

# ER-028

## SURVEY OF RADIO FREQUENCY (RF) PERFORMANCE STANDARDS FOR AERONAUTICAL RF SYSTEMS

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## FOREWORD

1. This document was developed jointly by EUROCAE Working Group 124 “Spectrum” and RTCA SC-242 ‘Spectrum Compatibility’ and approved by EUROCAE WG-124 on October 24, 2023 and approved by the RTCA Program Management Committee (PMC) on November 17, 2023.
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## EXECUTIVE SUMMARY

This report summarizes the results of the 2022/2023 survey conducted jointly by RTCA Special Committee-242 and EUROCAE Working Group-124 (SC-242/WG-124) on the applicable RTCA and EUROCAE published standards for Radio Frequency (RF) performance that could be used for spectrum compatibility analysis with external systems. The process involved existing RTCA Special Committees and EUROCAE Working Groups, plus additional experts if the responsible committees for certain documents were no longer active. The surveys and the resulting questions raised are intended to inform the spectrum guidance document that RTCA and EUROCAE are developing, and therefore this report does not provide any guidance of its own for the development of future aviation standards.

The results of the survey found significant variation in the level and use of RF performance parameters across different systems, with older documents generally having fewer parameters. However, even the documents with the most complete RF performance characteristics would still likely require manufacturer support to ensure all necessary considerations were captured in a spectrum study. In reviewing these survey responses and producing a high-level summary for each document, many questions were raised. These questions address both system specific items and policy considerations for standards development.

It is important to recognize that to date, the purpose of RTCA and EUROCAE standards has been to provide functional and operational performance requirements in order to ensure that equipment meets its intended function. In some cases this includes the need to function in the presence of RF in adjacent bands, when those emissions could affect the intended function of the aviation equipment. In other cases, the authors may have made a determination that there was no specific need to address spectrum compatibility at the time the standard was written, and further, the authors naturally could not have anticipated all future changes to the spectrum environment. Therefore, in this report which benefits from hindsight, comments that a standard lacks RF performance requirements should not be taken as a judgement on any document's quality at the time it was written. The intent of SC-242/WG-124 is to follow this report with an additional guidance document for future RTCA/EUROCAE committees, so that future standard revisions and new standards can have a more complete set of RF compatibility requirements that are forward-looking to the extent practical.

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## CHAPTER 1

### INTRODUCTION

The aviation industry is a global, mobility-based industry by its very nature, generally requiring harmonized wireless Communications, Navigation and Surveillance (CNS) applications to operate worldwide. More fundamentally, these and all other wireless technologies are dependent on access to sufficient, suitable, and appropriately protected radio frequency (RF) spectrum to maintain the required performance. RF spectrum is a scarce resource that has a limited capacity but a high level of demand that is increasing, and access to it is a critical requirement for a safe and effective global aviation industry. To maintain access to sufficient, suitable, and appropriately protected spectrum, the aviation industry must demonstrate to spectrum regulators that it is using this resource effectively and considering coexistence with other spectrum users.

Spectrum efficiency is becoming a leading consideration, and even a risk, during the process of system design and specification. RTCA and EUROCAE Minimum Aviation System Performance Standards (MASPS) and Minimum Operational Performance Standards (MOPS) are the basis for defining much of the RF performance of standardized aviation systems, yet these documents are primarily intended for system manufacturers to design, build, and certify aviation systems<sup>1</sup>, and not for spectrum compatibility assessments with other wireless systems. Yet, that is exactly the purpose for which aviation standards are frequently used in modern spectrum management processes in national and international proceedings.

Current system standards, that were designed with operational purposes in mind, will need to evolve to address spectrum compatibility analysis and policy decisions. Therefore, before building any future guidance that addresses new spectrum compatibility requirements for MASPS and MOPS, current RTCA/ EUROCAE aeronautical standards must be reviewed to determine a baseline for spectrum considerations. To perform this review, RTCA Special Committee-242 and EUROCAE Working Group-124 (SC-242/WG-124) jointly conducted a survey of current RTCA/ EUROCAE aeronautical standards. This report documents RF performance in current standards and identifies variations in how such performance is documented. The elements raised in this report will help develop a new guidance document to be used for the development of new or revised RTCA/EUROCAE standards for aviation wireless systems. It is intended that such work will improve aeronautical standards and ensure that aviation is better prepared for a more challenging RF spectrum environment.

#### 1.1 PURPOSE AND SCOPE OF THE REPORT

This report collects relevant information (e.g., minimum performance requirements) on current RTCA/EUROCAE aeronautical standards for aviation wireless systems and identifies variations in how such performance is documented. It is not intended to be a critical assessment of Special Committee (SC)/Working Group (WG) products or a compliance review to identify any corrections to existing RTCA/EUROCAE documents. Any trends identified as gaps in RF performance characteristics, or examples of spectrum best practice, are summarized. While this report does not propose solutions to any issues found during the course of the SC-242/WG-124 survey, the report will be considered during the development of the subsequent work by SC-242/WG-124 in developing a new document on Spectrum Guidance for the Developers of Standards for Aviation Wireless Systems.

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<sup>1</sup> Noting that in many cases the ground or satellite component of systems do not have a corresponding MASPS/MOPS.

## CHAPTER 2

### BACKGROUND

#### 2.1 THE RF SPECTRUM RESOURCE

The RF spectrum is a finite range of frequencies that provides an essential resource to all wireless applications. If a wireless application is not able to access the RF spectrum, it cannot operate. Specific frequency ranges are “allocated” to certain applications within the RF spectrum in order to balance access across the multiple users to allow those applications to be planned in a coordinated manner that enables operations at a certain level of performance. This spectrum management process is undertaken by radio regulators in consultation with other stakeholders to ensure all wireless applications can be authorized to operate in their respective frequency allocations and manage the impact to other in-band and adjacent band users of the spectrum. Much like land zoning, there are multiple users with different requirements, such as aeronautical/maritime, satellite/terrestrial, safety/non-safety, high-power/low-power, etc. Therefore, the range of different services that are formally allocated between 9 kHz and 275 GHz is extensive, with many frequency bands sharing multiple users for different allocation types.

Further complicating the management of spectrum are the different spaces of wireless technology development. With only a finite amount of spectrum to use, the growth of commercial and other wireless applications has led to the repurposing of existing spectrum. This has been driven by increased wireless demand and technology development, not necessarily by the incumbents' own timeline. The competing demands creates a high-pressure environment between users vying for spectrum to maintain or grow their applications, where spectrum performance and usage are scrutinized for improvements or removal by national regulators before potentially changing or limiting spectrum allocations.

Any assessment for a change to spectrum allocations first requires the RF performance and system characteristics to be known for each system involved. For aviation systems, RTCA/EUROCAE standards, in conjunction with ICAO Standards and Recommended Practices (SARPs), have become essential to conducting these RF system assessments as they are often the only source of detailed technical RF information. In recognition that these documents were created primarily to define system operational performance requirements to support aviation certification, RTCA/EUROCAE created SC-242/WG-124 to investigate how to develop spectrum guidance for future RTCA and EUROCAE standards.

#### 2.2 RF SPECTRUM MANAGEMENT

RF spectrum is managed at the international level by the International Telecommunications Union (ITU), a United Nations (UN) agency. Spectrum rules are implemented through the ITU Radio Regulations (RR), a UN treaty level document that specifies global and regional spectrum frequency allocations, restrictions, co-ordination procedures, high-level technical requirements, and monitoring/interference resolution. It is amended every 3-5 years during the World Radio Conference (WRC) based on work carried out within the relevant ITU Radiocommunication Sector (ITU-R) Study Groups and Working Parties against a set agenda that is defined by the previous WRC. The results of a WRC are then adopted by all countries into their national radio regulatory regime.

International aviation coordinates its needs and approach to the WRC through the International Civil Aviation Organization (ICAO), also a UN agency, by providing high-level positions and updates on aviation system development for the relevant WRC agenda items or specific requests for future work of the WRC. The ICAO position is often supported by national, regional, and even individual aviation organizations at the WRC. See [FIGURE 2-1](#) for an organizational overview of spectrum management relationships.

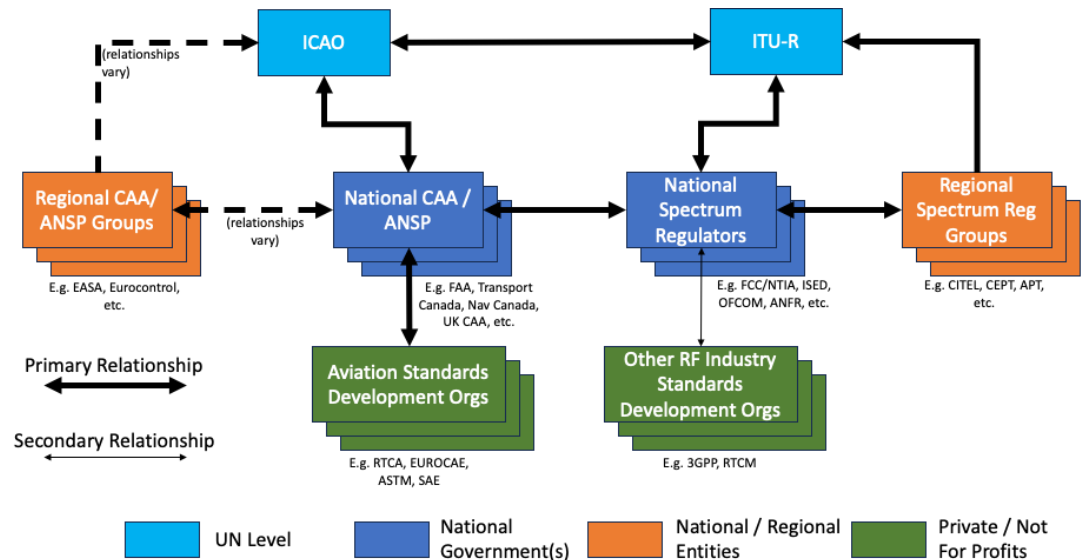


**FIGURE 2-1: ORGANIZATIONAL OVERVIEW OF WORLDWIDE SPECTRUM MANAGEMENT RELATIONSHIPS TO AVIATION AND STANDARDS DEVELOPMENT**

At the individual state level, national radio regulators are responsible for implementing spectrum allocations and policy, creating the necessary regulations to allow ITU-created allocations to operate. National radio regulators can also implement their own nation-specific allocations depending on their state's requirements and specific licensing conditions of Article 4.4 of the ITU Radio Regulations<sup>2</sup>. Many national radio regulators have a strong mandate to make the best use of the limited spectrum resource, attempting to maximize usage by more tightly packing users or implementing more advanced spectrum sharing techniques and processes. Given RF emissions do not stop at national borders, many States also implement regional or bi-lateral agreements to coordinate and harmonize usage. National aviation entities often participate in these proceedings.

## 2.3

### AVIATION STANDARDS AND THEIR ROLE IN SPECTRUM MANAGEMENT

Aviation standards, particularly those produced by industry standard development organizations (SDOs) such as RTCA and EUROCAE, are intended to be referenced by aviation regulatory documents for system manufacturers to design to and obtain airworthiness certification. At the same time, they are often the only or best source of detailed technical information for the RF performance characteristics of aviation systems. This has naturally meant that these documents are increasingly used and referenced in spectrum proceedings, despite most not having been written for that purpose. Therefore, in surveying MASPS and MOPS<sup>3</sup> for a more comprehensive approach to spectrum management, they may not provide all the needed RF performance characteristics or, in some cases, could mislead one to use RF performance characteristics that were not specified for such purpose. A parallel can also be made to ICAO Annex 10 to the Convention on International Civil Aviation, Aeronautical Telecommunications, SARPs, which are primarily intended for aviation system interoperability. This can often cause confusion when used for external regulator spectrum analysis, as the context of a particular RF performance characteristic may not be fully described. For example, a specified interference limit is only there to protect from harmful interference between aviation systems and is not necessarily intended as a protection criterion against all possible external sources of RF interference. In many cases with aviation standards, RF performance characteristics

<sup>2</sup> ITU Radio Regulations, Article 4.4., 2020 Edition: "Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations."

<sup>3</sup> Noting that these are minimum standards, and it may be necessary to exceed minimum requirements to satisfy all current and/or future situations.

are specified assuming that aviation has exclusive access to the relevant frequency band and that external interference from non-aviation sources from adjacent frequency bands will have been reduced to the point where it is not an issue for aviation. This is becoming less and less the case given the high demand for spectrum.

## 2.4 AVIATION SAFETY CONSIDERATIONS FOR SPECTRUM

Aviation has specific spectrum requirements, which provide a high assurance of safety, global harmonization of usage, and use of mobile platforms that can operate anywhere, anytime and in four-dimensional trajectory operations. Aircraft, their avionics, and the associated ground systems also have a long operational life cycle (30+ years) and a significant regulatory process for any system change in order to meet the necessary operational assurance. Combining these considerations together results in high standards for technical and operational requirements, and any change in system performance needed to be compatible with spectrum repurposing will therefore result in high cost and a lengthy design process. Such requirement levels are orders of magnitude higher than what many other industries and applications would need to consider. However, maintaining these performance levels has ensured the decreasing accident rate and safety record that the public demands and that modern aviation has demonstrated over the last several decades.<sup>4</sup>

## 2.5 CONCURRENT AVIATION ACTIVITY

Two ICAO groups are also reviewing current aviation spectrum processes. Their activities are summarized below:

### 2.5.1 ICAO Integrated Communications, Navigation, Surveillance, and Spectrum Task Force (ICNSS TF)

The ICNSS TF is studying CNS system elements and spectrum usage, in the short, medium, and long term. One aim of this ICAO study is to evolve the CNS systems roadmap and frequency spectrum access strategy in a performance-based and service-oriented manner, while ensuring that CNS systems remain efficient spectrum users. The ICNSS TF is also undertaking a study to define a new and more streamlined framework for the development of ICAO Annex 10 SARPs, including use of SDO standards and related detailed technical information, to realize more spectrum efficient and cost-effective CNS solutions and to take full advantage of state-of-the-art telecommunications technology.

### 2.5.2 ICAO Frequency Spectrum Management Panel (FSMP)

The FSMP advises the ICAO Air Navigation Commission on frequency spectrum matters relating to implementation and coordination of CNS services. In ICAO Document 9718: Handbook on Radio Frequency Spectrum Requirements for Civil Aviation ("ICAO Spectrum Handbook"), the panel develops and maintains the ICAO Spectrum Strategy and the ICAO Policy on Radio Frequency Spectrum, intended to enable the advancement of technological developments and innovation for aviation to efficiently manage the finite and limited frequency spectrum resource. The ICAO Spectrum Handbook also has a compilation of ICAO systems and their relevant standards. The handbook is currently undergoing a long-term revision to update the ICAO policy.

<sup>4</sup> For example, in the United States alone there are over ten million airline flights per year. The proverbial "one in a million" failure could therefore be expected to occur about ten times per year, which is not acceptable for high integrity systems that may have hazardous/catastrophic consequences.

## CHAPTER 3

### RF SURVEY OF RTCA AND EUROCAE MINIMUM PERFORMANCE STANDARDS

#### 3.1 RF SURVEY PROCESS

##### 3.1.1 RF Survey Creation

To collect information about current RF aviation systems standardized in RTCA/EUROCAE, SC-242/WG-124 first identified a list of MASPS and MOPS of systems that are still in current use<sup>5</sup>. The list was gathered by identifying standards referenced in current Technical Standard Orders (TSOs) published by the United States Federal Aviation Administration (FAA), and European TSOs (ETSOs) published by the European Union Aviation Safety Agency (EASA), as well as by looking through the current catalog of standards available at RTCA/EUROCAE. This list of standards was further refined using the expertise of the SC-242/WG-124 participants in whether these standardized systems are still in mainstream active service. In total, 86 initial documents were identified as potentially relevant. For the purposes of defining the scope, new standards approved by the RTCA Program Management Committee (PMC) and EUROCAE Council up to 10 July 2023 were included in the survey. Standards with an active RTCA SC and/or EUROCAE WG were identified, and an introductory letter and survey were sent to these SCs/WGs. The letter, survey, and list of SC/WGs contacted are detailed in [APPENDIX D](#). For standards without an active RTCA or EUROCAE committee, members of SC-242/WG-124 were identified to fill out the surveys ([APPENDIX E](#)), with preference given to committee members with experience or knowledge of the system. The preponderance of these standards is older and tend to have fewer RF parameters defined, which simplified, to an extent, the completion of the surveys.

##### 3.1.2 Level of Detail for Each RF Survey Review

For each current system that was surveyed, the following information categories were requested. This was intended to identify, for each system, whether a reader external to aviation could accurately conduct an RF compatibility study in a composite signal environment between aviation and non-aviation systems:<sup>6</sup>

- System summary and purpose
- Context of document
- Transmitter function (if applicable), including fundamental and unwanted emissions
- Receiver function (if applicable), including inside and outside of the receiver passband(s)
- Antenna characteristics
- System installation characteristics
- Guidance or environmental factors not covered in the above
- Any other information not covered by the above, or insights on spectrum considerations in the development of a document
- Suggestions for SC-242/WG-124 in development of the RF guidance material for future RTCA/EUROCAE standards and revisions

In practice, it was sometimes necessary to have further discussion with the responding SC/WG to obtain additional context about the survey results. For example, for Mode S systems (DO-181F/ED-73F), the value for receiver sensitivity in the MOPS is actually the Minimum Trigger Level as used in the Mode S pulse-position modulation encoding,

<sup>5</sup> Standards for systems whose TSOs/ETSOs have been cancelled, standards which have been withdrawn from publication, and standards which had yet to be published, were all excluded from consideration.

<sup>6</sup> While every potential spectrum compatibility study is unique depending on the different systems being considered, there are some base RF performance characteristics that are needed for all studies.

rather than the receiver sensitivity as it is typically understood for continuous wave systems.

### **3.2 COLLECTION OF RF SURVEY RESULTS**

#### **3.2.1 RF Survey Returns**

Of the 86 initial documents that were identified as potentially relevant, 45 were completed and returned by either SCs/WGs that were active, or by the SC-242/WG-124 membership with a best effort review for SCs/WGs that were inactive or did not respond. Many of the initial documents identified did not result in a survey response as they either had no RF requirements or could be consolidated as they had an equivalent/complementary RTCA or EUROCAE standard.

#### **3.2.2 RF Survey Review Process by SC-242/WG-124**

For all RF survey responses, the SC-242/WG-124 membership reviewed them as a group and developed high level notes on their contents in the context of whether the material could support a potential RF compatibility study. The results of these reviews are included in APPENDIX C for each document.

The SC-242/WG-124 membership notes that no formal standard guidance exists at this time for specifying a fully developed set of RF performance characteristics. As such, these assessments are deliberately qualitative given the subjective nature of the reviews.

Additionally, during these discussions, any questions that arose were catalogued in Section 4 of this report to assist with the development of the new document on Spectrum Guidance for the Developers of Standards for Aviation Wireless Systems

## CHAPTER 4

### QUESTIONS RAISED DURING THE SURVEY

#### 4.1 QUESTION TOPICS RAISED BY THE SURVEY RESPONSES

The following questions were raised based on the received RF survey responses listed in [APPENDIX B](#), and detailed in [APPENDIX C](#), and the subsequent discussions on these topics. These have been divided into two sections, general policy questions for spectrum guidance, and specific questions for certain parts of a defined aviation standard.

#### 4.2 POLICY QUESTIONS

##### 4.2.1 What Is the Level of Detail Needed (or Is Feasible) for Technical Characteristics?

The future RF environment is an unknown variable that prevents precisely defining the RF performance requirements for how future aviation systems can be spectrally efficient (particularly for coexistence with other spectrum users). However, broad statements that simply state the need for a “spectrally efficient” design are highly subjective and have no means of objective compliance. Therefore, what guiding principles should be set for how to balance these two extremes and not create either an unnecessarily constrictive, or ambiguous, set of requirements? How should this be supported by material that future SCs/WGs may need to demonstrate or justify they are meeting this guidance? Should it be assumed that manufacturers will be available to provide additional information that may not be included in the RTCA/EUROCAE standards?

##### 4.2.2 Should Operational Usage Be Considered/Explained? If So, to What Level and How?

Spectrum analysis fundamentally relies on operational scenarios accounting for both airspace procedure design standards and non-normal operations. The assumptions used to build these operational scenarios can vary and discussions to agree on the assumptions can be contentious. Should a description of the operational usage of a standardized system be considered in any MASPS or MOPS? And if so, to what extent should it be explained? Would a separate document be a consideration for all systems, such as an Operational Services and Environment Definitions (OSED) document, or material as provided, for example, in DO-235C or the Appendix F to DO-262F?

##### 4.2.3 How Should Numerous Different International/Regional/National RF Regulations Be Accounted For?

Multiple international/regional/national regulations exist outside of aviation that govern the RF performance of devices. Some of these are by UN treaty, others are regional or national recommendations/guidance. How should the RTCA and EUROCAE (and even other SDOs) standards development process account for these multiple regulations that can be different and subject to change? What is the process if there is an outlier set of requirements or some regulations are unachievable based on currently available RF technology?

##### 4.2.4 Should Example or Reference Link Budgets Be Included?

Several standards (such as DO-224D, DO-235C, and DO-292) have specified example link budgets for system operation. These link budgets provide good templates to use for RF calculations to reduce potential ambiguities. Should example or reference link budgets be recommended for all future RTCA and EUROCAE standards work?

##### 4.2.5 How Should Terminology Be Clarified for an External Audience?

The terminology used in aviation RF system performance standards can be very different from the terminology used in national and international spectrum regulation activities. Even if the terminology used is the same, the interpretation or definition of the terminology can be different. For example, even relatively straight forward terms such as “receiver sensitivity” could be interpreted several ways (as seen in DO-

181F/ED-73F). What guidance can be recommended for the writing of aviation standards language so that external entities can accurately understand and interpret these terms as intended by aviation standards, without realigning all RTCA/EUROCAE terminology to an external organization?

#### **4.2.6 What Context or Commentary Should Be Provided for Design Decisions Made During the Development of RTCA and EUROCAE Standards?**

Decisions made during the standards development process often have specific origins or needs that led to the performance specified in the final standard, yet these decisions are not always declared or explained. For example, DO-179 has several unusual requirements that were difficult to understand, but clearly had some basis for the way these requirements were specified. Additionally, design decisions on the level of RF performance may require justification in future spectrum compatibility studies. What context or commentary should be provided for the written requirements? Lastly, how should the operational scenario/performance framework aspects be accounted for?

#### **4.2.7 How Should RTCA/EUROCAE Documentation of RF Performance Be Related to External Standards Such as ARINC?**

External standards, such as ARINC, can provide additional RF performance details, including antennas and form/fit requirements. How should such external information be recognized or referenced to ensure the reader can be aware of all possible RF performance values for any aviation system and the rationale for any variation? Should guidance be provided to RTCA/EUROCAE committees that all RF performance requirements be specified within MOPS documents even if other industry standards (e.g., ARINC standards) contain the same RF performance details/requirements?

In addition, some RTCA/EUROCAE standards may reference external standards for performance requirements. However, these referenced performance standards may not address RF performance/compatibility. If this occurs, should RF performance requirements be added to the RTCA/EUROCAE document(s) in order to address RF performance/compatibility?

### **4.3 SYSTEM SPECIFIC QUESTIONS**

#### **4.3.1 Transmitter/Receiver Performance Questions**

- What RF performance characteristics should be specified for each system? Is it a prescriptive list of parameters (e.g., the United States Department of Defense DD Form 1494), or a list of performance-based parameters? How are these balanced to ensure they are not an overly prescriptive list that limits individual manufacturer innovation?
- How far in frequency from the allocated frequency bands/center frequency should RF performance be specified as a minimum? What guidance can be provided to promote RF coexistence with systems outside the intended frequency range? What guidance can be provided to promote onboard (co-site) interference compatibility?
- What should happen to the definition of receiver performance beyond the specified range? Is falling back to High Intensity Radiated Field (HIRF) requirements a viable option, and if so, should this be made clear?

#### **4.3.2 How to Define the Minimum Transmitter and Receiver Masks?**

Several international standards exist for certain RF transmitter and receiver performance parameters, such as the ITU-R radio regulations for spurious emissions, etc. While these international standards are generally considered the minimum requirement to legally operate, they may not lead to good spectrum efficiency. Should minimum transmitter and receiver masks be specified for new aviation systems? If yes, how should they be specified? Should the minimum performance be set at the existing international RF standards, or be driven for higher performance? Should SCs/WGs be encouraged during the standards development process to develop more stringent RF requirements over and above the minimums without a known threat to drive that performance?

#### **4.3.3 How Should Antenna Performance Be Documented?**

Only some standards (e.g., DO-144A, DO-181F/ED-73F, DO-301, and DO-373) consider antenna parameters in a form that could be used for external RF study. Should antenna RF characteristics be incorporated into MOPS, especially when they can be provided by a range of different providers that are not the avionics manufacturer? If so, how should supplier variation be considered and to what level of detail should parameters be documented/standardized?

#### **4.3.4 How Should Ground and Satellite Systems/Components RF Performance Be Captured?**

Multiple air-ground and air-satellite systems are specified in aviation. However, current system standards (e.g., DO-186B/ED-23C) only specify the avionics component, not the systems they connect to on the ground or satellite. Given that ground and/or satellite components are essential to many aspects of a system's operation, how should the RF performance aspects of the ground and satellite components of RF systems be accounted for in future standards?

#### **4.3.5 Should Emission Designators Be Specified for All Systems?**

There is a large variation between documents regarding whether an emission designator is defined or not. While emission designators are primarily required for frequency licensing, they are not essential when defining system performance, nor are they applicable if the exact method of implementation is not defined. Should the essential components be defined (necessary bandwidth, modulation, etc.), but an emission designator itself be optional?

#### **4.3.6 What Guidance or Framework Should Be Provided to Guide External Interference Analysis?**

Several SCs/WGs that have had experience with external interference have created their own proforma table or framework in their standards to better guide how those systems should be evaluated in spectrum compatibility assessments (e.g., DO-235C, DO-262F, and DO-292). Should this process be considered in all standards work to account for the unique use case of each system, and if so, what level of detail is needed?

## CHAPTER 5

### SUMMARY

The review of available RTCA and EUROCAE standards documents was a considerable task, resulting in 45 different documents being reviewed by SC-242/WG-124. The results show a large variation in the level of information provided that would assist a spectrum compatibility assessment. While older documents generally provided fewer details, even some more recent documents do not always have a complete list of RF characteristics. There were a few notable systems that had detailed sections addressing spectrum considerations, created because of a spectrum issue that informed further work and development of the SCs/WGs' document. However, even the documents with the most complete RF performance characteristics would still likely require some level of manufacturer support to ensure all necessary considerations were captured in a spectrum study.

In reviewing these standards, SC-242/WG-124 notes that RTCA and EUROCAE standards are written with certification to a functional performance level as their primary aim, and not necessarily spectrum compatibility. Nor does formal guidance exist for specifying RF performance characteristics. As such, SC-242/WG-124 acknowledges these assessments are deliberately qualitative given the subjective nature of the reviews. However, the insight gained in comparing the different responses has resulted in numerous questions that will help inform future guidance for spectrum in RTCA and EUROCAE standards. Although it will be complex to create a comprehensive spectrum guidance document to cover the diversity of CNS systems used in aviation, recent spectrum activities have shown the risks of not having the available data ready to participate at the early stages of any national or international spectrum decision-making process.

**APPENDIX A****ACRONYMS**

|                 |                                                    |
|-----------------|----------------------------------------------------|
| 1090ES          | 1 090 Extended Squitter                            |
| 3GPP            | 3rd Generation Partnership Project                 |
| A/G             | Air/Ground                                         |
| ACAS            | Airborne Collision Avoidance System                |
| ADF             | Automatic Direction Finder                         |
| ADS-B           | Automatic Dependent Surveillance - Broadcast       |
| AeroMACS        | Aeronautical Mobile Airport Communication System   |
| AM              | Amplitude Modulation                               |
| AMS(R)S         | Aeronautical Mobile Satellite (Route) Service      |
| AMSS            | Aeronautical Mobile Satellite Service              |
| ANSP            | Air Navigation Service Provider                    |
| ARNS            | Aeronautical Radio Navigation Spectrum             |
| ATAR            | Air-To-Air Radar                                   |
| ATC             | Air Traffic Control                                |
| ATCRBS          | ATC Radio Beacon System                            |
| C2              | Command and Control                                |
| C/A             | Coarse Acquisition                                 |
| CAA             | Civil Aviation Authority                           |
| CNR             | Carrier-to-Noise Ratio                             |
| CNS             | Communications, Navigation and Surveillance        |
| CW              | Continuous Wave                                    |
| dB              | Decibel                                            |
| dBc             | Decibels relative to carrier                       |
| dB <sub>i</sub> | Decibels relative to isotropic                     |
| dB <sub>m</sub> | Decibel referenced to 1 milliwatt                  |
| dBW             | Decibel referenced to 1 watt                       |
| DFMC            | Dual Frequency Multi-Constellation                 |
| DLNA            | Diplexer Low Noise Amplifier                       |
| DME             | Distance Measuring Equipment                       |
| EASA            | European Union Aviation Safety Agency              |
| ELT             | Emergency Locator Transmitter                      |
| EMC             | Electro Magnetic Compatibility                     |
| ES              | Extended Squitter                                  |
| ETSO            | European Technical Standard Order                  |
| EUROCAE         | European Organisation for Civil Aviation Equipment |
| FAA             | Federal Aviation Administration                    |

## Appendix A

### A-2

|          |                                                                                   |
|----------|-----------------------------------------------------------------------------------|
| FCC      | Federal Communications Commission                                                 |
| FM       | Frequency Modulation                                                              |
| FMCW     | Frequency Modulated Continuous Wave                                               |
| FSMP     | ICAO Frequency Spectrum Management Panel                                          |
| GBAS     | Ground Based Augmentation System                                                  |
| GHz      | Gigahertz                                                                         |
| GNSS     | Global Navigation Satellite System                                                |
| GPS      | Global Positioning System                                                         |
| HF       | High Frequency                                                                    |
| HFDL     | HF Data Link                                                                      |
| HIRF     | High Intensity Radiated Field                                                     |
| Hz       | Hertz                                                                             |
| I/N      | Interference-to-Noise ratio                                                       |
| ICAO     | International Civil Aviation Organization                                         |
| ICNSS TF | ICAO Integrated Communications, Navigation, Surveillance, and Spectrum Task Force |
| IF       | Intermediate Frequency                                                            |
| ILS      | Instrument Landing System                                                         |
| ITU      | International Telecommunications Union                                            |
| ITU-R    | ITU Radiocommunication Sector                                                     |
| kHz      | Kilohertz                                                                         |
| kW       | Kilowatt                                                                          |
| LAAS     | Local Area Augmentation System                                                    |
| LRRA     | Low Range Radio/Radar Altimeter                                                   |
| m        | Meters                                                                            |
| MASPS    | Minimum Aviation System Performance Standard                                      |
| MHz      | Megahertz                                                                         |
| MLAT     | MultiLATERation                                                                   |
| MMR      | Multi-Mode Airborne Receiver                                                      |
| MOPS     | Minimum Operational Performance Standard                                          |
| Mode S   | Mode Select                                                                       |
| MPS      | Minimum Performance Standard                                                      |
| N        | Noise                                                                             |
| NDB      | NonDirectional Beacon                                                             |
| NGSS     | Next Generation Satellite Systems                                                 |
| OSD      | Operational Services and Environment Definitions                                  |
| PAPR     | Peak to Average Power Ratio                                                       |
| PED      | Portable Electronic Device                                                        |
| RA       | Resolution Advisory                                                               |
| RF       | Radio Frequency                                                                   |

## Appendix A

### A-3

|        |                                              |
|--------|----------------------------------------------|
| RFI    | Radio Frequency Interference                 |
| RR     | Radio Regulations (of the ITU)               |
| Rx     | Receive                                      |
| S+N    | Signal + Noise                               |
| SAR    | Search And Rescue                            |
| SARPs  | Standards and Recommended Practices          |
| SATCOM | Satellite Communication                      |
| SBAS   | Satellite Based Augmentation System          |
| SBB    | Swift BroadBand                              |
| SC     | Special Committee                            |
| SDO    | Standards Development Organization           |
| SINAD  | Signal-to-Noise And Distortion ratio         |
| SSR    | Secondary Surveillance Radar                 |
| TA     | Traffic Advisory                             |
| TCAS   | Traffic-alert and Collision Avoidance System |
| TDOA   | Time Difference Of Arrival                   |
| TIS-B  | Traffic Information Services - Broadcast     |
| TSO    | Technical Standard Order                     |
| Tx     | Transmit                                     |
| UAS    | Unmanned/Uncrewed Aircraft System            |
| UAT    | Universal Access Transceiver                 |
| UN     | United Nations                               |
| VHF    | Very High Frequency                          |
| VDL    | VHF Digital Link                             |
| VOR    | VHF Omni-directional Range                   |
| VSWR   | Voltage Standing Wave Ratio                  |
| W      | Watts                                        |
| WAIC   | Wireless Avionics Intra-Communications       |
| WG     | Working Group                                |
| WRC    | World Radio Conference                       |
| μV     | micro Volt                                   |

**APPENDIX B****SUMMARY OF RF SURVEYS RECEIVED**

The RF survey responses from the following documents were assessed as having RF performance characteristics that could be reviewed. These are the final outcome after considering all the documents listed in [APPENDIX D](#), Enclosure 3, and [APPENDIX E](#).

**B.1 System Specific Surveys****TABLE B-1: SUMMARY OF RF SYSTEM SPECIFIC SURVEYS**

| Frequency range       | Technology                             | RTCA Documents Number | EUROCAE Document Number | Survey Summary Section |
|-----------------------|----------------------------------------|-----------------------|-------------------------|------------------------|
| 190 – 850 kHz         | ADF (Rx)                               | DO-179                | ED-51                   | C.7                    |
| 1 615 – 1 799 kHz     |                                        |                       |                         |                        |
| 1.5 – 30 MHz          | HF voice communication (Tx/Rx)         | DO-163                | None                    | C.5                    |
| 2 – 30 MHz            | HFDL (Tx/Rx)                           | DO-265                | None                    | C.22                   |
| 75 MHz                | Airborne radio marker (Rx)             | DO-143                | Document 1/WG 7/70      | C.1                    |
| 108 – 112 MHz         | ILS localizer (Rx)                     | DO-195                | ED-46B                  | C.14                   |
| 108 – 117.95 MHz      | Airborne VOR (Rx)                      | DO-196                | ED-22B                  | C.15                   |
|                       | Ground VOR beacon (Tx)                 | None                  | ED-52                   | C.32                   |
| 108 – 117.975 MHz     | GBAS airborne equipment (Rx)           | DO-253D               | None                    | C.38                   |
|                       | GBAS ground equipment (Tx)             | None                  | ED-114B                 | C.38                   |
| 117.975 – 137.000 MHz | VHF voice communication (Tx/Rx)        | DO-186B               | ED-23C                  | C.10                   |
|                       | VDL Mode 2 (Tx/Rx)                     | DO-281C               | ED-92C                  | C.23                   |
|                       | VHF narrowband digital link (Tx/Rx)    | DO-224D               | None                    | C.19                   |
| 328.6 – 335.4 MHz     | ILS glide slope (Rx)                   | DO-192                | ED-47B                  | C.13                   |
| 406 – 406.1 MHz       | ELT (Tx)                               | DO-204B               | ED-62B                  | C.17                   |
| 960 – 1 215 MHz       | Airborne DME (Tx/Rx)                   | DO-189                | ED-54                   | C.11                   |
| 962 – 1 213 MHz       | DME ground equipment (Tx/Rx)           | None                  | ED-57                   | C.33                   |
| 978 MHz               | UAT ADS-B (Tx/Rx)                      | DO-282C               | None                    | C.24                   |
| 1 030 MHz             | ATCRBS transponder (Rx interrogations) | DO-144A               | None                    | C.2                    |
|                       | Mode S transponder (Rx interrogations) | DO-181F               | ED-73F                  | C.8                    |
|                       | TCAS II (Tx interrogations)            | DO-185B               | ED-143                  | C.9                    |

Appendix B

B-2

| Frequency range   | Technology                                         | RTCA Documents Number | EUROCAE Document Number | Survey Summary Section |
|-------------------|----------------------------------------------------|-----------------------|-------------------------|------------------------|
|                   | TCAS I (Tx interrogations)                         | DO-197A               | None                    | C.16                   |
|                   | ACAS X (Tx interrogations)                         | DO-385                | ED-256                  | C.31                   |
|                   | Modes S MLAT ground systems (Tx interrogations)    | None                  | ED-117A                 | C.35                   |
|                   | Wide area MLAT ground systems (Tx interrogations)  | None                  | ED-142                  | C.36                   |
| 1 090 MHz         | ATCRBS transponder (Tx replies)                    | DO-144A               | None                    | C.2                    |
|                   | Mode S transponder (Tx replies)                    | DO-181F               | ED-73F                  | C.8                    |
|                   | TCAS II (Rx replies)                               | DO-185B               | ED-143                  | C.9                    |
|                   | TCAS I (Rx replies)                                | DO-197A               | None                    | C.16                   |
|                   | ADS-B and TIS-B (Tx broadcast)                     | DO-260C               | ED-102B                 | C.20                   |
|                   | ACAS X (Rx replies)                                | DO-385                | ED-256                  | C.31                   |
|                   | Modes S MLAT ground systems (Rx receptions)        | None                  | ED-117A                 | C.35                   |
|                   | Wide area MLAT ground systems (Rx receptions)      | None                  | ED-142                  | C.36                   |
| 1 164 – 1 215 MHz | GNSS (Rx)                                          | DO-292                | None                    | C.38                   |
| 1 215 – 1 240 MHz | GBSS for traffic surveillance (Tx/Rx)              | DO-381                | None                    | C.30                   |
| 1 240 – 1 300 MHz | GBSS for traffic surveillance (Tx/Rx)              | DO-381                | None                    | C.30                   |
| 1 300 – 1 350 MHz | GBSS for traffic surveillance (Tx/Rx)              | DO-381                | None                    | C.30                   |
| 1 350 – 1 370 MHz | GBSS for traffic surveillance (Tx/Rx)              | DO-381                | None                    | C.30                   |
| 1 518 – 1 559 MHz | NGSS – Inmarsat SwiftBroadband extended range (Rx) | DO-262F Appendix E    | ED-243C Appendix E      | C.21                   |
| 1 525 – 1 559 MHz | NGSS – Inmarsat SwiftBroadband standard range (Rx) | DO-262F Appendix E    | ED-243C Appendix E      | C.21                   |
| 1 559 - 1 610 MHz | GNSS (Rx)                                          | DO-229E               | None                    | C.38                   |
|                   |                                                    | DO-235C               | None                    |                        |
|                   |                                                    | DO-253D               | None                    |                        |
|                   |                                                    | DO-316                | None                    |                        |