Regulations regarding civil aviation EMC

1. International Regulations

Modern aircraft are subject to mandatory safety rules to ensure these complex machines pose minimal risk to crew, passengers, as well as the people and property around them. These rules apply in different stages that describe the certification process as the aircraft is designed, manufactured, and operated over its life. Certification refers to some accepted form of proof that these rules have been followed. So far, on a global level, the International Electrotechnical Commission (IEC) does not have any standards about certification of civil aviation that centers on electromagnetic compatibility (EMC), nor has it defined specific regulations for airport environments, but some IEC standards are closely related to aviation EMC. In terms of electromagnetic environment, the IEC standard 61000-6-4: *Generic standards - Emission standard for industrial environments* considers high-voltage areas of airports as industrial locations [1]. While in the IEC standard 61000-6-8: *Generic standards - Emission standard for professional equipment in commercial and light-industrial locations*, public areas of an airport are classified as commercial or light-industrial environments [2]. In addition, the IEC 61000-4 series contain EMC testing (radiated emission, ESD, etc) and measurement methods that can be applied to electric aircraft.

Furthermore, the Comité International Spécial des Perturbations Radioélectriques (CISPR), which is within the IEC framework, has published standards such as CISPR 11: *Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement* and CISPR 32: *Electromagnetic compatibility of multimedia equipment - Emission requirements* that can be applied to airborne equipment [3][4]. The CISPR standard defines two classes of equipment, namely class A (not suitable for residential environments) and class B (suitable for residential environments). Since the classification of airports is still hanging, the classification of charging equipment for electric aircraft requires further clarification. Both IEC and CISPR standards are not specifically for airplanes, but they will certainly be the basis of future regulations regarding the EMC of electric aircraft and their charging infrastructure.

2. USA Regulations

From a continental and national level, efforts have been made in terms of aviation certification. In USA, the Federal Aviation Administration (FAA) oversees the four main types of certifications for aircraft and aircraft operations as follows: 1. A type certificate (TC) ensures that an aircraft design conforms to the appropriate airworthiness rules. 2. A production certificate approves the manufacturing process to produce an aircraft as per the approved design. 3. An airworthiness certificate is required to ensure the aircraft enters service, and 4. a continued airworthiness certification to ensure that the aircraft can be operated throughout its life [5]. According to FAA, fixed-wing aircraft under 19,500 pounds and a passenger seating configuration of 19 or less are certified under Part 23 of the Code of Federal Regulations (CFR). Small Rotorcraft (i.e., helicopters) are certified according to Part 27 airworthiness

standards. Aircraft certifying under Part 23 or Part 27 must also comply with Part 33 (Engine) and Part 35 (Propeller) certification requirements as applicable. The certification framework of electric aircraft shares both Part 23 and 27. The general rule is if the electric aircraft flies most of its flight profile in wing-born lift, Part 23 will probably apply; if the aircraft flies its whole flight under thrust, then Part 27 applies [6].

When it comes to EMC, the FAA has published AC 20-190 - *Aircraft Electromagnetic Compatibility Certification* as recommended practices for showing compliance pursuant to Part 14 of CFR, which prescribes airworthiness standards for the issue of type certificates and changes to those certificates, for aircraft engines [7]. The AC 20-190 describes guidelines to demonstrate that aircraft electrical and electronic systems are not adversely affected by electromagnetic emissions from other electrical and electronic systems onboard the aircraft. It should be pointed out that AC 20-190 is not mandatory and does not constitute a regulation. For electric aircraft, special conditions are developed by FAA mainly using technical criteria from ASTM F3338–18: *Standard Specification for Design of Electric Propulsion Units for General Aviation Aircraft* as well as product information provided by aircraft manufacturers [8]. These special conditions establish a level of safety that is equivalent to the level of safety required by Part 33 of CFR.

3. European Regulations

In Europe, since 2003, The European Union Aviation Safety Agency (EASA) is responsible for the certification of aircraft in the EU and for some European non-EU Countries. In 2018, the Regulation (EU) 2018/1139 was published as the Basic Regulation to establish the EASA as regulatory organization as well as common rules of civil aviation [9]. The certification process contains four steps: 1. Technical familiarization and certification basis. 2. Establishment of the certification programme. 3. Compliance demonstration. 4. Technical closure and issue of approval [10].

In 2012, the European Commission released Regulation (EU) 748/2012 on rules to attain an initial airworthiness and environmental certification of aircraft including products and parts as well as the certification of design and production organizations [11]. An important part of 748/2012 is the Annex I, Part-21, which is divided into Section A – Technical Requirements and Section B – Procedures for Competent Authorities. Section A is organized into several subparts whereas Subpart B describes the actions to gain a Type Certification (TC) or a restricted TC for the aircraft. A valid TC or restricted TC is necessary to operate the aircraft in civil airspace. To obtain a TC, the manufacturer has, amongst other things, to comply with the applicable Certification Specification for the aircraft type. There are several Certification Specifications available such as the CS-25 for large airplanes and the CS-23 for Normal-Category airplanes [12][13].

The EASA mainly deals with general rules of safety, while another organization, the European Organization for Civil Aviation Equipment (EUROCAE), deals exclusively with aviation standardization, for both airborne and ground systems and equipment. EUROCAE documents are widely referenced by EASA as means of compliance to European Technical Standard

Table 1 Sections in EUROCAE ED-14G that concerns EMC

Section	Test
15	Magnetic Effect
16	Power Input
17	Voltage Spike
18	Audio Frequency Conducted Susceptibility – Power Inputs
19	Induced Signal Susceptibility
20	Radio Frequency Susceptibility (Radiated and Conducted)
21	Emission of Radio Frequency Energy
22	Lightning Induced Transient Susceptibility
23	Lightning Direct Effects
25	Electrostatic Discharge (ESD)

Orders (ETSOs) and other regulatory documents. The EUROCAE ED-14G defines a comprehensive standard environmental test conditions (categories) and applicable test procedures for airborne equipment [14]. The purpose is to provide a laboratory means of determining the performance of airborne equipment in scenarios that represent real conditions. The document contains 26 sections and covers most environmental factors, such as vibration, humidity and sand, that might cause an avionics component to falter or fail. Table 1 lists the sections that concerns EMC.

Under the framework of ED-14G, there are two other standards that are dedicated to EMC. The EUROCAE ED-248 provides guidance and test methods for electrical and electronic systems on civil aircraft [15]. It considers both conducted and radiated emissions generated by installed systems on an airplane and it does not cover interactions with external electromagnetic environments such as high-intensity radiated fields (HIRF) and lightning. The other standard is EUROCAE ED-90B [16], which is basically an extension of Sections 20 and 21 of ED-14G, providing additional information as well as clarification on test procedures. When it comes to RF tests, ED-14G should be read in conjunction with ED-90B.

Besides EASA and EUROCAE, the European Committee for Electrotechnical Standardization (CENELEC) also involved in aircraft EMC. Their report CLC(SG)819 Ed.5 digs into how aircraft safety is addressed and how aircraft interacts with EMC environments [17]. It provides detailed information on aircraft certification process and EMC requirements. As for EMC tests, CENELEC follows technical specifications in EUROCAE ED-14. The EN 50081-2 (now withdrawn): *Electromagnetic compatibility - Generic emission standard - Part 2: Industrial environment* is also taken into account as a comparison [18].

In conclusion, both Europe and North America have developed regulations on aircraft certification, some involve EMC. The published standards, although not identical, are similar in certification process. The test items and procedures have already been defined in CISPR standards. However, all aforementioned regulations and reports only consider planes that use fossil fuel. Therefore, EMC of electric aircraft and their charging stations still requires more research in the future and previous studies on traditional planes can certainly serve as references.

Acknowledgements

This work performed as part of the project “Test track for eVTOL”, funded by the Swedish Energy Agency, decision 2021-016037.

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