1: Aircraft radio frequency spectrum

Receiver	Frequency (MHz)
Automatic direction finding	0.190-1.750
High frequency voice and data	2-30
Marker beacon	75
Instrument landing system - localiser	108-112
Very high frequency - communications	118-137
Instrument landing system - glideslope	329-335
Distance measuring equipment	962-1213
Mode A/C/S transponder receiver	1030
Traffic collision avoidance system interrogator	1090
Global navigation satellite system (GNSS) L5/E5 band	1164-1215
Satellite communications	1530-1559
GNSS L1 band	1559-1610
Radio altimeter	4200-4400
Microwave landing system	5030-5090
Weather radar - C band	4000-8000
Weather radar - X band	8000-15700

2.5.2 The ACMA chart details all allocated radio frequency usage in Australia. This chart includes all aircraft communication, navigation and surveillance frequency bands.

2.5.3 The *Radiocommunications (Aircraft and Aeronautical Mobile Stations) Class Licence 2006*, issued under the *Radiocommunications Act 1992*, details all frequencies in use for aeronautical and radionavigation frequency equipment. Radio systems for use in, or in connection with, aircraft are approved under Part 8 of the *Civil Aviation Regulations 1988 (CAR)* or under regulations 21.305 or 21.305A.

2.5.4 Radio systems for use in, or in connection with, aircraft are approved under Part 8 of CAR or Part 21 of CASR.

2.5.5 Under regulations 174A and 177, the Civil Aviation Safety Authority (CASA) can issue instructions specifying radio equipment systems in the Civil Aviation Orders (CAOs), Notices to Airmen (NOTAMS) or the AIP (i.e. AIP GEN 1.5 and AIP GEN 3.4).

3 Electromagnetic interference / electromagnetic compatibility

3.1 Interference

3.1.1 Electromagnetic interference (EMI) is the phenomenon occurring when electromagnetic energy present in the intended operational environment interacts with the electrical or electronic equipment, causing unacceptable or undesirable responses, malfunctions, interruptions, or degradations in its performance. Aircraft systems may suffer from degraded system performance by EMI.

3.2 Compatibility

3.2.1 Electromagnetic compatibility (EMC) is the ability of any electrical or electronic equipment to operate without suffering or causing adverse degradation in performance attributed to the interaction with electromagnetic energy present in the intended operational environment.

3.2.2 Addressing EMC

3.2.2.1 The designs used in an aircraft have an effect on EMC. The following factors can help to promote EMC:

- equipment/wiring isolation and separation (particularly in flight critical systems)
- aircraft structure conductivity
- transients caused by equipment
- connectors
- bonding
- length of wiring
- shielding
- power and signal returns
- earthing design
- dielectrics of insulation material (which can weaken with altitude)
- environmental qualification (paragraph 3.2.6).

3.2.3 Wiring techniques

3.2.3.1 In redundant aircraft systems, or systems critical to flight safety, the operator should consider routing wiring through separate connectors (where possible). It is also a good practice to separately route wiring associated with flight crew alerting functions.

3.2.3.2 Inadequate bonding or grounding can lead to EMI. Sufficient bonding provides conductive paths for electric currents.

3.2.3.3 Sensitive circuits are more prone to the effects of EMI. Separately grounding two components of a transducer system may introduce ground plane voltage variations.

3.2.3.4 Wiring terminations placed in external areas on an aircraft are particular prone to corrosion as a failure mode and deterioration can cause EMI if not adequately addressed.

3.2.3.5 For further information on EMI techniques, if not detailed in the approved design, see:

– AC 21-99
– FAA AC 43.13-1B
– FAA AC 43.13-2B.

3.2.4 Airworthiness design standards - aircraft systems and components

3.2.4.1 Table 2 contains the airworthiness design standards that are applicable under the FAA and EASA.

Table 2: Electromagnetic interference airworthiness standards

Airworthiness Standard (14CFR), Joint Aviation Regulation (JAR) or Certification Specification (CS)				
Airworthiness standard requirement	**Part 23**	**Part 25**	**Part 27**	**Part 29**
Function and installation	23.1301	25.1301	27.1301	29.1301
Equipment, systems and installation	23.1309	25.1309	27.1309	29.1309
Electrical Systems and Equipment - General		25.1353		29.1353
External loads			27.865	29.865
Lightning standards - see section 4				
HIRF standards - see section 5				

3.2.5 Airworthiness design standards - engines

3.2.5.1 EMI requirements for engines control systems were introduced in airworthiness standard (14CFR) 33.28 (from amendment 33-26 in 2008).

3.2.5.2 EASA has requirements for EMI protection for engines in CS-E 80 and CS-E 170 from the initial issue in 2003. Auxiliary Power Unit (APU) protection requirements for control systems are in CS-APU 90, released in the initial issue in 2003.

3.2.6 Environmental equipment qualification

3.2.6.1 Equipment that is qualified through technical standard orders will meet a minimum performance specification, which includes environmental testing in accordance with RTCA/DO-160 or EUROCAE/ED-14.[3]

[3] For equipment qualified to older versions of RTCA/DO-160, see FAA AC 21-16G for acceptance.

3.2.6.2 The following sections of industry standards RTCA/DO-160 or EUROCAE/ED-14 are relevant for EMC:

– *Section 15 - Magnetic Effect*: finding the closest distance to compasses or flux valves at which that a unit is allowed to be installed
– *Section 18 - Audio Frequency Conducted Susceptibility*: Power Inputs: provides test procedures and test levels that can be used to test equipment for audio frequency conducted susceptibility of power input lines
– *Section 19 - Induced Signal Susceptibility*: test determines whether the equipment interconnect circuit configuration will accept a level of induced voltages caused by the installation environment
– *Section 20 - Radio Frequency Susceptibility*: tests whether the equipment will operate within performance specifications when the equipment and its interconnecting wiring are exposed to a level of RF modulated power
– *Section 21 - Emission of Radio Frequency Energy*: tests determine that the equipment does not emit undesired RF noise.

3.2.6.3 Equipment that does not have environmental qualification may require further verification as there is an assumption it may cause EMI. The category rating specified in the environmental qualification determines the suitability of its intended installation.

Note: Additional testing beyond RTCA/DO-160 may be required following installation of equipment.

3.2.7 Victim/source testing

3.2.7.1 Victim/source testing requires observation of the behaviour of aircraft systems in a condition as close as possible to the intended operating environment. Some systems in an aircraft may not operate on ground and these may require verification during in-flight testing. Ground testing should also take into account any possible interference or reflections around the general testing area that may cause unintended results.

3.2.7.2 Interference during testing can result in false warnings of unsafe conditions. This can lead to an increased work load for the flight crew and a reduced confidence in aircraft systems. This human/machine interface issue can lead to genuine warnings and cautions being ignored.

3.2.7.3 A victim/source testing is a complementary approach and should only be considered in specific cases for which the demonstrated margins are not considered reliable or sufficient. Rigorous testing is usually based on analytical methods based on verification of emission levels or induced threats for HIRF and lightning. An EMI victim/source matrix provides a means for identifying the equipment, modes of operation and potential EMI victims.

3.2.7.4 The matrix may be populated by identifying the equipment by type or by specifying the function performed by the equipment. The approved design, aircraft records and flight manuals can assist in the identification of installed equipment. Each aircraft may require further verification depending on the installed equipment present in its configuration.

3.2.7.5 Appendix 1 of CASA AC 21-46 lists avionics equipment according CASA's standard, and provides a list of equipment that can populate a victim/source matrix. An example of a victim/source matrix for a simple aircraft is available at Appendix A.

3.2.7.6 Most mobile phones can output between 20 mW to 5 W. The transmitting power of a mobile phone is dependent on:

- traffic on the network
- distance to the nearest mobile phone tower
- any obstacles or attenuation in the signal path.

3.2.7.7 There is a likelihood of proximity to mobile phone towers during ground testing near airport locations and, under these circumstances a mobile phone is likely to output a low power signal. A mobile phone in standby mode can maintain a link to the mobile network. Mobile phones have been identified as providing false smoke detection warnings (Figure 6). In the tests provided in the example, severe interference resulted in continuous smoke detector warnings and moderate interference resulted in intermittent smoke detector warnings. It is recommended the design engineer check warning circuits, displays and other malfunction detection systems during tests. Examples of mitigation strategies are provided in Appendix A.

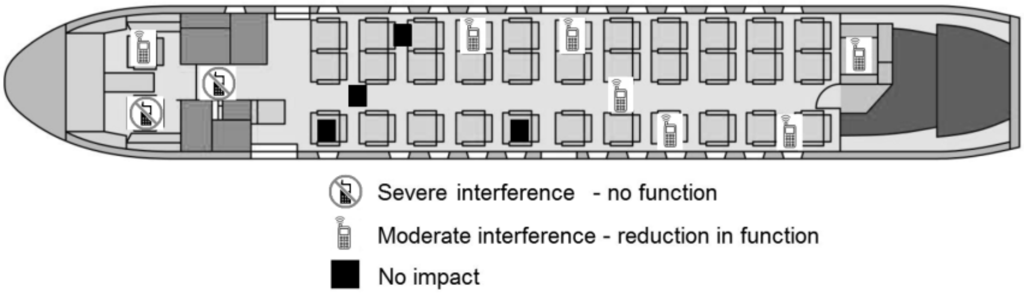

Figure 6: Example of false smoke detection identified during mobile phone testing

3.2.7.8 Bluetooth is an industry specification for short range and ad-hoc connectivity for personal devices. The Bluetooth standard is published by the Institute of Electrical and Electronics Engineers under standard 802.15.1. There are three different classes of power output ranging from 100 m down to 1 m. Wireless LAN operates on the same band between 2.4–2.485GHz.[4]

3.3 Portable electronic devices

3.3.1 A portable electronic device (PED) is any piece of lightweight, electrically powered equipment. These devices are typically consumer electronic devices that are functionally capable of communications, data processing and/or entertainment. It is assumed that the definition of PEDs also includes intentionally transmitting PEDs, as consumer electronic devices generally incorporate at least one radio technology for communication and data networking.

3.3.2 While aircraft systems are subject to Part 21 design requirements, PEDs are not assessed to this criterion. PED manufacturers do not typically perform fault mode analysis and airworthiness environmental testing on their products. Analysis is typically performed on PEDs to ensure that they operate reliably on communication networks,

[4] For analysis on Bluetooth transmitters see Mobile Architecture Lab Technology & Research Labs report on Safety Evaluation of Bluetooth Class ISM Brand Transmitters on board Commercial Aircraft.

meet market demands for customer satisfaction and meet revenue expectations. Because detailed fault mode data is unavailable for PEDs, alternative approaches are needed to consider worst-case scenarios.

3.3.3 There are four conditions under which PEDs could contribute interference to aircraft electrical and electronic systems (Figure 7):

- the PED must have RF emissions that occur at a frequency at which the aircraft system may be susceptible
- the aircraft system must be sensitive to the PED emissions at the particular frequencies of the emissions
- PED emissions must have an RF emission of a high enough field strength to exceed the appropriate susceptibility level when measured at the appropriate point
- there must be a path for the RF emissions to be radiated or conducted to the potentially susceptible aircraft system.

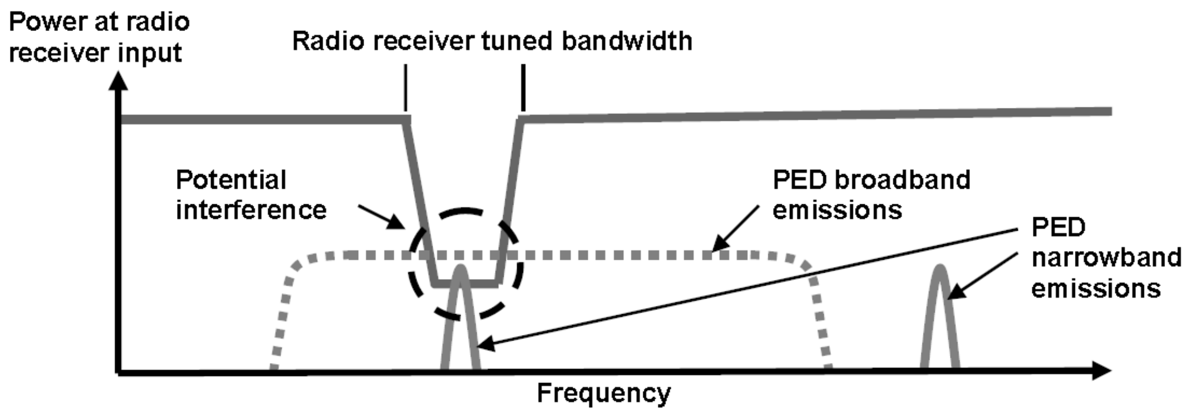

Figure 7: Potential portable electronic device emissions to aircraft systems

3.3.4 There is usually no control over variations in characteristics of PEDs, which can result in various RF output levels. Decreasing the sensitivity of aircraft radio is not an option, as decreasing aircraft receiver sensitivity will cause a decrease in effective range and performance. Operational frequencies allocated to transmitting PEDs should not interfere with aircraft receivers however unintentional spurious radiations may cause interference.

3.3.5 Commercial PED manufacturers test each of their products to ensure compliance with government telecommunications regulations mandated by ACMA. The manufacturers test for power output, modulation and frequency spectrum.

3.3.6 The results of the tests performed on each device are only valid at the time of manufacture or repair. Once a PED leaves the factory it is no longer within a controlled environment and there are no guarantees regarding its physical state or the correctness of its operation.

3.3.7 Typically, PEDs are in close proximity to aircraft systems or wiring, as they are located within the flight deck, cabin or baggage areas and potentially operate for large portions of the flight. This results in very low path loss, increasing the path loss by using shielding materials is generally considered impractical. The most viable option is to increase the RF immunity of aircraft systems. If adequate aircraft system RF immunity is established, then the aircraft system installations are tolerant of PED emissions. With the use of PEDs, the following are assumed:

- almost one third of passengers will accidently leave PEDs on during flight
- passengers will only put their PEDs into aircraft mode
- passengers who will disregard instructions to switch off mobile devices.

3.3.8 Responsibilities

3.3.8.1 There are no CASA regulations prohibiting the use of PEDs in flight. The responsibility for permitting the use of PEDs lies solely with the operator. The decision to allow the use of PEDs is based on a risk based assessment of the potential for EMI with aircraft systems.

3.3.8.2 Under subregulation 224 (2) of CAR, the pilot-in-command of an aircraft is responsible for the operation and safety of the aircraft during flight. Under regulation 309A of CAR, an operator or pilot-in-command may give instructions limiting activity on board the aircraft during flight.

3.3.8.3 The operator, or pilot-in-command, must not give an instruction unless they are satisfied on reasonable grounds that the instruction is necessary in the interests of the safety of air navigation. These instructions can require switching off any PEDs that may cause EMI with aircraft systems.

3.3.9 Assessing PEDs

3.3.9.1 The potential for PEDs to cause EMI is assessed by one of the following methods:

- evaluating potential EMI using RTCA/DO-294C
- demonstrating aircraft tolerance EMC using RTCA/DO-307: FAA AC 20-164
- conducting a safety risk assessment (see Appendix F of PED ARC Final Report).

3.3.9.2 Aircraft designed and certified after 1987 were subject to FAA and Joint Aviation Authorities (JAA) HIRF protection requirements. Therefore, these aircraft have some level of HIRF protection for systems with catastrophic, hazardous and major failure conditions, which may meet RF susceptibility requirements.

Note: Appendix C lists steps to determine the level of HIRF protection applied to an aircraft.

3.3.9.3 The FAA has published extensive guidance for operators that expands on the use of PEDs. To determine if further assessment is required see:

- FAA InFO 13010
- FAA 13010SUP
- FAA AC 91-21-1C.

3.3.9.4 If PEDs cause interference with aircraft systems during flight, the types of devices causing interference should be isolated, turned off and applicable conditions recorded. PEDs are not subject to any form of acceptable airworthiness configuration control.

3.3.10 Stowage of PEDs

3.3.10.1 Section 9 of CAO 20.16.3 requires stowage of loose articles in flight. CASA Instrument EX102/14 allows carriage of PEDs during flight provided they weigh less than 1 kg. This exemption is subject to a number of conditions as listed in the CASA Instrument, in order to avoid the risk of injury or damage.

3.3.11 On-ground usage of PEDs

3.3.11.1 Paragraph 4.2 of CAO 20.9 requires that persons on board may not use certain electrical equipment during fuelling operations while passengers are on board. The electrical equipment specified in clause 4 of Appendix to CAO 20.9 refers to electrical items that are declared or prescribed on the approval list of SAA. These electrical items are connected to a general power outlet and are not PEDs, which are categorised by other standards under ACMA.

3.3.11.2 CASA Instrument EX66/14 allows the use of mobile phones and other electronic devices inside the cabin when loading fuel.

3.3.11.3 Use of mobile phones while walking can lead to increased distraction, reduced situational awareness and increases in unsafe behaviour. CASA recommends procedures that exercise caution using mobile phones in apron areas outside of fuelling areas.

> **Note:** Studies have proven that using mobile devices while walking impacts executive brain function, working memory and influences gait to such a degree that it may compromise safety around the ramp.

3.3.12 Airborne mobile phone/internet access nodes

3.3.12.1 Dedicated access nodes allow wireless voice and/or data services to PEDs during flight. These access nodes may interface with the ability of aircraft systems to provide information such as location and altitude.

3.3.12.2 Testing of access nodes is required to demonstrate that the aircraft continues to remain airworthy. This is usually achieved by completion of a safety assessment/analysis for the system components and installation. The safety analysis should address any possible failure effects of the access nodes on the aircraft systems.

3.3.12.3 As a minimum, the following considerations should be reviewed for all access node components:

- node components should not cause interference with aircraft systems
- power management should be kept to the minimum required to provide service to the occupied spaces of the aircraft
- fire hazards
- security of aircraft systems (refer CAAP 232A-1)
- impact on crew workload for normal and abnormal access node operation.

3.3.12.4 Testing regimes should maintain an acceptable level of accuracy and repeatability. Victim/source testing is an acceptable method (paragraph 3.2.7).[5]

[5] Further guidance on certification of access node installations is detailed in Appendix 12 of RTCA/DO-294C.

3.4 Aircraft lighting

3.4.1 EMI is considered a concern for light emitting diodes (LED) and high intensity discharge (HID) lights. Unshielded wiring from the lighting system wires to lights could act as an antenna and affect other installed equipment.

3.4.2 HID lights can be a source of EMI. Installation of lighting may require ground testing and possible EMI shielding. Lighting may also require further verification for other lighting-related performance specifications and installation requirements that are not within the scope of this AC.[6]

3.5 Cargo tracking devices

3.5.1 Cargo tracking devices are usually based on mobile phone technology.

3.5.2 There are no CASA regulations prohibiting the use of cargo tracking devices. Cargo tracking devices are usually inaccessible to the flight crew during flight. It is assumed that the flight crew cannot manually turn off these devices in the event of an emergency. Therefore, cargo tracking devices may cause a hazard if they continue to operate unintentionally during flight.[7]

3.5.3 Passive radio frequency identification (RFID) systems can be installed in baggage, mail containers, cargo devices and galley carts. These are considered passive and are different to mobile phone devices, which use higher power transmissions.

3.5.4 Any safety assessment should demonstrate that any failures or malfunctions will not have greater adverse impact than minor failure criticality.[8]

3.6 Medical equipment

3.6.1 There are no CASA regulations that specifically prohibit the use of medical equipment. An operator's risk assessment and procedures need to address the security of installation and any associated unintentional interference of medical devices during aircraft operations. It is recommended that any small medical devices are secured during aircraft taxiing, take-off, approach and landing.

3.6.2 Some medical equipment may come with alerts or alarms that are not normally observed during normal operations. These functions should be evaluated to ensure there is no unintentional interference to aircraft systems.

3.6.3 The Australian Therapeutic Goods Administration (TGA) and ACMA specify acceptable standards for medical devices. Equipment that is approved to standards specified by the TGA or ACMA should come with accompanying documents from the Original Equipment Manufacturer (OEM), which detail radio frequencies of the operation and bandwidth. These frequencies require evaluation for possible EMI compared to known aircraft frequencies (paragraph 2.5). If the equipment uses Wi-Fi or Bluetooth for wireless interconnectivity, it is acceptable to use guidance in paragraph 3.3.

[6] FAA AC 23-17C provides guidance on installation of non-required lights.
[7] FAA AC 91.21-1C provides guidance on various automatic methods to switch off these devices inflight.
[8] FAA AC 20-162 provides further guidance on airworthiness approval of RFID systems.

3.6.4 Deviations from the OEM instructions, including any interconnections specified as any variation, could cause EMI and non-compliance with the TGA or ACMA accepted standard.

3.7 Verification

3.7.1 Verification that any installed equipment complies with the airworthiness design standards is met by one or more of the following methods:

- inspection or review
- analysis
- test or demonstration - ground and/or flight testing
- modelling
- service experience.

Note: The use of service history will require comparison to the requirements of similar in-service items or systems. It is possible that not all in-service history will be relevant when claiming similarity.

4 Lightning

4.1 Overview

4.1.1 Lightning strike punctures on aircraft are common. The use of software and digital electronics in aircraft components has made aircraft more susceptible to transient effects of induced electrical current and voltage caused by lightning. This chapter addresses lightning strike damage that causes latent or intermittent faults in equipment, otherwise known as indirect effects of lightning.

4.1.2 There are three types of lightning flashes:

- discharges between cloud and ground
- inter-cloud discharges
- intra-cloud discharges (over 50% of lightning flashes are intra-cloud).

4.1.3 Lightning events are usually accompanied by precipitation. Due to the location of cloud, lightning strikes are more commonly encountered by aircraft flying at less than 15,000 ft altitude. The majority of lightning strikes occur when the aircraft is climbing or descending within clouds, or in cloud that is near freezing point; due to lower breakdown voltage.

4.1.4 There have been rare occasions of aircraft being struck by lightning when there was no nearby precipitation. Piston-engine aircraft are struck more often due to the longer exposure time in the presence of storms and the plane's flight path being predominately at low or intermediate altitudes.

4.1.5 Lightning may be either a positive flash or a negative flash. Positive flashes are responsible for the highest peak current ever recorded. The positive flash usually consists of one high current strike and lacks the restrike phase typical of negative flashes.

4.2 Lightning environment in Australia

4.2.1 Lightning is the second most commonly reported weather-related incident according to the ATSB. Most of the reported lightning strikes have resulted in no reported damage or injury, and only about 10% result in an operational deviation.

4.2.2 Lightning activity is recorded from meteorological observation sites around Australia and is commonly expressed as the number of days per year when thunder is heard. These observations are backed up by data received from satellite based instruments.

4.2.3 Thunderstorms are most frequent over the northern half of Australia, with the frequency generally decreasing southward. The lowest frequencies occur in southeast Tasmania. The northern regions of Australia are prone to thunderstorms as the result of unstable atmospheric conditions caused by:

- high surface temperatures
- rapid temperature of the atmosphere with height
- convergence of airstreams
- high atmospheric moisture levels.

4.2.4 There is a secondary area with a high frequency of thunder days in southeast Queensland, through NSW and extending into north-eastern Victoria (Figure 8).[9]

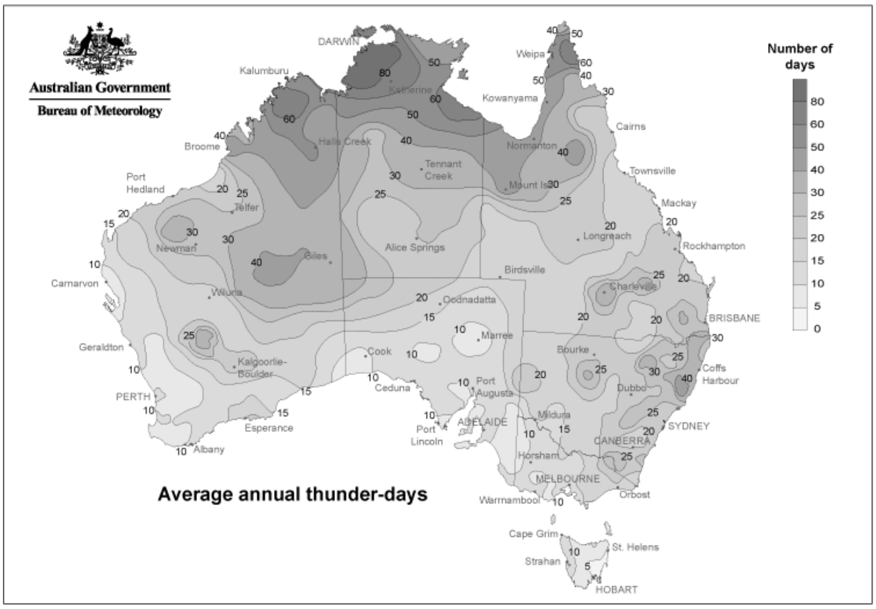

Figure 8: Lightning activity in Australia

4.2.5 Electric field effects

4.2.5.1 Aircraft in flight are assumed to have the electrical potential of the surrounding air, provided there is no deterioration to the aircraft structure, bonding, surfaces or wiring. The aircraft is conductive, the electric fields are reinforced because the airframe is an equipotential with sharp edges resulting in a compression of the electrical field lines and field reinforcement at all edges and extremities.

4.2.5.2 If the aircraft is near the start of the lightning strike (which is referred to as the leader)the increased field intensity may attract the strike towards the aircraft. When the leader advances to the point where the electric field adjacent to an aircraft extremity is approximately 30 kV/cm, the air will ionise and electrical sparks will form at the extremities and extend in the direction of the oncoming leader.

4.2.5.3 A group of several of these sparks is called a streamer. These usually occur simultaneously from several extremities and will continue to propagate outward until the electric fields drops to approximately 5 kV/cm (Figure 9). When the aircraft is attached to the leader some of the charge, in the form of free electrons, will flow a stream of energy towards the aircraft.

[9] For further information on lightning activity including current data, see the Bureau of Meteorology website.

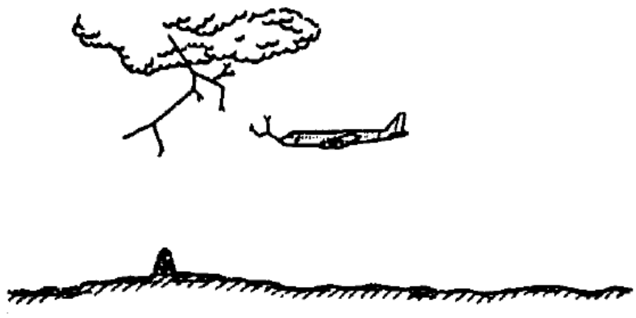

Figure 9: Aircraft interaction with a lightning leader and streamer

4.2.5.4 Lightning strikes expose equipment installed in an aircraft to electromagnetic fields. Electromagnetic fields can penetrate through windows, seams or other apertures (Figure 10).

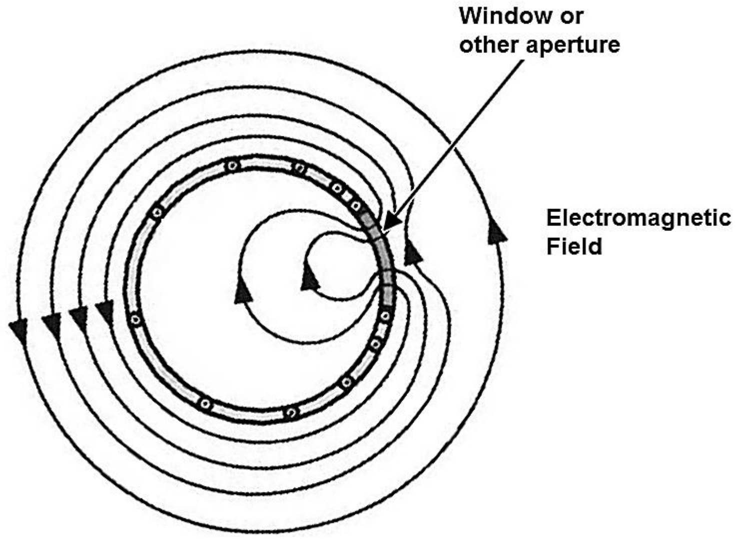

Figure 10: Propagation of an electromagnetic field through a window or other aperture

4.2.5.5 The resistance of structural joints and non-metallic structures permit voltages to occur between equipment locations in the aircraft. Sparking or arcing can occur on fasteners, causing strong currents to flow (Figure 11). This can have hazardous effects in the fuel tank area.

4.2.5.6 When lightning strikes, a significant part of the current may cross gaps between the rivet and the surrounding skin or rib. The intense energy in this small gap creates arc plasma that increases the internal pressure and blows out in the form of sparks. In the past, accidents have been linked to rivets in fuel tanks where the rivets and surrounding skin were melted away by hot lightning arc.[10]

[10] Refer to accident overview on Pan American flight 214 for further information as referenced in section 1.3.

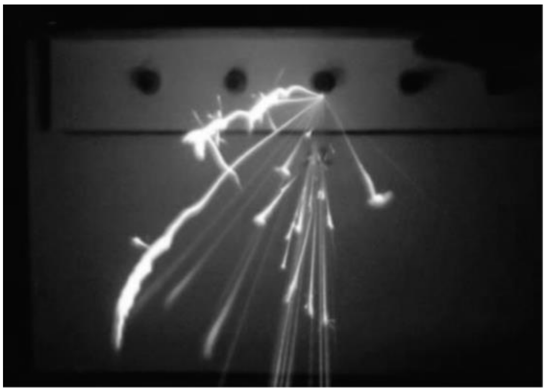

Figure 11: Sparking rivets

4.2.5.7 These voltages caused by lightning strikes may damage or upset electrical or electronic equipment. Figure 12 depicts the catastrophic failure of a surface mounted transistor fitted on a microprocessor circuit board, caused by a lightning strike.

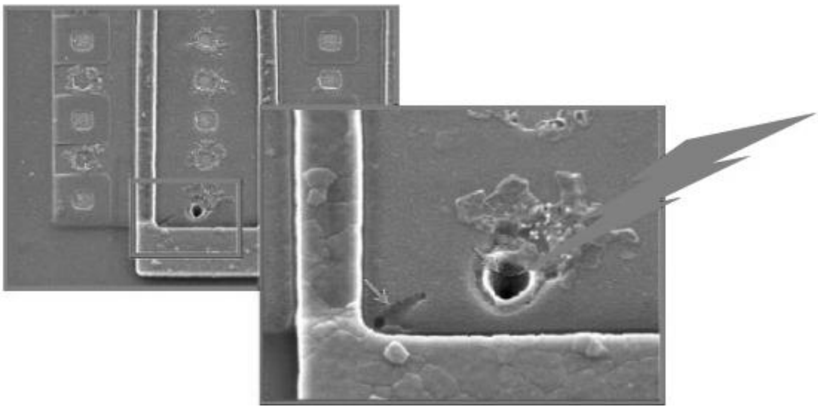

Figure 12: Microprocessor damage by the indirect effects of lightning

4.2.5.8 Potential hazards are increased by the reliance on computerised equipment, which are more prone to damage due to their lower operating voltages, and composite materials used in aircraft construction, which rely on different methods of conduction. The proximity of components and tracks in integrated circuits is also a significant factor in equipment catastrophic failure.

4.2.5.9 Since bonding and wiring extend throughout the aircraft, an issue can occur anywhere in an aircraft at some distance away from a direct lightning strike. For further information on bonding and the protection of equipment, see the approved data for the design; in the absence of this information, refer to paragraph 4.3.11.

4.2.6 Lightning strike zones

4.2.6.1 An aircraft is moving throughout the duration of a lightning strike. This movement can cause successive lightning attachment points on the aircraft (Figure 13). As a result, there are some regions on the aircraft where lightning is likely to attach, and others which are only exposed to attachment for a short duration of the lightning flash. These regions that the lightning attaches to an aircraft are called lightning zones (refer paragraph 4.2.6.3).

4.2.6.2 There are a number of factors that affect the dwell time of the attachment point, such as the aircraft speed, insulation conductivity and paint thickness.

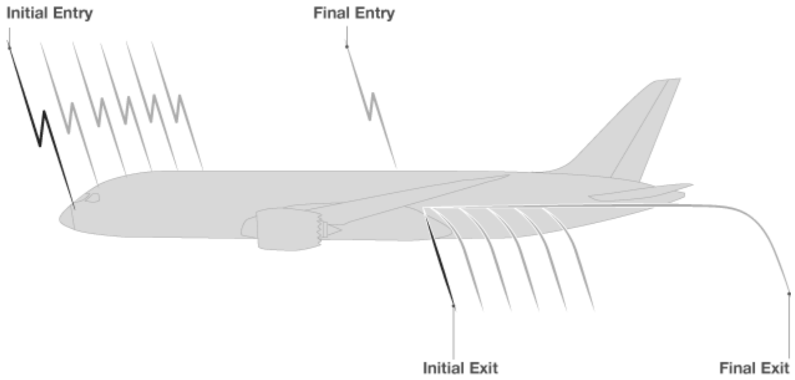

Figure 13: Leader and return stroke attachment

4.2.6.3 There are 3 major lightning zones on an aircraft (Figure 14)[11]:

- Zone 1: likely to experience initial lightning attachment and first return strokes
- Zone 2: likely to experience subsequent return stroke caused by the relative motion of the aircraft and lightning channel
- Zone 3: likely to conduct lightning current between attachment points.

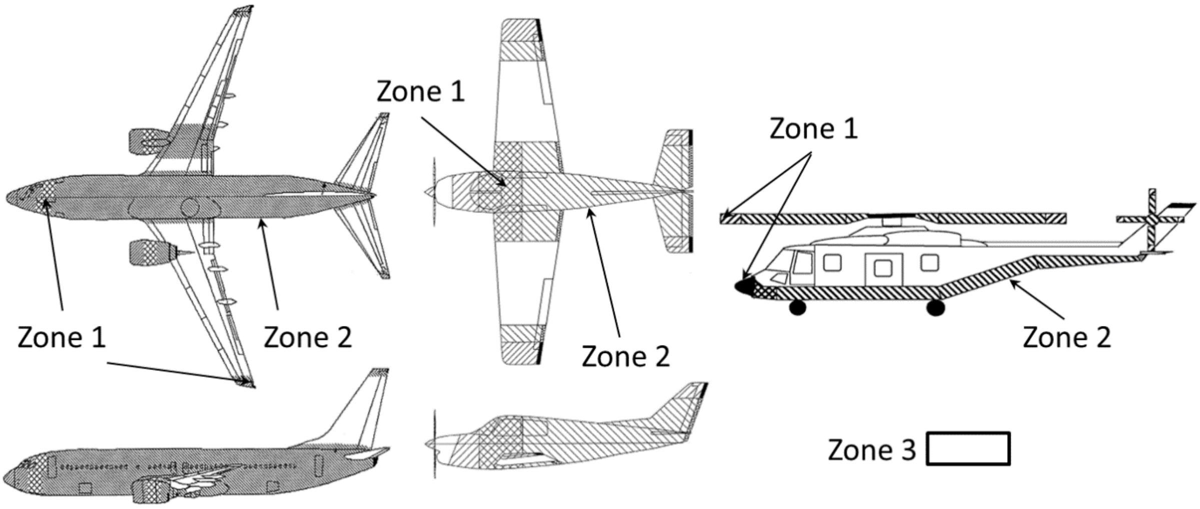

Figure 14: Examples of aircraft lightning strike zones

4.2.6.4 The amount of damage to on any dwell point or attachment point on the aircraft depends on:

- the type of aircraft skin material
- dwell time
- lightning currents
- any deterioration previously present on the aircraft surface.

[11] For further information on assessing lighting zones see SAE ARP 5414.

4.2.6.5 Indirect effects of lightning can include malfunctions such as:

- tripped circuit breakers
- computer malfunctions
- physical damage to electronic equipment.

4.2.6.6 Location of components in a lightning zone will require analysis of potential failures depending on their susceptibility to damage from lightning (see paragraph 4.3).

4.3 Lightning protection in equipment

4.3.1 Significant effects, other than what lightning strikes can generate, are magnetic field effects and capacitive changes.

4.3.2 Induced transient current and voltages can degrade electronic system performance by damaging components or malfunctions in system functions. Damage can occur by breakdown of dielectric material and effects from heat on components.

4.3.3 Function upset refers to impairment of operation that is either permanent or momentary in nature. Upsets can cause logic changes in any systems with computers or processors causing undesirable consequences.

4.3.4 Lightning can induce dynamic forces, such as pinch effect and slit effect. Metal skins or structures may also be deformed as a result of intense magnetic fields, which accompany lightning currents near attachment points.

4.3.5 Parallel wires with current travelling in the same direction are mutually attracted to each other. Lightning can draw wiring together due to dynamic forces. If a structure is not rigid enough, pinching or crimping can occur.

4.3.6 The slit effect can occur when narrow apertures are affected by lightning. If lightning strikes an aperture, there is an increase in pressure caused by a higher voltage across the aperture—the higher pressure is caused by an increase in power leading to intense heating. If the pressure across the aperture is high enough, then surrounding material can fracture or deform. One of the threats linked to the direct strike to external equipment is an internal voltage breakdown that could result in a massive current injection into system parts that would not be designed for that purpose. [12]

Note: Qualified equipment that is mounted externally is required to meet Section 23 of RTCA/DO-160.

[12] Section 22 of RTCA/DO-160 or EUROCAE/ED-14 provides procedures for dealing with lightning-induced transient susceptibility.

4.3.7 Category designation in accordance with section 22 of RTCA/DO-160 or EUROCAE/ED-14 appears on the equipment qualification as shown in Figure 15:

B	3	G	4	L	3
Pin Test Waveform Set	Pin Test Level	Cable Bundle Single and Multiple Stroke Test Waveform Set	Cable Bundle Single and Multiple Stroke Test Level	Cable Bundle Multiple Burst Test Waveform Set	Cable Bundle Multiple Burst Test Level

Figure 15: Section 22 category designation for Lightning Induced Transient Susceptibility

4.3.8 RTCA/DO-160 and EUROCAE/ED-14 provide further details on each of the designations and their applicability in an installation. Responsibility exists for authorised persons or approved design organisations under regulation 21.437 to make sure the test results satisfy the requirements of the proposed installation and the aircraft continues to meet the type design.[13]

4.3.9 Assuming that a piece of equipment has not maintained in accordance with the OEM instructions, it will still meet the original environmental qualification. Equipment that has not been qualified to acceptable standards may fail to meet any lightning-related specifications and may require further verification. A subpart 21M authorised person or 21J approved design organisations should ensure that unqualified equipment has not compromised the aircraft type certification basis by addressing the criticality of the item and safety of flight. Refer paragraph 4.4.7 for information on conducting a system safety analysis.

4.3.10 The location of equipment can have an impact on lightning protection, depending on:

- proximity to the surface of the aircraft or separation inboard
- distance to any apertures
- surrounding materials
- other proximity-related issues.

4.3.11 Interconnection and wiring of equipment will determine the degree of additional testing or analysis required. The more that unprotected wiring is used to install any equipment in addition to the aircraft type certification basis, the greater the potential for damage to occur. This interface includes any wiring, connectors, terminations and structure used in the connection of the equipment to the aircraft. In the absence of OEM data, it is recommended to use wiring practices as per AC 21-99 or FAA AC 43.13-1B.

4.4 Lightning protection in aircraft

4.4.1 The standards for aircraft electrical and electronic system lightning protection are based on the aircraft's potential for lightning exposure and the consequences of system failure. An example would be legacy aircraft that were type certified at a different amendment status, which were designed with mechanical systems or simple avionics systems. The airframe components were made from aluminium alloys that provided electrical conductivity and offered protection against lightning as long as there was no

[13] For equipment qualified to older versions of RTCA/DO-160, refer to FAA AC 21-16G for acceptance criteria.

deterioration of paint or corrosion protection, and no conductivity change as a result of corrosion.

4.4.2 Installation of new equipment into any type of aircraft may require development of a new certification basis in accordance with regulation 21.101.

4.4.3 Table 3 shows the airworthiness design standards applicable for lightning protection on various aircraft types. This table is applicable to FAA, JAR and EASA regulations and CASA highly recommend that the operator check the amendment status of the applicable airworthiness standard according to the type certificate data sheet.

Table 3: Airworthiness design standards applicable to lightning protection

Code of Federal Regulations 14CFR, Joint Aviation Requirement JAR or Certification Specification CS				
Airworthiness standard requirement	**Part 23**	**Part 25**	**Part 27**	**Part 29**
Lightning protection		25.581		
Electrical bonding and protection against static electricity	23.867	25.889	27.610	29.610
Fuel systems lightning protection	23.954	25.954	27.954	29.954
Equipment, systems and installation	23.1309	25.1309	27.1309	29.1309
Electrical and electronic system lightning protection	23.1306 Not JAR/CS	25.1316 Not JAR/CS	27.1316 Not JAR/CS	29.1316 Not JAR/CS
External loads			27.865	29.865

4.4.4 There are also lightning requirements in 14CFR 33.28 for engine electrical and electronic control systems (from amendment 33-15 in 1993). EASA has requirements for engine lightning protection in CS-E 80 and CS-E 170, released in the initial issue in 2003. CS-APU 90 has requirements for lightning protection in APU control systems, released in the initial issue in 2003.

4.4.5 FAA AC 20-136 and EASA AMC 20-136 provide guidance for FAA and EASA regulations/specifications 23.1306, 25.1316, 27.1316, and 29.1316. These regulations require lightning protection of aircraft electrical and electronic systems with catastrophic, hazardous, or major failure conditions for aircraft certificated under Parts 25 and 29. CASR Parts 23, 25, 27 and 29 mandates these requirements specified under CFR or JAR/CS.

4.4.6 The requirements also apply to Part 23 (airplanes) and Part 27 (rotorcraft) approved for operations under instrument flight rules, which are mandated under these parts. These categories that are approved solely for operations under visual flight rules require lightning protection for electrical or electronic systems that have catastrophic failure conditions.[14]

[14]Additional guidance on protection against lightning damage for external equipment and sensor installations is available in SAE ARP 5577.

4.4.7 Rotorcraft external loads

4.4.7.1 Introduced requirements for protection against EMI and lightning, so as to prevent inadvertent load release, are available in:

- Amendment 36 of 14CFR 27.865 (b) (3) (ii)
- Amendment 43 of 14CFR 29.865 (b) (3) (ii).

4.4.7.2 These requirements are more stringent when human external cargo (HEC) is being carried. Prior to these amendments, carriage of HEC was not previously addressed in the type certification basis.

4.4.7.3 Equipment for the carriage of HEC that was installed into rotorcraft before the above mentioned amendment status for the type certification basis may require re-evaluation. Failure of an external hook in HEC operations is considered hazardous, as it can prove fatal for the human cargo if the external hook releases unintentionally.

4.4.7.4 HEC requirements state the equipment must be able to absorb a minimum of 200 V/m designated as category ’Y’ RF field strength.[15] [16]

4.4.7.5 For EASA certified rotorcraft, HEC requirements were required from the initial issues of EASA CS-27 and CS-29.

4.5 Showing compliance

4.5.1 The following steps describe how an operator may comply with the requirements of 14 CFR/CS 23.1306, 25.1316, 27.1316, and 29.1316 for their aircraft’s electrical and electronic systems, in accordance with guidance material detailed in FAA AC 20-136B or EASA AMC 20-136. The operator must do the following:

a. Identify systems:
   i. identify systems to be assessed
   ii. address failures that may cause or contribute to an adverse effect on the aircraft – this should cover all aircraft operating modes, stages of flight and operating conditions
   iii. identify lightning-related failure conditions and their subsequent effect on aircraft operations and the flight crew
   iv. conduct safety assessment as per FAA ACs 23.1309-1, 25.1309-1, 27-1 or 29-2C, or EASA AMC 25.1309.

b. Determine the lightning strike zones for the aircraft as per FAA AC 20-155 or EASA AMC 20-136.

c. Establish the aircraft lightning environment for each zone.

d. Determine the lightning transient environment associated with the systems.

e. Establish equipment transient design levels (ETDLs - as determined by SAE ARP5415) and determine/specify the ETDL that defines the voltage, current and waveforms that the systems, wiring, structure and equipment must withstand without any adverse effects. The margin between the ETDLs and the actual

[15] In accordance with RTCA/DO-160G or EUROCAE/ED-14.
[16] Further guidance for this information is provided in section 27.865B of FAA AC 27-1 and FAA AC 29-2C depending on the type of rotorcraft.

transient levels (ATLs - as determined by SAE ARP5415) then must be established (see Figure 16).[17]

f. Determine the lightning transient environment associated with the systems.

g. Verify compliance to the requirements. The ETDL should exceed the ATL. Verification may be accomplished by test, analysis or demonstrating similarity.

h. Take corrective measures (if needed).

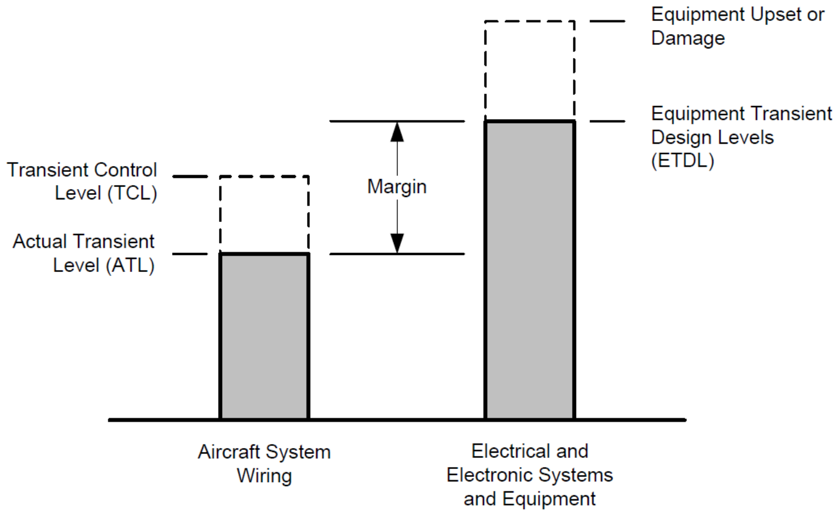

Figure 16: Margin between ETDL and ATL

4.5.2 Similarity

4.5.2.1 CASA may accept compliance demonstrated by similarity. To use similarity, the operator should assess the aircraft, wiring, and system installation differences that can adversely affect the system susceptibility. When assessing a new installation, the operator should consider differences affecting the internal lightning environment of the aircraft and its effects on the system.

4.5.2.2 Similarity can be used for credit in showing compliance only when:

- minor differences have been introduced since the previously certified aircraft and system installation
- there are no unresolved in-service history of problems related to lightning strikes for the previously certified aircraft.

[17] The ATL is the actual voltage, current and waveforms generated by the aircraft, as determined by test, analysis or similarity.

5 High intensity radiated fields

5.1 Overview

5.1.1 The electromagnetic HIRF environment results from transmission of electromagnetic energy from radar, radio, television, and other ground-based shipborne or airborne RF transmitters. This environment has the potential to adversely affect the operation of aircraft electrical and electronic systems.

5.1.2 HIRF transmitters are typically very high power transmitters in specific geographic locations, usually at some distance to the aircraft. The exposure time for HIRF is typically only for a few seconds.

5.1.3 The HIRF environment has been divided into four distinct environments. External HIRF emitters are classified in the following environments:

- airport
- non-airport ground
- shipboard
- air-to-air.

5.2 Factors for change

5.2.1 External HIRF environments did not pose a significant threat to earlier generations of aircraft. However, in the late 1970's, proposed designs for civil aircraft included flight-critical electronic controls, electronic displays, and electronic engine controls similar to those used in military aircraft. These systems are more susceptible to the adverse effects of operation in the HIRF environment.

5.2.2 Accidents and incidents involving civil aircraft with flight-critical electrical and electronic systems have highlighted the need to protect critical aircraft systems from HIRF.

5.2.3 Concern for the protection of aircraft electrical and electronic systems has increased substantially in recent years due to:

- a greater dependence on electrical and electronic systems to perform functions required for the continued safe flight and landing of 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 or processor operating speeds, higher density integrated circuits and cards, and greater sensitivities of electronic equipment
- expanded frequency usage, especially above 1 GHz
- increased severity of the HIRF environment due to an increase in the number and power of RF transmitters
- adverse effects experienced by some aircraft when exposed to HIRF.

5.2.4 In the example in Figure 17, a temporary restriction was issued for an area around Tidbinbilla ACT, where a high-powered ground-based transmitter for space communication was exceeding HIRF limits during 2 days of trial operations.

Figure 17: Example of temporary HIRF restriction

5.3 HIRF regulations

5.3.1 Since 1986, the FAA has required operators to comply with HIRF requirements. Before this, HIRF special conditions were applied to systems whose failure or malfunction would prevent continued safe flight and landing of the aircraft.

5.3.2 For European type certified aircraft, the majority of aircraft certified since 1989 have certified to JAA/EASA to meet HIRF by special conditions, which requires compliance for major, hazardous and catastrophic failure conditions.

Note: Appendix C includes a procedure to determine the level of HIRF protection that should be applied to an aircraft.

5.3.3 The FAA issued HIRF regulations under FARs Parts 23, 25, 27 and 29 in 2007. Table 4 lists applicable FAA regulations.

Table 4: HIRF airworthiness standards in FAA Parts 23, 25, 27 and 29

14CFR, JAR or CS				
Airworthiness standard requirement	**Part 23**	**Part 25**	**Part 27**	**Part 29**
HIRF Protection	23.1308	25.1317	27.1317	29.1317
Equipment systems and installations	23.1309	25.1309	27.1309	29.1309

5.3.4 EASA has only amended the certification specification to introduce HIRF requirements into regulation 25.1316 (introduced in JAR-25 Change 15). EASA relies upon certification review items to introduce special conditions and interpretative material based on JAA INT POLs 23/1, 23/3, 25/2, 25/4, 27 and 29/1. [18]

[18] Referring to the draft JAA NPAs, AMJ 20.1317 and EUROCAE Documents ED-81, ED-84, ED-91. EASA is in the process of updating the certification specifications.

5.4 Showing compliance

5.4.1 The following activities are established steps for HIRF certification as per FAA AC 20-158A or EASA AMC 20-158:

- identify the systems requiring HIRF assessment
- establish the applicable aircraft external HIRF environment (see Appendix B)
- establish the test environment for installed systems
- apply the appropriate method for HIRF compliance verification
- verify HIRF protection effectiveness.

Note: Further information is provided in industry standard documentation SAE ARP 5583A/EUROCAE ED-107A.

5.4.2 HIRF compliance plan

5.4.2.1 The HIRF compliance plan should be discussed with, and submitted to, either CASA, an authorised person or an approved design organisation (ADO) for approval before initiating HIRF compliance activities.

5.4.2.2 If the aircraft, system, or installation design is modified after approval, a revised HIRF compliance plan should be submitted for re-approval (to CASA, an authorised person or an ADO). 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
- HIRF environment for the aircraft and installed systems
- verification methods (i.e. test, analysis, or similarity).

5.4.2.3 Test, analysis and similarity in HIRF compliance are all acceptable approval methods that can be used in preparing an HIRF compliance plan.

5.4.3 Similarity

5.4.3.1 Similarity reports should document the aircraft, equipment and installation features that remain unchanged between the previously certified system and the proposed installation.

5.4.3.2 The operator must identify all significant differences encountered, along with an assessment of the impact of these differences on HIRF compliance.

5.4.3.3 Similarity may be used as the basis for system-level verification without the need for additional integrated system testing, provided there are no unresolved in-service HIRF problems related to the previously certified system.

5.4.3.4 If there is uncertainty about the effects of the differences, then additional tests and analyses should be conducted by subpart 21M authorised persons or subpart 21J approved design organisations as necessary and appropriate to resolve the uncertainty. The extent of additional testing should be commensurate with the degree of difference identified between the proposed new system and the system previously certified.

Appendix A

Victim/source testing

A.1 Victim/source test

A.1.1 Plan conditions

A.1.1.1 The scope of the victim/source test plan should be defined such documents as:

- the aircraft type certification basis
- subsequent modification
- alteration (as per engineering drawings, aircraft flight manuals or aircraft records).

Note: Appendix 1 of AC 21-46 contains a detailed list of avionics equipment and their relevant standards.

A.1.1.2 The aircraft ground test should represent as close to flight conditions as practical. A comprehensive ground test may reduce or eliminate the requirements to conduct a flight test. A check flight may be required if the equipment or function is not operable on ground (e.g. weight on wheels function).

A.1.1.3 Acceptable requirements for a test plan are:

- The victim/source test plan should specify the relevant test conditions and assumptions for conducting the test. The operator must identify any prerequisite or aircraft preconditioning for conducting the test.
- Select test conditions on the basis of establishing a test environment that will reasonably likely reveal any EMI.
- Verify the correct functioning of all the electrical and electronic equipment before commencing the victim/source test.
- Close aircraft doors and windows during the victim source testing. This is to provide the similar conditions of apertures that are representative of the aircraft in flight.
- Close all normally closed circuit breakers that are representative of inflight condition.
- Avoid using ground support equipment (where practical) to provide a realistic operating environment as possible.
- During the victim/source test use:
  - the aircraft engine(s)
  - auxiliary power unit(s) (when installed)
  - aircraft electrical systems
  - aircraft hydraulic power systems
  - any installed aircraft environmental control systems.

  Note: Ground power units may have poor output quality which can affect tests.
- The normal practice for communication and navigation equipment is to select three test frequencies:
  - one at the lower end
  - one at mid-range
  - one at the higher end of the operating range.
- Use additional test frequencies where there are potential susceptibility issues (refer paragraph 2.5) for aircraft avionics systems frequency spectrum, emergency frequencies (e.g. 121.5 MHz, 406 MHz) and where harmonic components are known to exist.
- Aircraft control settings should be in positions that are representative of inflight conditions (where practical).

– Locate the site for conducting victim/source test away from large reflecting surfaces such as buildings or other aircraft.

A.1.2 Victim/source testing equipment

A.1.2.1 The operator should identify all test equipment required for the purpose of the victim/source test. This includes:

- any ramp equipment
- test setup
- stands
- any lighting required
- specialised equipment
- any commercial testing equipment.

A.1.2.2 The operator should identify equipment considered as EMI source and EMI victim. The use of a tailored matrix specific to the actual aircraft configuration to assist testing and record results is recommended (Table 5).

A.1.2.3 It is possible that equipment is both a victim and a potential source EMI. It is recommended that the operator list equipment by ATA chapter number (or in the same manner the OEM uses) to provide a cross references to various operational tests in the aircraft maintenance manual.

Note: Engineering judgement can reduce the number of source/victim pairs when conducting a test.

Table 5: Example of a victim/source matrix

	Victims					
	A ATA 22	B ATA 23	C ATA 31	D ATA 34	E ATA 73	F ATA 77
Sources						
Equipment A	N/A					
• Function 1 in equipment A	N/A					
• Function 2 in equipment A	N/A					
• Function 3 in equipment A etc.	N/A					
Equipment B		N/A				
Equipment C			N/A			
Equipment D				N/A		
Equipment E					N/A	
Equipment F						N/A

A.1.2.4 To determine that no significant conducted or radiated interference exists, the operator must individually operate, switch on/off, cycle or exercise each electrically operated piece of equipment and system identified in the plan.

A.1.2.5 The operator must record results of operation during the test, including:

- successful operation
- upsets
- circuit breaker disconnection
- changes in state
- autopilot disconnect (if fitted)
- warning/caution/status annunciations
- flags or any failure.

A.1.3 Victim/source test report

A.1.3.1 The victim/source test report should detail the following:

- details of personnel who carried out the test
- equipment used
- environmental conditions

- test location
- date
- aircraft registration
- aircraft serial number.

Note: CASA can request this report in accordance with regulation 21.455.

A.1.3.2 The operator must provide an assessment of the results, evaluated with respect to the:

- criticality of function performed by the equipment
- pilot workload i.e. does the equipment recover automatically or is pilot action required?
- possible phase of flight that EMI could occur—problems identified on the ground may behave differently inflight
- severity of effects—whether there is nuisance or misleading information presented to the pilot
- presence of any other factors considered relevant to the safe operation of the aircraft
- EMI found to pose an adverse effect will require possible corrective action and retesting (corrective action is not always practical). Appropriate mitigation can include:
  - aircraft flight manual revision
  - prohibition during certain phases of flight
  - placarding, or other CASA acceptable methods.

Note: A re-engineering solution is preferable to flight operations procedures.

Appendix B

HIRF environments

B.1 Certification - HIRF environment I

B.1.1 Emitter databases from the United States together with designated minimum distances were used to calculate the values of field strengths for the various operating environments. The average field strength is based on the maximum average field strength (peak output power of the transmitter times the maximum duty cycle times the antenna gain) for the frequency range. All the measurements or calculations of the field strength were derived from power density then converted to linear volts per metre.

B.1.2 Certification HIRF environment I serve as test and/or analysis levels to demonstrate that the aircraft and its systems meet the certification requirements (Table 6).

Table 6: Certification HIRF environment I

Frequency		Field strength (linear volts per metre)	
Lower limit	**Upper limit**	**Peak**	**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	2000	200
2 GHz	6 GHz	3000	200
6 GHz	8 GHz	1000	200
8 GHz	12 GHz	3000	300
12 GHz	18 GHz	2000	200
18 GHz	40 GHz	600	200

B.2 Normal - HIRF environment II

B.2.1 The normal HIRF environment is the electromagnetic field strength level in the airspace on and about airports in which routine departure and arrival operations take place. It does not include the shipboard or air to air intercept environments and Table 7 includes the frequency ranges and field strength values in volts per meter.

Table 7: Normal HIRF environment II

Frequency		Field strength (Volts per metre)	
Lower limit	**Upper limit**	**Peak**	**Average**
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
400 MHz	1 GHz	700	40
1 GHz	2 GHz	1300	160
2 GHz	4 GHz	3000	120
4 GHz	6 GHz	3000	160
6 GHz	8 GHz	400	170
8 GHz	12 GHz	1230	230
12 GHz	18 GHz	730	190
18 GHz	40 GHz	600	150

B.3 Rotorcraft severe - HIRF environment III

B.3.1 The rotorcraft severe HIRF environment is derived from a worst case estimate of the electromagnetic field strength levels in the airspace in which rotorcraft flight operations are permitted (Table 8). Environment III was established to allow rotorcraft to fly and hover closer to obstacles and the ground during operations.

Table 8: Rotorcraft severe HIRF environment III

Frequency		Field strength (Volts per metre)	
Lower limit	**Upper limit**	**Peak**	**Average**
10 kHz	100 kHz	150	150
10 0kHz	400 MHz	200	200
400 MHz	700 MHz	730	200
700 MHz	1 GHz	1400	240
1 GHz	2 GHz	5000	250
2 GHz	4 GHz	6000	490
4 GHz	6 GHz	7200	400
6 GHz	8 GHz	1100	170
8 GHz	12 GHz	5000	330
12 GHz	18 GHz	2000	330
18 GHz	40 GHz	1000	420

Appendix C

Level of HIRF protection

C.1 Level of HIRF protection

The following procedure may assist the operator to determine the level of HIRF protection applied to an aircraft:

1. Find the Type Certificate Data Sheet (TCDS) for the make and model of aircraft being assessed.

2. Check the type certification basis for the aircraft make and model. Does the certification basis include Amendment Nos. 23-57, 25-122, 27-42 or 29-49?

> YES – The aircraft incorporates the necessary HIRF certification levels. No further review is necessary unless the aircraft has been modified or repaired and the possibility exists that it no longer complies with the above amendment.
>
> NO – Proceed to step 3.

3. Search the TCDS for HIRF special conditions.

Is there an HIRF special condition listed for the make and model?

> YES – Record the number of the special condition. Review the special condition to ensure it covers electrical and electronic systems. If it does, proceed to step 6. If not, proceed to step 5.
>
> NO – Proceed to step 4.

4. Is there a HIRF special condition applicable to aircraft electrical and electronic systems for the make and model of aircraft?

> YES – Record the number of the special condition and return to the TCDS for your make and model. Search the TCDS to verify that the special condition is listed for your aircraft. If it is, proceed to step 6.
>
> NO – Proceed to step 5.

5. Is there a HIRF special condition applicable to a specific critical electrical or electronic system on the make and model of aircraft?

> YES – Record the number(s) of the special condition(s), and the system(s) covered. Proceed to step 6.
>
> NO – Proceed to step 7.

6. Review the critical aircraft systems to determine if any electrical or electronic system(s) was type-certificated with a Hazard Class (failure condition) of ‘Catastrophic’.

Does a special condition cover the critical system(s)?

> YES – The critical systems are adequately covered for PED tolerance to back-door interference. No further review is necessary unless the aircraft has been modified or repaired and the possibility exists that it no longer complies with the above amendment.
>
> NO – Proceed to step 7.

7. The critical systems for the aircraft cannot be determined to be PED tolerant to back-door interference based on HIRF certification. Testing and analysis for critical systems (those certified with a catastrophic failure effect) to ensure PED tolerance to back-door interference must be (or have been) accomplished.