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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Technical Characteristics for Airborne In-Flight Entertainment Systems operating in the frequency range 5 150 MHz to 5 875 MHz

Reference

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

Introduction

The present document discusses wireless airborne In-Flight Entertainment (IFE) equipment, operating in the frequency ranges 5 150 MHz to 5 350 MHz, 5 470 MHz to 5 725 MHz and 5 725 MHz to 5 875 MHz.

The wireless distribution system of IFE uses commercially available IEEE-standardized 802.11a [i.3] or, when the standard is ratified, 802.11n [i.4] communications technologies. Use of wireless distribution systems in airborne platforms offers significant advantages to operators of aircraft by increasing operational flexibility while reducing costs.

Status of the System Reference Document

The present document has been prepared by ETSI BRAN and has been considered during ERM meeting #35.

Target version	**Pre-approval date version**				
V1.1.1	**a**	**s**	**m**	**Date**	**Description**
V1.1.1		0.0.2		6th March 2008	Revised version at ERM#34
V1.1.1				16th April 2008	Final draft prepared by TC BRAN
V1.1.1				17th June 2008	Version approved by ERM#35

1 Scope

The present document has been developed in order to provide information on the usage of RLAN equipment to provide wireless distribution of streaming audio and/or video in airborne platforms. This equipment is proposed to use the license-exempt frequencies 5 150 MHz to 5 875 MHz for this purpose.

When operating in the bands 5 150 MHz to 5 350 MHz and 5 470 MHz to 5 725 MHz, the equipment is in line with ECC Decision (04)08 [i.6] and comply with the ETSI standard EN 301 893 [i.1]. Therefore the discussions in the present document are limited to the band 5 725 MHz to 5 875 MHz as an increase in the permitted power for these IFE equipment is required only for that band.

It includes necessary information to support the co-operation between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Post and Telecommunications administrations (CEPT), including:

- Detailed market information (clause A).
- Technical information (clause B).
- Expected compatibility issues (clause C).

The present document does not cover equipment compliance with relevant civil aviation regulations. In this respect, a wireless IFE system, for its installation and operation on-board an aircraft is subject to additional national or international civil aviation airworthiness certification requirements, for example to EUROCAE ED-14E [i.15].

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific.

- For a specific reference, subsequent revisions do not apply.
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2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

Not applicable.

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area**.** For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] ETSI EN 301 893 (V1.4.1): "Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN; Harmonized EN covering essential requirements of article 3.2 of the R&TTE Directive".

[i.2] IEEE 802.11: "IEEE Standard for Information Technology - Telecommunications and information exchange between systems - Local and Metropolitan area networks - Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications".

[i.3] IEEE 802.11a-1999 [ISO/IEC 8802-11:1999/Amd 1:2000(E)] (Supplement to IEEE Std 802.11, 1999 Edition): "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band".

[i.4] IEEE 802.11n: "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications: Enhancements for Higher Throughput".

[i.5] ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)".

[i.6] ECC/DEC/(04)08: "ECC Decision of 12 November 2004 on the harmonized use of the 5 GHz frequency bands for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs)".

[i.7] "Commission Decision 2005/513/EC of 11 July 2005 on the harmonized use of radio spectrum in the 5 GHz frequency band for the implementation of wireless access systems including radio local area networks (WAS/RLANs)".

[i.8] "Commission Decision 2007/90/EC of 12 February 2007 amending Decision 2005/513/EC on the harmonized use of radio spectrum in the 5 GHz frequency band for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs)".

[i.9] ECC Report 68: "Compatibility studies in the band 5 725 - 5 875 MHz between Fixed Wireless Access (FWA) systems and other systems".

[i.10] ECC Report 101: "Compatibility studies in the band 5 855 - 5 925 MHz between Intelligent Transport Systems (ITS) and other systems".

[i.11] ECC Report 110: "Compatibility studies between Broad-Band Disaster Relief (BBDR) and other Systems".

[i.12] ECC Report 109: "The aggregate impact from the proposed new systems (ITS, BBDR And BFWA) in the 5 725 -5 925 MHz Band on the other services/systems currently operating in this band".

[i.13] ECC Report 93: "Compatibility between GSM equipment on board aircraft and terrestrial networks".

[i.14] Boeing Report "D6-83753, Airborne DFS functionality test report", Whetten F.L., 18 Feb 2007.

[i.15] EUROCAE ED-14E (2005) (Equivalent to RTCA DO-160E): "Environmental Conditions and Test Procedures for Airborne Equipment".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Dynamic Frequency Selection (DFS): radar detection and evasion algorithm employed by RLAN equipment to prevent RF interference in to radars

Radio Local Area Network (RLAN): in the present document, refers specifically to IEEE-standardized 802.11 [i.2] wireless networking equipment

In-Flight Entertainment (IFE): any of several modalities of In-Flight Entertainment, including but not limited to fixed streaming audio, audio on demand, fixed streaming video, video on demand, and public announcement audio and/or video

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AVoD	Audio/Video on Demand
BFWA	Broadband Fixed Wireless Access
CEPT	European Conference of Postal and Telecommunications Administrations
DFS	Dynamic Frequency Selection
ECC	Electronic Communications Committee
EIRP	Effective Isotropic Radiated Power
EME	Externally Mounted Equipment
EMI	Electro-Magnetic Interference
FS	Fixed Services
FSS	Fixed Satellite Services
IEEE	Institute of Electrical and Electronics Engineers
IFE	In-Flight Entertainment
ITS	Intelligent Transport Systems
LAN	Local Area Network
MAC	Medium Access Control
PHY	PHYsical layer
RF	Radio Frequency
RLAN	Radio Local Area Network
RTTT	Road Transport and Traffic Telematics
SRD	Short Range Device
SRDoc	System Reference Document
TPC	Transmit Power Control

4 Comments on the System Reference Document

No statements have been received on the present document yet.

5 Executive Summary

5.1 Background Information

The present document provides an overview of the functionality, market information, and co-existence profile for an RLAN-based wireless distribution system for airborne IFE.

5.2 Market information

Entertainment while travelling has become an expectation of the flying public, and a competitive advantage among airlines attempting to gain or protect market share. Consequently, IFE systems continue to evolve with added functionality, capability, and user convenience being the highest priorities. The current state-of-art IFE systems offer video and audio "on demand", meaning that every passenger may be watching or listening to different content. This type of system requires independent distribution systems to each seat location, and if a wired system, can incorporate hundreds of kilometres of wiring.

Not only is wiring heavy and bulky, leading to increased fuel burn, it is difficult to maintain due to the number of connectors with resulting reliability issues. Furthermore, the need to frequently reconfigure the cabin means that the cabling will be moved replaced, and adjusted often during the life of the IFE system.

Wireless distribution offers many distinct advantages over a similar wired system; including: less weight, increased reliability due to fewer connectors, less likelihood of damage since no cables run through the floor or up the seat legs. Additionally, reconfiguring the cabin can be reduced to simply moving the seat, rather than needing to replace all the wiring bundles.

Detailed market information is in annex A.

5.3 Technical system description

A modern IFE system consists of three fundamental components: the head-end, where the content is stored and the system controller is housed; the passenger display devices, typically one per seat in sophisticated systems; and the distribution system, which carries control systems and content throughout the cabin.

The content delivery for the current generation of wireless IFE systems depends upon reliable network performance of approximately 1 Mbit/s to each seat-back display to achieve high-quality motion video. Every seat potentially can be watching different content (or different locations in the same video stream), thus the network bandwidth ought to be sufficient to support a 1 Mbit/s video stream to every seat in the cabin. Cabins typically range between 130 and 350 seats. Longer-range aircraft, where good IFE is more important, tend to have larger cabins.

For a 300-seat aircraft, total network bandwidth then is 300 Mbit/s. Given a wireless IFE system, common design considerations provide approximately 20 Mbit/s per 802.11a channel, leading to a 15-channel availability requirement. The total bandwidth requirements for new larger aircraft will exceed 300 Mbit/s thus requiring more than 15 channels.

Not all 5 GHz channels are available at all times, however, due to the potential for DFS events due to radars within the radio horizon. Thus considerably more than 15 channels need to available for an adaptive IFE system to avoid halting IFE functionality while avoiding interference into radar systems.

Additional technical discussion can be found in clause B.

5.4 Compatibility Issues

Although the Airborne In-Flight Entertainment Systems operate over the entire spectrum 5 150 MHz to 5 350 MHz, 5 470 MHz to 5 725 MHz and 5 725 MHz to 5 875 MHz, compatibility issues addressed in the present document are limited to the band 5 725 MHz to 5 875 MHz.

Table 1 below provides an overview of the current users of the 5 725 MHz to 5 875 MHz frequency band, where the increased power limit for airborne RLAN is proposed.

Table 1: Current users of the additional desired frequency band

Frequency range	Possible impacted services
5 725 MHz to 5 855 MHz	Radar (5 725 MHz to 5 850 MHz)
	FSS (Earth to Space)
	BFWA
	RTTT (5 795 MHz to 5 805 and 5 805 MHz to 5 815 MHz)
	Amateur (5 725 MHz to 5 850 MHz)
	Generic SRDs
	FS (5 850 MHz to 5 855 MHz)
5 855 MHz to 5 875 MHz	FSS (Earth to Space)
	BFWA
	ITS
	Generic SRDs
	FS

Interference from the wireless IFE system with these existing services can be shown to be highly improbable. Aircraft have been shown to have an attenuation factor in the 5 GHz band of 17 dB, which, in the eyes of the CEPT, the EC, the ITU, and many administrations around the world, is an indoor environment.

Analysis has shown that, for an airplane in flight, the noise interference power is well below the thermal noise floor, and thus little or no interference can be expected in terrestrial systems.

Additional details and analysis are seen in clause C.

6 Current regulations

The 5 GHz band has license-exempt frequencies between 5 150 MHz and 5 875 MHz, which are available to non-specific Short Range Devices and RLANs. The use of the bands 5 150 MHz to 5 350 MHz and 5 470 MHz to 5 725 MHz is regulated by annex 3 of CEPT Recommendation 70-03 [i.5], the ECC Decision (04)08 [i.6] and the EC decisions 2005/513/EC [i.7] and 2007/90/EC [i.8].

The use of the frequency band 5 725 MHz to 5 875 MHz is regulated by annex 1 of CEPT Recommendation 70-03 [i.5], however, the output power generic short range devices operating in this band is limited to a maximum EIRP of 25 mW (+14 dBm).

The present document discusses the need to increase the maximum power limit in the 5 725 MHz to 5 875 MHz band for these airborne in-flight entertainment systems to 100 mW EIRP for systems without TPC or to 200 mW EIRP for systems with TPC.

Investigation regarding the availability of the band 5 725 MHz to 5 875 MHz around the world for RLANs has shown that this band is available in many regions and countries with a range of power limits of 100 mW, 1 W and 2 W.

Clause E provides a sample list of countries that have been investigated.

7 Proposed regulations

As the technology used for these IFE systems is based on current RLAN technology, ETSI proposes a similar regulation for the 5 725 MHz to 5 875 MHz band as currently defined for RLANs in the band 5 250 MHz to 5 350 MHz. This would mean that airborne wireless IFE systems be permitted to operate within the 5 725 MHz to 5 875 MHz band with a maximum EIRP of 200 mW (+23 dBm) if TPC is used, or 100 mW (+20 dBm) if no TPC is used.

Standard IEEE RLAN technologies are proposed for use in airborne applications, thus the channel width of 20 MHz is expected to be used.

The use of 5 725 MHz to 5 875 MHz for inflight applications is proposed to be limited to aircraft altitudes above 3 000 m.

Noting that these systems are used on board of aircrafts flying across Europe, ETSI believes that a specific ECC decision is the preferred type of deliverable for these IFE systems in the band 5 725 to 5 875 MHz. In addition ETSI also proposes to have an EC decision, or as a minimum an appropriate Sub-Class being developed for these IFE systems.

In case the CEPT would decide that, in addition to the above, a revision of Annex 3 of ERC Recommendation 70-03 [i.5] would be desirable, clause D of the present document includes a proposal for changes to be made to this Annex.

8 Main conclusions

Wireless IFE systems have the potential to reduce costs, improve functionality and passenger experience, and improve reliability of IFE systems for commercial airlines operating within Europe. The current limitations on radiated power in the band 5 725 MHz to 5 875 MHz (generic SRDs) limit the capability of IFE systems to function reliably in a heavily-loaded passenger cabin. Furthermore, analysis has shown that the radiated power levels impinging the ground from an aircraft in flight are so low as to assure no harmful interference to terrestrial systems.

9 Expected ETSI and ECC actions

ETSI requests ECC to consider the present document, which includes necessary information to support the co-operation under the MoU between ETSI and the Electronic Communications Committee (ECC) of the European Conference of Postal and Telecommunications Administrations (CEPT).

It is proposed that ECC considers the proposed regulation in clause 6 and as further provided in clause D of the present document.

ETSI would appreciate if the ECC would be able to finalize the appropriate regulation by the end of 2008.

As these systems will be installed during the manufacturing phase of the aircraft, this type of equipment will not be placed on the market separately and therefore ETSI does not see the need to revise the 5 GHz Harmonized Standard EN 301 893 [i.1].

Annex A: Detailed Market Information

A.1 Motivation for Wireless IFE

Operating an airline is a highly competitive business, combined with very high capital costs and operational costs. Airlines are in a constant search to reduce fuel burn, improve air cargo carrying capability, reduce maintenance issues during gate turns, and maintaining competitive advantage in acquiring and keeping loyal customers.

High-quality IFE is a clear advantage in attracting passengers, and a strong differentiator between service offerings.

A.1.1 Weight Comparison

A primary consideration in any airplane system design is the weight of the system. While it is difficult to analyze the weight differential between existing and proposed systems, for a typical 787 airplane (approximately 250 passengers) analysis predicts that a well-designed wireless IFE system would save about 60 kg of weight. A maximally configured 787 (330 passengers) would save about 90 kg over an equivalent wired system.

Every unit of added weight has the following penalties:

- it increases aerodynamic drag during flight, requiring additional fuel burn to overcome. Additional fuel burn, in turn, reduces the range of the airplane, increases the costs to the operator, and increases the exhaust emissions from each airplane;
- increased weight of airplane systems reduces the potential payload capacity. Reduced payload capacity, in turn, reduces the efficiency of the airplane to the operator by either reducing the number of passengers the airplane may carry, or reducing the amount of air cargo.

The costs for additional fuel burn depend heavily upon a number of factors, including configuration of airplane, specific routes flown, as well as the price of fuel. The increased costs to the operator have been approximated at 600 € per kg of weight per airplane per year (2005 data). Using the 60 kg weight savings figure above, the savings to an air carrier would be 40 000 € per airplane per year. Given that a typical airline might operate 25 each 787 airplanes, the savings runs into the millions of Euros per year due to reduced fuel burn.

A.1.2 Maintenance considerations

An airplane is only an economic asset when it is in a revenue flight. When an airplane is on the ground for maintenance, it is an economic liability of approximately 35 000 € per day (2005 data). Consequently operators have an incentive to equip their aircraft with airplane systems which reduce flight turn-around times at the gate, and minimize the potential for faulty systems operation.

Wireless IFE systems have significant advantages over wired systems in two different maintenance activities:

- Wireless systems make the aircraft cabin significantly easier to reconfigure, since no cabling to the seat is required. Operators frequently reconfigure passenger accommodations by expanding or reducing the size of the various cabins (First Class, Business Class, Economy Class), sometimes during a gate turn at an airport.
- The most unreliable component of a wired system is the connectors - which have a variety of failure modes, including pushed or bent pins, arcing between pins, and intermittent contacts. The problems with connectors are exacerbated when they are frequently mated and de-mated, operations which need to be performed at the seat during a cabin reconfiguration.

The amount of time required to remove and replace a wireless seat into the powered track may be compared to the time required to remove and replace the wired seats and all associated cabling. Again, depending upon installed systems and airplane configuration, the time differential can vary, but reconfiguring a wired system typically can be expected to take approximately three to four times longer than an equivalent wireless system. When the time required to troubleshoot and resolve faulty connector issues is considered, the advantages of a wireless system become even more compelling.

A.2 IFE Use Cases

IFE systems have functionality during all phases of aircraft operations, however, generally IFE is used after the aircraft has climbed above the lower altitudes and into the cruise phase of flight. A comprehensive list of use cases follows:

- **At Airport:** The IFE system may be used to broadcast the safety video to the passengers prior to takeoff. Additionally, during periods when the aircraft cannot take off for extended periods of time, IFE is often enabled to allow passengers to entertain themselves while waiting for the airplane to launch. Both of these uses of IFE on the ground are generally restricted to a single channel of content, and thus have limited network bandwidth requirements.

NOTE: This use case is not expected to require use of the 5 725 MHz to 5 875 MHz band - thus an operational restriction of only using the 5 725 MHz to 5 875 MHz band at altitude is acceptable.

- **At Cruise:** This is the most common use of IFE, after the aircraft has reached a high altitude, and the crewmember duties have migrated from strictly safety-related functions and started including passenger comfort activities. At altitude, and as passengers begin to explore the IFE service offerings, the bandwidth requirements for conveying the content to the passenger increases.

Annex B: Detailed Technical Information

B.1 Types of IFE

Examples of the varying types of IFE found in modern aircraft today include:

- No IFE.
- Large, public monitors with one movie playing. All passengers have access to the same content at the same time.
Network Bandwidth Requirements: Sufficient for a single channel of content.
- Individual monitors for each passenger, with synchronized content. In this scenario the cabin crew starts several video and audio tracks in a ganged tape or DVD deck. The passenger can select which of the films or audio they wish to enjoy, but they cannot choose when to start, stop, or pause the material. Additionally, there often is a low limit on the overall selection - for example, six films to choose between.
Network Bandwidth Requirements: Sufficient to carry all offered content; six channels of content in the example above.
- A complete Audio/Video on Demand (AVoD) system. Each passenger seat is equipped with a video monitor, and content is streamed as the user directs. Any of a large selection of video content may be selected at any time, and paused or discarded at will. These IFE systems frequently have a substantial library of films, television programming, and other content from which to select.
Network Bandwidth Requirements: Sufficient to distribute unique content to each seat in the airplane.

B.2 Details of Wireless IFE Implementation

B.2.1 Use of Commercial Technologies

Wireless IFE is a viable solution to the complexity and weight problems primarily because of reliance on commercially available RLAN equipment, particularly IEEE 802.11a-1999 [i.3] wireless networks. The advantages of using IEEE 802.11a-1999 [i.3] for wireless networking are:

- Standardized solutions widely available in the commercial market are much more inexpensive than custom aviation-specific niche products. The aviation industry prefers to leverage the success of the commercial consumer industry by using the same equipment in order to improve performance and reduce costs.
- The wireless industry is highly competitive, and improvements to technology occur at a rapid pace. IEEE 802.11a-1999 [i.3] offers approximately 20 Mbit/s bandwidth in a 20 MHz channel within the fuselage. Note that the throughput within the fuselage is approximately 20 % lower than expected RLAN throughput in a home or office environment.
- Total radiated power can be adjusted, typically between 1 mW and 100 mW in 1 dB or 2 dB increments.

Extensive experimentation and development has shown that a single channel of highly-compressed video content can be successfully transmitted using as little as 1 Mbit/s data throughput. A quick estimate of total bandwidth required to offer AVoD throughout an airplane is to multiply the number of seats by 1 Mbit/s each. Thus a 787 airplane in standard configuration would require between 250 Mbit/s and 330 Mbit/s total throughput in order to offer AVoD. The total throughput capacity is dependent on the available channel capacity taking into account loss of channels due to DFS, as discussed in clause B.3.

B.2.2 Transmit Power Requirements

Wireless RLAN performance is dependent upon robust success in receiving data packets reliably upon the first transmission. The IEEE 802.11 [i.2] protocol requires an acknowledgement of a received packet prior to the transmission of a subsequent packet. If an acknowledgement is not received within a time-out period, the transmitter will re-send the packet at a lower data rate. The combination of waiting for the timer to expire, then retransmission of the same data at a lower rate conspires to significantly degrade network throughput in a given channel. In an effort to minimize the number of channels and total spectrum required, ensuring that robust network performance is an important parameter to optimize.

Propagation within an aircraft fuselage is substantially different than within a home or office environment. While the fuselage is largely constructed of reflective materials at 5 GHz frequencies, the closely-spaced seating, galleys, lavatories, and high passenger density all result in a high path loss for propagating RF. Extensive testing has been performed on aircraft with actual and simulated passenger loads to determine the optimum power levels for wireless IFE operations. This testing has shown, that for the proposed wireless IFE configuration, transmit power levels must be above 75 mW for proper operation. Power levels at or below 50 mW EIRP suffered unacceptable network degradation for wireless IFE use.

B.3 Spectrum Requirements and DFS

B.3.1 Spectrum requirements

As noted in clause B.1, the AVoD-style of IFE requires an individually controlled video channel for each seat on the airplane. Thus total spectrum required is a function of the number of seats on board the airplane. For the larger airplanes, passenger loads exceeding 500 people are not uncommon, and thus an equal number of video streams need to be supported.

IEEE 802.11a-1999 [i.3] networks have been extensively tested to support video streaming capability within the aircraft cabin, with the following metrics found to be true and repeatable:

- with MPEG-4 encoding, a viewer-acceptable video stream consumes 1 Mbit/s on 802.11a technology;
- within the aircraft fuselage, 802.11a can reliably supply approximately 20 Mbit/s total IP throughput per RLAN channel.

Analysis assumptions:

- aircraft passenger loads vary between 250 and 450 passengers per aircraft;
- each passenger requires continuous 1 Mbit/s RLAN service performance (i.e.; interruptions due to lack of channel availability because of DFS radar detections is unacceptable);
- radar installations are no less common in Europe than they are in Washington State, USA.

With the assumed seat counts, between 250 Mbit/s (250 seats) and 450 Mbit/s (450 seats) total throughput will be required of the RLAN. Given this total throughput requirement and a channel capacity of 20 Mbit/s, a minimum of 13 (250 seats) and 23 (450 seats) IEEE 802.11 [i.2] channels respectively ought to be available for use at all times during flight. While much of the 5 GHz band has been approved for license-exempt RLAN use, significant restrictions exist on RLAN operations in order to protect the co-primary radar operators in the same band. This is the purpose of the DFS requirements and algorithm.

In Europe the bands, IEEE 802.11 [i.2] channel count, and operational restrictions are shown in table B.1.

Table B.1: Frequency bands, channel count, total capacity, and DFS requirements in Europe

Frequency Band	Channel Count	Total Capacity	DFS Requirements
5 150 MHz to 5 250 MHz	4	80 Mbit/s	None
5 250 MHz to 5 350 MHz	4	80 Mbit/s	DFS Required
5 470 MHz to 5 725 MHz	11	220 Mbit/s	DFS Required
5 725 MHz to 5 875 MHz	6	120 Mbit/s	DFS Required in the band 5 725 MHz to 5 850 MHz

Examining the table reveals that IEEE 802.11 [i.2] RLANs have a potential channel count of 25 channels, however, 20 channels are required to implement DFS, and thus could become unavailable at any point in time during a flight. It should be noted that airborne wireless IFE systems operated in the bands above will have a maximum EIRP of 200 mW (+23 dBm) if TPC is used, or 100 mW (+20 dBm) if no TPC is used.

B.3.2 Impact of DFS

DFS was designed assuming that RLAN networks would be fixed and terrestrial, leading to timing requirements which optimize the radar detection capability. An example of the timing requirements is a requirement to exclude use of a channel for 30 minutes if a radar has been detected in the given channel. For a typical terrestrial installation, it is unlikely that the RLAN would be able to detect more than a small number of radars. Likewise, it would be unlikely that the radar configuration would be dynamic, permitting the RLAN to determine the frequencies of any detected radars, and avoid those channels.

In an airborne platform, the situation is somewhat different. At altitude, the radio horizon is approximately 400 km in radius - a much larger radio horizon than a terrestrial installation. As a result, the RLAN has the potential of detecting a substantially larger number of radars at any given point in time, and in a larger number of channels simultaneously. Combined with the fact that the airplane is moving at approximately 1 000 km per hour, new radar detections can rapidly occur in numerous channels, requiring evacuation of the channel for 30 minutes. As a result, a significant number of IEEE 802.11 [i.2] channels could be unavailable for network use for significant amounts of time.

A number of flight tests have been conducted in western Canada and United States to assess the impact of DFS on installed RLANs, and to assess the performance of DFS in detecting radars. In figure B.1 the number of radar detections in each of a number channels observed in a single flight across Washington State, USA, is depicted. Noting that a cruise-phase flight across Washington takes approximately 30 minutes, one can conclude that seven 802.11 channels would be unavailable for IFE use during this period.

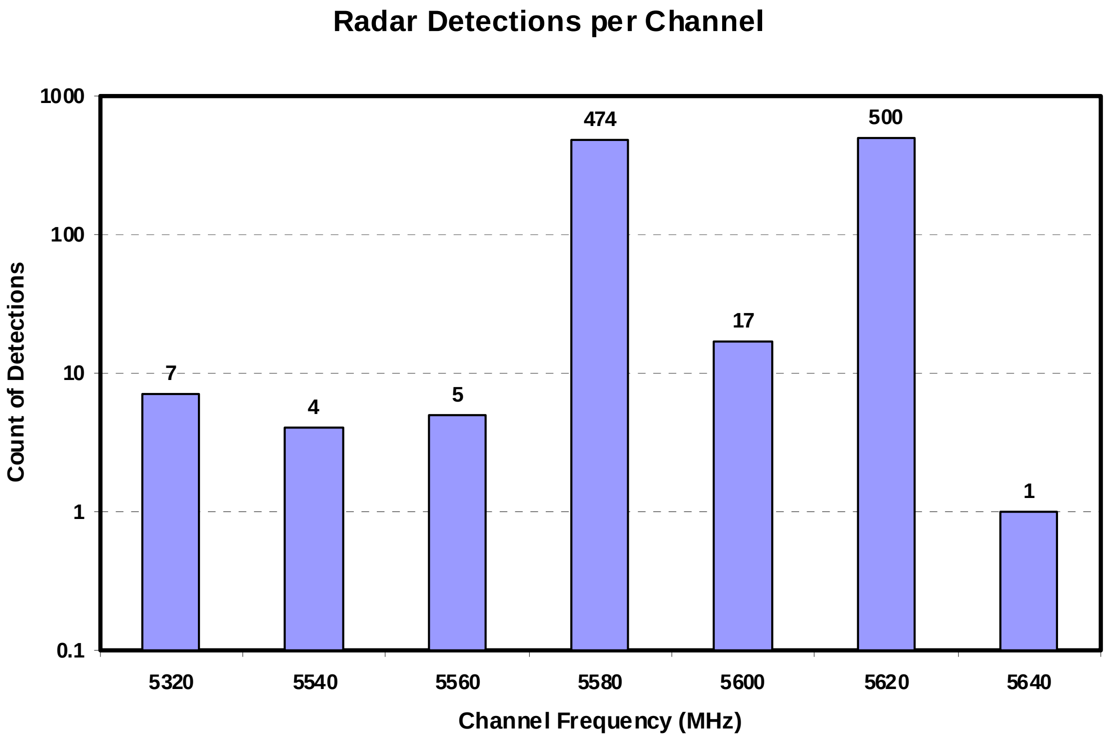


Figure B.1: Radar detections during test flight across Washington State, USA

Thus, in Washington (a state with only two military installations and sparsely populated eastern two-thirds of the state), the number of usable 802.11 channels is reduced from the nominal 25 to 18 total available channels. Assuming that the density of radars in Europe is no less than Washington, the potential for further reductions in channel availability is significant.

As a note, the results of this testing have also shown that the airborne RLAN can easily detect the radar long before the radar encounters interference [i.14], thus assuring radar operators that airborne systems will successfully detect radars and change channels prior to the interference threshold.

The conclusion which may be drawn from this testing and analysis is that despite having a fairly large number of channels hypothetically available for use, an airplane in flight could have a significant number of channels restricted from use due to DFS radar detections. Consequently sufficient spectrum, and number of channels, needs to be available to allow the RLAN to robustly maintain network performance while evacuating channels to avoid radar interference.

Annex C: Expected compatibility issues

C.1 Existing allocations

The European table of allocations for the frequency range of concern is as follows:

Table C.1: Excerpt of European table of allocations for the frequency ranges under discussion

Frequency band	Allocations	Applications
5 725,0 MHz to 5 830,0 MHz	Fixed Satellite (Earth-to-space) Radiolocation Amateur Mobile	Detection of movement (4 500,0 MHz to 7 000,0 MHz) Weather radar (5 250,0 MHz to 5 850,0 MHz) Amateur Radiolocation (military) (5 725,0 MHz to 5 850,0 MHz) ISM (5 725,0 MHz to 5 875,0 MHz) Non-specific SRDs (5 725,0 MHz to 5 875,0 MHz) RTTT (5 795,0 MHz to 5 805,0 MHz) RTTT (5 805,0 MHz to 5 815,0 MHz)
5 830,0 MHz to 5 850,0 MHz	Fixed Satellite (Earth-to-space) Radiolocation Amateur Amateur satellite (space-to-Earth) Mobile	Detection of movement (4 500,0 MHz to 7 000,0 MHz) Weather radar (5 250,0 MHz to 5 850,0 MHz) Radiolocation (military) (5 725,0 MHz to 5 850,0 MHz) ISM (5 725,0 MHz to 5 875,0 MHz) Non-specific SRDs (5 725,0 MHz to 5 875,0 MHz) Amateur satellite
5 850,0 MHz to 5 925,0 MHz	Fixed Fixed Satellite (Earth-to-space) Mobile	Detection of movement (4 500,0 MHz to 7 000,0 MHz) ISM (5 725,0 MHz to 5 875,0 MHz) Non-specific SRDs (5 725,0 MHz to 5 875,0 MHz) FSS Earth stations (5 850,0 MHz to 6 700,0 MHz)

The compatibility considerations should pay attention to military and meteorological radars in the band 5 250 MHz to 5 725 MHz, investigating the feasibility of operating DFS on onboard aircraft.

C.2 Coexistence and sharing issues

The following existing ECC reports might contain useful information when considering the proposals in the present document:

- ECC Report 68 [i.9] on compatibility studies in the band 5 725 MHz to 5 875 MHz between Fixed Wireless Access (FWA) systems and other systems.
- ECC Report 101 [i.10] on compatibility studies in the band 5 855 MHz to 5 925 MHz between Intelligent Transport Systems (ITS) and other systems.
- ECC Report 110 [i.11] on Compatibility studies between Broad-Band Disaster Relief (BBDR) and other Systems.
- ECC Report 109 [i.12] on the aggregate impact from the proposed new systems (ITS, BBDR And BFWA) in the 5 725 MHz to 5 925 MHz Band on the other services/systems currently operating in this band.

Additionally, the ECC Report 93 [i.13] (Compatibility between GSM equipment on board aircraft and terrestrial networks) might contain valuable information, e.g. information on aircraft fuselage attenuation.

In addition to the above, the following information is provided:

A significant amount of study has been devoted to assessing the compatibility between airborne RLANs and terrestrial systems. In many regulatory domains, the 5 150 MHz to 5 250 MHz band is limited to "indoor" use only, where "being indoors" was defined by the ITU as having an average of 17 dB attenuation in the RF propagation path. Both aircraft materials and entire aircraft have been tested and evaluated to determine the average RF path loss inside to outside of the fuselage across a variety of frequency ranges. The results have been shared with regulatory domains around the world, and aircraft are widely accepted as meeting the ITU definition of "indoors" environments, particularly in the 5 GHz band. Europe is among the many regulatory agencies which agree with this designation. See footnote 2 on page 3 of ECC Decision (04)08 [i.6] where it is written:

"Use of RLAN inside an aircraft is also considered to be an indoor use, due to the strong attenuation offered by the aircraft, their operational conditions, and taking account of the fact that the installation and use of RLAN equipment inside an aircraft is regulated by administrations due to the specific certification required from the relevant aviation authorities".

An analysis of the RF propagation shows that, for a 100 mW IEEE 802.11 [i.2] transmitter, the signal outside an airplane falls below the thermal noise floor in approximately 700 meters. This performance is depicted in figure C.1.

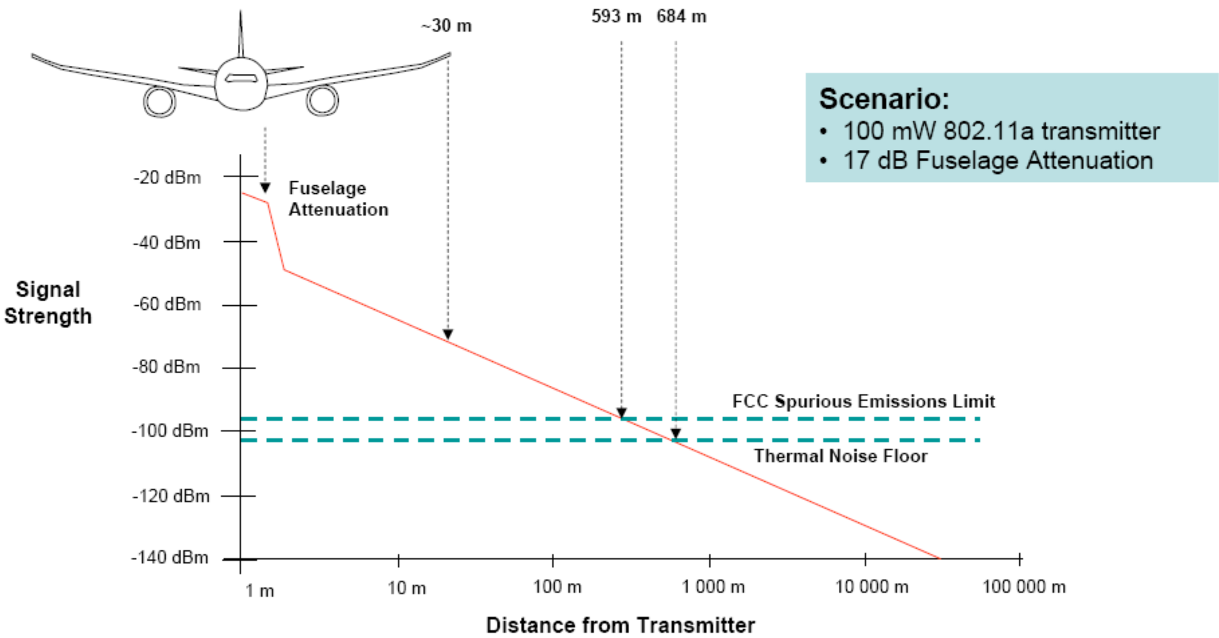


Figure C.1: Depiction of RF power as a function of distance from an airplane

In conclusion, an installed RLAN onboard an aircraft in flight is highly unlikely to pose interference risks to co-users of the spectrum at the proposed power levels of 20 dBm, 6 dB higher than the current limits.

C.3 Measurements of Aircraft Fuselage Attenuation at 5 GHz performed by Boeing

This clause summarizes the tests Boeing undertook in 2004 related to the measurements of aircraft fuselage attenuation in the 5 GHz band.

In summary, with this test campaign it was possible to establish that aircraft fuselage can provide average attenuation of 5 GHz signals in excess of 17 dB.

Discussion

The purpose of the measurements was to determine the average signal attenuation from passage through an airplane fuselage. Standard electromagnetic effects (EME) techniques and calibrated equipment were used by specially trained

Boeing engineers. These measurements indicate the magnitude and variations of fading that can be expected for signal transmission through a fuselage.

The test procedure compared the signal level at 27 points/location (see figure C.2) of a 5 GHz emitter located inside an aircraft (see figure C.3) to an emitter located in free space at the same height from the ground and at the same test locations.

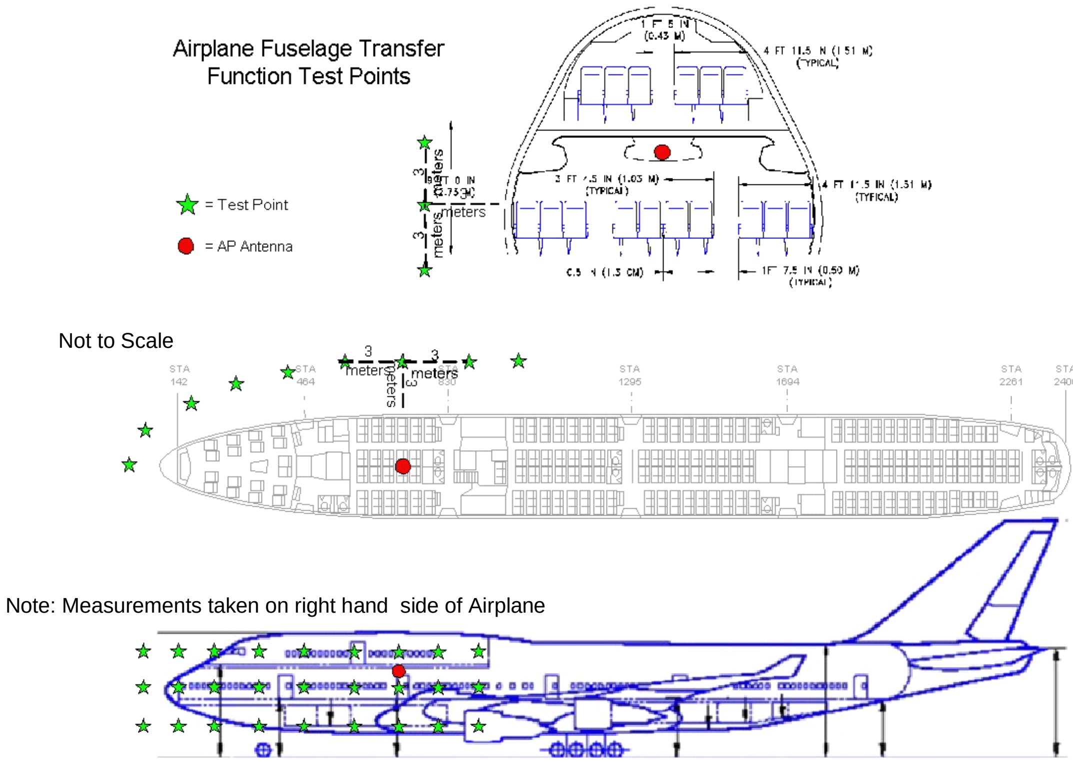
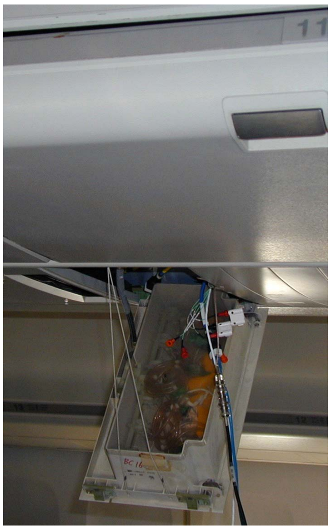


Figure C.2: Diagram showing position of 5 GHz access point emitter and the 27 test points



Antenna location in airplane in the same place the access point will be installed

Access point antenna used in the test

Figure C.3: Pictures showing access point emitter antenna installed inside aircraft

These tests were performed as follows:

- Through Airplane (figure C.4):
    - Aircraft parked in desert on a concrete platform in open space.
    - Aircraft was empty during test, in normal seat configuration, galleys, etc. Nobody was inside during testing.
    - All measurements were made by experienced Boeing engineers certified for making electromagnetic interference (EMI) measurements using special calibrated test equipment.
    - Installed an access point antenna in a typical airplane installation position, in the middle of the airplane in the overhead compartment.
    - Transmitted 15 dBm EIRP at 5,2 GHz using a Rhode Schwarz signal generator.
    - Measured distance directly to centre of access point antenna.
    - Measured the received power level outside the airplane 3 meters from the airplane fuselage at window level, at 3 meters above and at 3 meters below window height.
    - Measurements were taken at locations at 3 meter spacing from the airplane nose to the wing leading edge. Nine measurement locations at three different heights resulted in 27 data points.

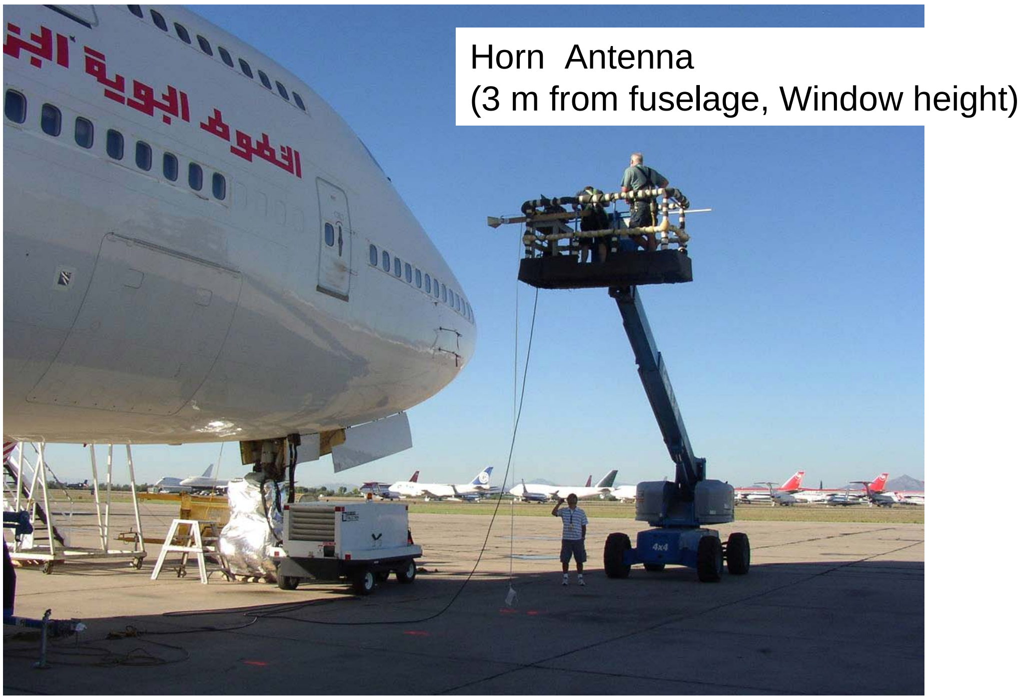


Figure C.4: Picture of measurements "Through Airplane"

- Free Space (figure C.5):
    - Removed the airplane.
    - Positioned the access point antenna and signal generator on forklift and raised to the same height and location as inside airplane tests.
    - Repeated all measurements in "free space".

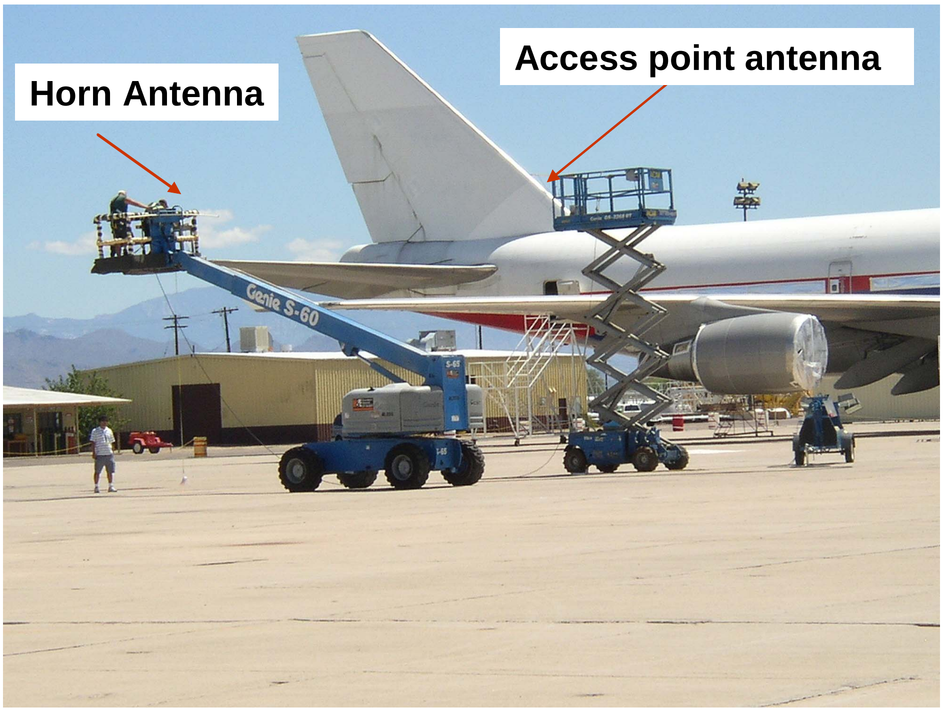


Figure C.5: Picture of measurements in "Free Space"

- Comparison of Measurements:
  - The "free space" measurements were compared with the "through airplane" measurement levels to obtain the fuselage attenuation at each measurement point.

Results of Measurements

After the comparison between the 27 data points in the two configurations, i.e. with and without the aircraft, the calculated average loss over the 27 points through the airplane fuselage was measured to be 17,3 dB (median 19,3 dB).

These results show that 5 GHz wireless systems operating inside an aircraft should be considered to be operating in an indoor environment.

C.4 Measurements of Aircraft Composite Fuselage Attenuation at 5 GHz

Because new Boeing aircraft (Boeing is developing a new aircraft 787 with composite fuselage) will have a fuselage made of composite materials, tests have been performed to determine the attenuation characteristics of this type of fuselage in the 5 GHz band.

For these tests a comparison between a normal aluminium aircraft door and a composite fuselage were made.

These doors were mounted in the wall between two RF screened rooms and a test signal was generated one of the rooms. Then the signal level was measured in the adjacent screened room with the aircraft door closed and sealed. It was found that the attenuation of the aluminium fuselage was greater than 30 dB in the 5 GHz band.

With a similar test set-ups using the composite material itself found that the attenuation of the test signal is similar to that of aluminium, with greater than 50 dB of attenuation.

Additionally, since on the Boeing 787 its windows are larger than a normal aircraft and are also shielded, the tests above have also shown that the attenuation of these windows will be greater than 30 dB.

In conclusion, future Boeing aircraft fuselage will be made of a composite material that has been tested to measure its RF shielding effectiveness. The tests show that the composite material will attenuate RF signals as effectively as an aluminium fuselage at frequencies in the 5 GHz band.

Annex D: Proposed new Annex 3 to 70-03

Annex 3 Wideband Data Transmission systems

Scope of Annex

This annex covers frequency bands and regulatory as well as informative parameters recommended for Wideband Data Transmission Systems and Wireless Access Systems including Radio Local Area Networks (WAS/RLANs) (formerly known as Radio Local Area Networks (RLANs)) within the band 2400-2483.5 MHz and for Wireless Access Systems including Radio Local Area Networks (WAS/RLANs) within the bands 5150-5250 MHz, 5250-5350 MHz, 5470-5725 MHz, 5725-5875 MHz and 17.1-17.3 GHz.

Regulatory parameters related to Annex 3

	Frequency Band	Power	Duty cycle	Channel spacing	ECC/ERC Decs	Notes
a	2400 - 2483.5 MHz	100 mW e.i.r.p.	No Restriction	No spacing	ERC/DEC/(01)07	For wide band modulations other then FHSS (e.g. DSSS, OFDM, ..), the maximum e.i.r.p. density is limited to 10 mW/1 MHz
b	5150 - 5250 MHz	200 mW Max mean	No Restriction		ECC/DEC/(04)08	Restricted to indoor use. The maximum mean e.i.r.p. density shall be limited to 0.25 mW/25 kHz in any 25 kHz band.
c	5250 - 5350 MHz	200 mW Max mean	No Restriction		ECC/DEC/(04)08	Restricted to indoor use. The maximum mean e.i.r.p. density shall be limited to 10 mW/MHz in any 1 MHz band.
d	5470 - 5725 MHz	1 W Max mean	No Restriction		ECC/DEC/(04)08	Indoor as well as outdoor use allowed. The maximum mean e.i.r.p. density shall be restricted to 50 mW/MHz in any 1 MHz band.
e	5725 - 5875 MHz	200 mW Max mean	No Restriction		T.B.D.	Restricted to onboard aircraft use. The maximum mean e.i.r.p. density shall be limited to 10 mW/MHz in any 1 MHz band.
f	17.1 - 17.3 GHz	100 mW e.i.r.p.	No Restriction	No spacing		

Additional Information

Harmonized Standards

EN 300 328 sub-band a)

EN 301 893 sub-bands b), c) and d)

sub-band e): the requirements when operating in the 5725 to 5850 MHz band are identical to the technical requirements included in EN 301 893 for the band 5250-5350 MHz. The requirements when operating in the 5850 MHz to 5875 MHz band are identical to the technical requirements included in EN 301 893 for the band 5150-5250 MHz with the addition of TPC.

Frequency issues

Wireless Access Systems including Radio Local Area Networks (WAS/RLANs) within the bands 5250-5350 MHz and 5470-5725 MHz shall only be allowed to operate when the mandatory features required in the ECC Decision (04)08 are implemented.

Wireless Access Systems including Radio Local Area Networks (WAS/RLANs) within the band 5725-5850 MHz shall implement TPC and DFS similar the requirements for the band 5250-5350 MHz.

Technical parameters also referred to in the harmonized standard.

The power level for band b, c, d and e refers to Maximum mean e.i.r.p. The mean e.i.r.p. refers to the highest power level of the transmitter power control range during the transmission burst if transmitter power control is implemented.

Annex E: Sample list of countries around the world where access to 5 725 MHz to 5 875 MHz by airborne IFE systems is allowed

Table E.1

AUSTRALIA	SOUTH AFRICA
BAHRAIN	SOUTH KOREA
BARBADOS	SAUDI ARABIA
BRAZIL	SINGAPORE
BRUNEI	SRI LANKA
CANADA	UNITED ARAB EMIRATES
COLOMBIA	UNITED STATES
COSTA RICA	VENEZUELA
ECUADOR	VIETNAM
EGYPT	
EL SALVADOR	
HONG KONG	
INDIA	
JAMAICA	
JORDAN	
KENYA	
LEBANON	
MALAYSIA	
MALDIVES	
MEXICO	
MOROCCO	
NEW ZEALAND	
NIGERIA	
OMAN	
PAKISTAN	
PANAMA	
PERU	
PHILIPPINES	

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