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Technical Report

Electromagnetic compatibility and Radio spectrum Matters (ERM); System Reference Document; Technical characteristics for airborne Ultra-WideBand (UWB) applications operating in the frequency bands for 3,1 GHz to 4,8 GHz and 6 GHz to 8,5 GHz

Reference

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Foreword

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

Introduction

Use of wireless UWB communications in airborne platforms offers significant advantages to operators of aircraft by increasing operational flexibility while reducing costs.

The document is intended to also help to find solutions on this subject by defining the spectrum needs for airborne UWB applications.

The EC funded FP 7 European R&D Project EUWB [i.6] has work package 8A on airborne UWB applications and work package 9 dedicated to standardization and regulation.

The purpose of producing the present document is to lay a foundation for industry to quickly bring innovative and useful products to the market while avoiding harmful interference with other services and equipment.

1 Scope

The present document provides information on radio frequency usage for airborne Ultra Wide Band (UWB) applications.

These airborne UWB applications are operating in the frequency range from 3,1 GHz to 4,8 GHz and from 6 GHz to 8,5 GHz.

The operating radio link distance is limited typically to a maximum of about 30 m.

Airborne UWB devices may be installed onboard an aircraft or may form an integral part of other portable electronic equipment carried by the passengers, such as future generation cellular phones equipped with UWB enabled Bluetooth V 3.0.

The present document 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 (see annex A).
- Technical information (see annex B).
- Expected compatibility issues (see annex C).

The present document does not cover equipment compliance with relevant civil aviation regulations. In this respect, an installed wireless airborne UWB-based communications is subject to additional national or international civil aviation airworthiness certification, for example to EUROCAE ED-14E [i.5].

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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  - for informative references.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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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] CEPT/ECC Report 64: "The protection requirements of radiocommunications systems below 10,6 GHz from generic UWB applications", Helsinki, February 2005. .

[i.2] CEPT/ERC Report 25: "The European table of frequency allocations and utilisations covering the frequency range 9 kHz to 3000 GHz - Lisboa 02- Dublin 03- Kusadasi 04- Copenhagen 04- Nice 07- Baku 08". .

[i.3] CEPT/ECC/DEC/(06)04: "ECC Decision of 24 March 2006 amended 6 July 2007 at Constanta on the harmonised conditions for devices using UWB technology in bands below 10,6 GHz".

[i.4] CEPT ECC/DEC/(06)12: "ECC Decision of 1 December 2006 amended Cordoba, 31 October 2008 on supplementary regulatory provisions to Decision ECC/DEC/(06)04 for UWB devices using mitigation techniques.

[i.5] EUROCAE ED-14E (2005) (Equivalent to RTCA DO-160E): "Environmental Conditions and Test Procedures for Airborne Equipment".

[i.6] EUWB consortium.

NOTE: Available at http://www.euwb.eu.

[i.7] CEPT ECC Report 93: "Compatibility between GSM equipment on board aircraft and terrestrial networks".

[i.8] NASA/TP-2005-213606 (Vol. 1): "UWB EMI To Aircraft Radios: Field Evaluation on Operational Commercial Transport Airplanes". Ely, J.J. Martin, W.L. Fuller, G.L. Shaver, T.W. Zimmerman.

[i.9] ETSI EN 302 065: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Ultra WideBand (UWB) technologies for communication purposes; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

[i.10] IEEE 802.15.4a (August 2007): "Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low-Rate Wireless Personal Area Networks (WPANs) - Amendment 1: Add Alternative PHYs".

[i.11] ECMA 368 (3rd edition, December 2008): "High Rate Ultra Wideband PHY and MAC Standard".

[i.12] ECMA 369 (3rd edition, December 2008): "MAC-PHY Interface for ECMA-368".

[i.13] ETSI TR 102 631 (V1.1.1): "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".

[i.14] FCC 03-33: "Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems".

[i.15] ACARE (Advisory Council for Aeronautics Research in Europe): "Strategic Research Agenda", (published in 2004 and amended in 2008).

3 Definitions, symbols and abbreviations

3.1 Definitions

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

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 Symbols

For the purposes of the present document, the following symbol applies:

c	velocity of light in a vacuum

3.3 Abbreviations

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

ACARE	Advisory Council for Aeronautics Research in Europe
AP	Access Point
AVOD	Audio/Video on Demand
BW	BandWidth
CEPT	Conference Europeenne des Administrations de Postes et des Telecommunications
CMS	Cabin Management System
CVMS	Cabin Video Monitoring System
DAL	Design Assurance Level
dBm	deciBel relative to 1 mW
DL	DownLink
ECC	Electronic Communications Committee
EMI	ElectroMagnetic Interference
ERC	European Radiocommunications Committee
ERM	Electromagnetic compatibility and Radio spectrum Matters
HDR-LT	High Data Rate - Location Tracking
IFE	In-Flight Entertainment
ITU	International Telecommunication Union
IU	Illumination Unit
LDC	Low Duty Cycle
LDR-LT	Low Data Rate - Location Tracking
LT	Location Tracking
MBOFDM	Multi-Band Orthogonal Frequency Division Multiplexing
PA	Passengers Announcement
PAX	PAssenger
PSU	Passenger Service Unit
RF	Radio Frequency
SEB	Seat Electronic Box
UL	UpLink
USB	Universal Serial Bus
UWB	Ultra Wide Band
VHF	Very High Frequency

4 Executive summary

4.1 Comments on the System Reference Document

No statements have been received on the present document yet.

4.1.1 Status of the System Reference Document

The present document has been created by TC ERM TG31A. It was in ETSI internal consultation and, in parallel, already submitted to ECC (WGFM and WGSE) for information. Comments from the consultation were considered and resulted in a revised draft document. Final approval for publication of the present version is expected for ERM#37. The final document will be submitted to WGFM and WGSE for their considerations.

Table 4.1: Documnt status

Target version	Pre-approval date version				
V1.1.1	**a**	**s**	**m**	**Date**	**Description**
V1.1.1	0.0.1			5th October 2008	First version chairman TG31A
V1.1.1	0.0.2			5th December 2008	Second version chairman TG31A based on input from EUWB [i.6] project
V1.1.1	0.0.3			8th December 2008	Third version from ERM TG31A#25 discussions
V1.1.1	0.0.4			17th December 2008	Fourth version after confirmation from EADS/Airbus and EUWB - for submission to ERM
V1.1.1	0.0.5			18th February 2009	Resolution of comments received from MINEA-NL as well as Bosch and EADS (on WAIC clarification) - version for submission to ERM#37

4.2 Market information

There are four main application fields for airborne UWB:

- The Cabin Management System (CMS) application field.
- Passenger communication and in-flight entertainment.
- Mobile devices which will become part of the future cabin equipment for crew or maintenance staff.
- Communication headsets for pilots in the cockpit to ground and for the flight crew.

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.

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 increase 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.

Currently pilots use wired headsets to communicate to ground stations. Use of wireless headsets will increase the pilot freedom of movement, comfort and increase efficiency. This application specifically calls for the use of UWB due to high interference immunity in existing avionics/navigations equipments.

Medical emergency headsets or biometric data systems will help in-flight crew assist an unexpected emergency, where flight crew need to communicate via aircraft systems to get urgent medical assistance from ground. This application can be design as a part of the CMS or part of the pilot to ground communication system.

UWB technology is only used for wireless communication inside the aircraft. The connection to the outside world will be provided with the normal aircraft communication means as usual.

All of the above described use cases need high reliable, low latency, and robust communications. The large channel capacity provided by UWB technology facilitates the employment of highly redundant, interference-robust and encrypted communications which are considered to not affect other electronics inside the Aircraft.

Nevertheless, the envisaged applications do not plan to use UWB technology for safety- relevant system components or avionic equipments which are being contemplated in the discussions on WAIC systems (Wireless Avionics Intra-Communications) in CEPT/WGFM and ITU-R WP5B.

For detailed market information see annex A.

4.3 Technical system description

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 is needed 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.

The aggregated total application bandwidth needed for new larger aircraft such as the A380 will exceed 800 Mbit/s.

In the aircraft environment the envisaged applications range from location and tracking to signalling and data communication. The spectrum masks, the mitigation techniques and activity factors which will be implemented are thought to be compatible with ECC Decisions [i.3] and [i.4]. Both options for LT are still considered, LDR-LT based on pulsed transmissions (similar to IEEE 802.15.4a [i.10]) as well as HDR-LT based on MBOFDM (similar to ECMA 368 [i.11]).

Usage of UWB in portable devices can be predicted for the future, as UWB devices will be widely used. Normally it will not be possible to enforce the use of UWB devices onboard an aircraft. The only possible technical way to control the UWB devices on board is to use the fixed installation of UWB base stations to control the portable UWB devices and put them into in-flight mode.

In in-flight mode, the on board systems can monitor the signal power levels and indicate non-compliant UWB devices. In this mode critical communication such as medical/ safety emergencies and pilot to crew and ground communications is given precedence to other entertainment/ business communications.

For detailed technical information see annex B.

4.4 Compatibility Issues

It is expected that new ECC studies will be based on existing material from ECC Report 64 [i.1] with additional dedicated consideration on airborne UWB usage.

Tests performed by Boeing in 2004 [i.13] related to the measurements of aircraft fuselage attenuation in the 5 GHz band showed results that the aircraft fuselage can provide average attenuation of 5 GHz signals in excess of 17 dB. This information was recently given to CEPT/ECC-SE24 when having studied usage of 5 GHz frequencies for airborne usage. Those tests were already performed on the new aircraft 787 with composite fuselage. Comparison between a normal aluminium aircraft door and a composite fuselage was also made and it was found that the attenuation of the aluminium fuselage was greater than 30 dB in the 5 GHz band. 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.

The study done by NASA [i.8] concluded that use of UWB at the FCC regulated levels [i.14] do not impede system such as Very High Frequency Communication, VHF Omni Ranging- navigations aid, Instrument Landing System Localizer, Instrument Landing System Glideslope, Distance Measuring Equipment and Air Traffic Control Radio Beacon System.

Consequently, airborne UWB can be considered to be operating in an environment comparable to indoors.

4.5 Enforcement Issues

One can foresee enforcement challenges for the future when UWB air interfaces will be implemented in mobile phones or laptops (e.g. wireless USB). The present document is intended to also help to find solutions on this subject by defining the spectrum needed for airborne UWB applications.

5 Current regulations

There is no regulation permitting the use of airborne UWB devices in aircraft and other airborne platforms.

Concerning the application of UWB devices installed in "aircraft" no dedicated coexistence investigations have been performed by ECC so far and therefore it is by default not allowed at this moment. However, ECC TG3 recommended that ETSI should release an ETSI System Reference Document to trigger investigation of potential coexistence issues targeting the application of UWB installed inside "aircrafts". The present document is the response to that recommendation.

6 Proposed regulations

Based on the needs of the intended applications described in the scope of the present document, the following limits for airborne UWB are proposed as shown in table 6.1.

Table 6.1: Proposed limits for equipment

Frequency	Area of operation / Category	Maximum Average power density (EIRP) (dBm/MHz)
3,1 GHz to 4,8 GHz	LT and communications inside an aircraft	-41.3 dBm/MHz and using LDC
6,0 GHz to 8,5 GHz	LT and communications inside an aircraft	-41,3 dBm/MHz

LDC use is defined as in the amended ECC Decision (06)12 [i.4].

Licence-exempt regulation is proposed.

As depicted in clause 4.4 of the present document, airborne UWB can be considered to be comparable to an indoor environment.

7 Main conclusions

Airborne UWB may be used for communications and location tracking purposes in several application fields (cabin management, in-flight-entertainment, short range communication for crew and other onboard an aircraft purposes).

It will help to reduce the weight of the electrical harness of an aircraft, leading to decreased fuel burn, lower number of connectors with resulting reliability and flexibility increases.

Nevertheless, the envisaged applications covered by the present document do not plan to use UWB technology for safety- relevant system components or avionic equipments which are being contemplated in the discussions on WAIC systems (Wireless Avionics Intra-Communications) in CEPT/WGFM and ITU-R WP5B.

Airborne UWB can be considered comparable to an indoor environment and does not a-priori lead to an increased risk of interference to other outdoor radio services and applications.

The subject is also studied in the EU project EUWB [i.6].

Defining the spectrum needed for airborne UWB applications will help reduce the inevitable enforcement issue since UWB air interfaces will be in use in the future in devices such as mobiles and laptops.

The UWB frequency ranges covered by the existing regulation for UWB are proposed to also be used by airborne UWB applications.

The communication/entertainment devices used inside the aircraft are considered to not interfere with the avionics/navigation equipments. This will be confirmed independently by organizations responsible for these avionic security aspects. As a technology, UWB provides very low power transmission solutions, which are ideal for this application.

8 Expected ECC, EC and ETSI actions

8.1 Expected ECC and EC actions

ETSI requests ECC to consider the present document, which includes necessary information under the MoU between ETSI and the ECC for airborne UWB equipment.

ETSI asks CEPT-ECC to perform the relevant compatibility studies to determine whether the emissions of airborne UWB applications as described in the present document are appropriate to protect other outdoor radio services not previously covered in ECC reports. An amendment of the existing ECC Deliverables [i.3] and [i.4] may be envisaged by end of 2009.

Expected EC action is a revision of the existing EC Decision [i.7] or a new dedicated EC Decision for airborne UWB applications.

8.2 Expected ETSI actions

Mandate M/407 was received by ETSI, calling for release of Harmonized Standards for UWB.

The creation of a flight mode in the air interface specification, e.g. Wimedia protocol, may also be envisaged. ETSI has a MoU with Wimedia.

The EC funded FP 7 European R&D Project EUWB has work package 8A on airborne UWB applications and work package 9 dedicated to standardization and regulation. This work may also provide additional information on the number of devices and their expected usage profile in the aircraft as well as technical support for the ETSI standardization process.

Airborne UWB devices are to be covered in a Harmonized European Standard. It may be covered by a future revision of EN 302 065 [i.9].

Annex A: Detailed market information

A.1 Range of applications

This clause describes the four main fields of application in which the use scenarios are identified.

The Cabin Management System (CMS) application field refers to all core services and functions of the cabin. It includes among others passenger audio announcement services, reading lights, passenger call signs, passenger information displays, cabin illumination and light control units, monuments (light dome, bar, mobile office corner, lavatories, galleys), emergency lights (floor path marking, exit signs, etc.), sensors (temperature, pressure, etc.), wireless info displays, wireless crew services such as crew intercommunication and wireless cockpit alert. An important part of the future CMS is the cabin security system which includes video monitoring system, aircraft access control and staff location and tracking.

The second application field is passenger communication and in-flight entertainment which includes all the services which are directly addressed to the passenger to enable an improved comfort experience like high definition video- or audio-on-demand and internet/intranet connectivity services for e-mail, internet surf, information about flight status (position, speed, weather, etc.), information about the destination place and services such as hotel booking, rental cars, restaurants, etc.

The third application field is critical communication headsets. The pilots to ground communication need to be extremely robust, secure and have low latency. Nowadays, wired communication is chosen due to these criteria and in the near future it will be replaced with wireless UWB communication systems. The benefit will be an increase of flexibility, freedom and efficiency of the pilot and crew personal. The large bandwidth and low emissions used by UWB technology make it the only viable option due to immunity needed in the cockpit environment.

The last application field addresses the mobile devices which could be part of the future cabin equipment such as a mobile wireless flight attendant device for crew or maintenance staff, a wireless trolley or a crew wireless communication terminal.

A.1.1 Cabin Management System

The Cabin Management System provides the core services and functions inside the cabin. In the next two clauses first the current CMS implementation will be described and later the advantages of extending it through the wireless technology will be explained providing an overview of the functions which could take advantage of a wireless network infrastructure.

A.1.2 Wireless Cabin Management System

The current CMS do not have any wireless function and the network is based on a star topology. This implies a large number of cables and a high effort for the system installation and its maintenance. Extending the current CMS through a wireless infrastructure for the flexible wireless connection of wireless devices would enable an increased possibility to customize the cabin layout and the service available to the client specific needs and make possible at the same time a fast reconfiguration of the cabin layout to react to the passenger requests (e.g. increase the number of business class seats by removing economy class seats). The block diagram in figure A.1-1 shows a general network architecture which provides wireless connectivity for fixed installed and mobile devices. In order to increase the reliability and availability of the system, dual mode transceivers will have to be used in order to have a redundant link in case of Access Point (AP) failure, interference other link problems.

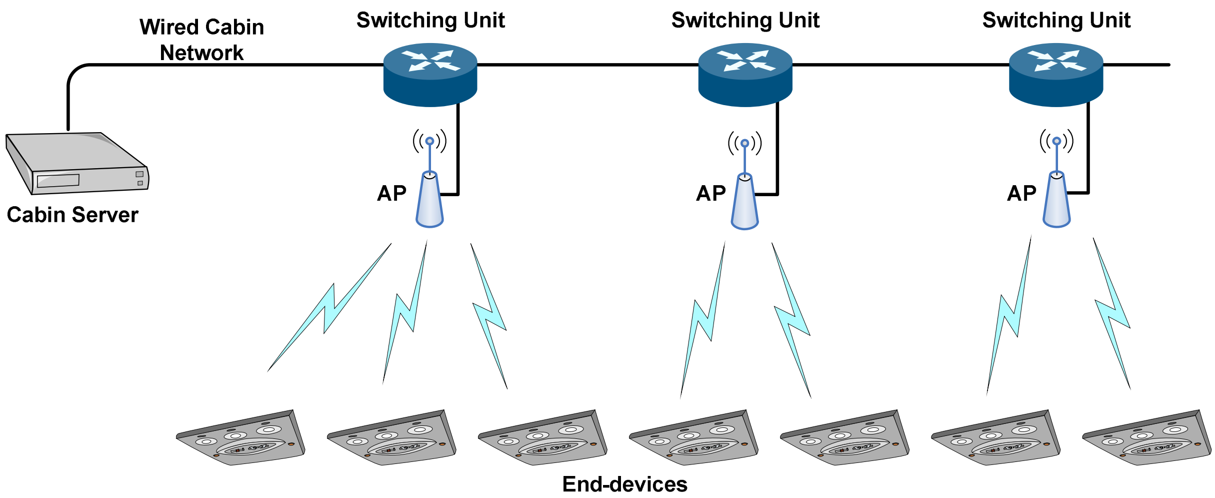

Figure A.1-1: Block diagram of Wireless Cabin Management System

The following functions and applications are seen as potential candidates to be provided and supported by the CMS wireless extension:

1) Wireless PSU (Passenger Service Unit) including:
   - PA (passengers announcement) and audio.
   - Reading light.
   - PAX (passenger) call.
   - Signs and PAX information display.
2) Wireless illumination-/ light control units including:
   - Control and monitoring of general Illumination Units (IUs).
   - Spot lights, signs, stairs.
   - Monuments (light dome, bar, mobile office corner, lavatories, galleys).
   - Emergency lighting (floor path marking, exit signs, etc.).
3) Wireless sensors (e.g. temperature, pressure, etc.).
4) Wireless info displays.
5) Wireless crew services:
   - Crew intercom and cockpit alert.
6) Cabin security system including:
   - Wireless CVMS.
   - A/C (Aircraft) access control, staff location & tracking.
7) Contact-less passenger seat or other electronic devices.

A.1.3 Passenger communication and IFE

The In-Flight Entertainment (IFE) system in aircraft is currently based on wired connections with disadvantages in terms of low flexibility, considerable weight, and high installation costs. These disadvantages could be eased by the implementation of a wireless IFE system. However, the high demands on data distribution capacity for Audio/Video On Demand (AVOD) in a large aircraft with many passengers/users, as well as the fact that the system is operable worldwide, has made it difficult to find a wireless solution.

Classical IFE system overview

As a background to the following descriptions it can be mentioned that an IFE system traditionally consists of:

- An IFE Centre with media and file servers and Ethernet switches.
- An IFE distribution network from the IFE centre to the seats.
- Passenger In-seat equipment connected through the Seat Electronic Box (SEB).
- Overhead video display units.
- An IFE control panel located within a Remote Control Centre for Cabin Crew control and operations.
- A schematic of a traditional IFE system is depicted in figure A.1-2.

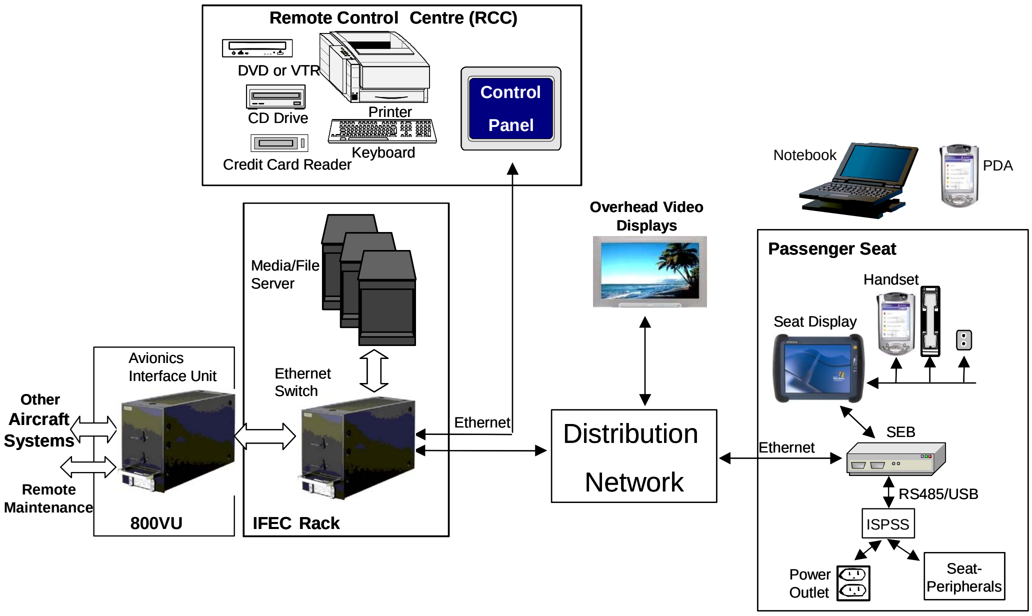

Figure A.1-2: Schematic of a traditional IFE System

The IFE cabin distribution network, installed throughout the cabin, connects the IFE Centre with the cabin area. Figure A.1-3 gives an idea of the complexity of the wiring needed in a traditional wired IFE data distribution network. The dashed lines indicate options for redundant data distribution at seat level.

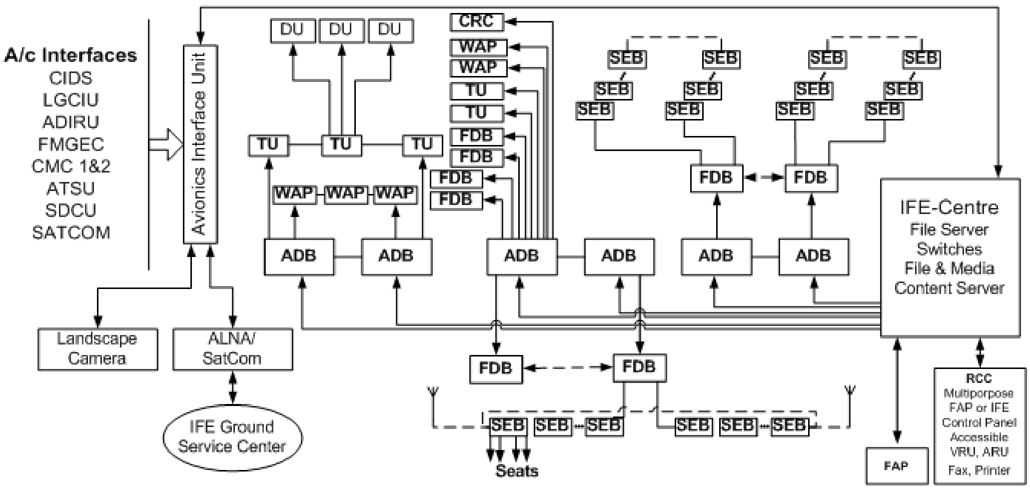

Figure A.1-3: Architecture of a classical wired IFE Data Distribution Network

A.1.4 Mobile Devices

The availability of a reliable and powerful wireless access infrastructure inside the aircraft cabin with localization capabilities opens the possibility for new types of cabin devices and functions for an increased level of services, comfort and security. Mobile devices would extend the availability of functions for the cabin crew to the entire cabin surface and thus increase their efficiency and save cost for the airlines. Figures A.1-4 and A.1-5 show some prototypic examples of these new kinds of cabin devices.

Figure A.1-4: Prototype of a wireless Flight Attendant Panel Terminal

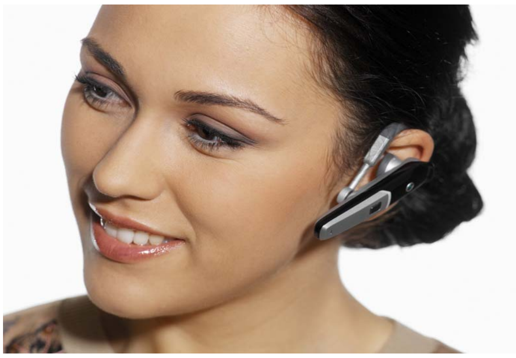

Figure A.1-5: Example of wireless crew communication terminal

The same wireless infrastructure could be used as well to connect mobile maintenance terminals to the aircraft network. Figure A.1-6 shows a prototype of a mobile wireless maintenance terminal developed by EADS.

Figure A.1-6: Prototype of a mobile maintenance terminal

A.1.5 Critical communication headsets for pilots

The UWB headset can be used by pilots and co-pilots to communicate to ground and in-flight crew. These units transmit very low emission signals that can be used inside an aircraft cockpit without affecting avionics. This communication system replaces the traditional wired headsets used inside aircrafts. The basic concept and functional block diagrams are shown in figures A.1-6, A.1-7 and A.1-8 respectively.

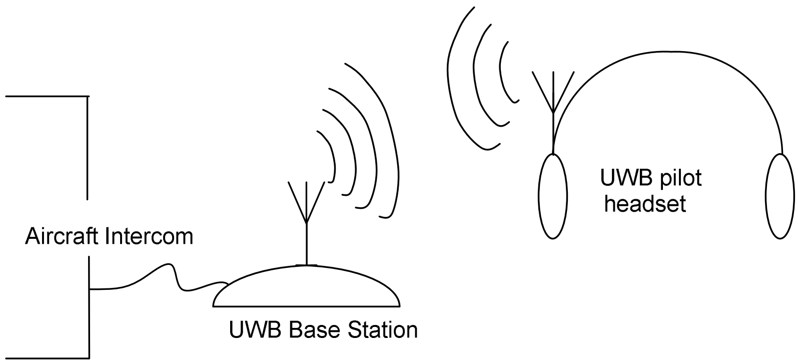

Figure A.1-7: Basic concept diagram of an UWB pilot headset system

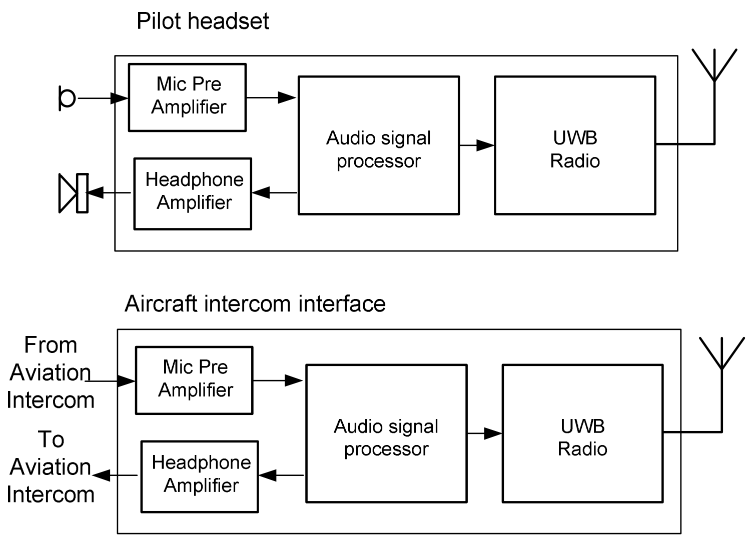

Figure A.1-8: Functional block diagram of t an UWB pilot headset system

A.2 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 consumption, 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.2.1 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 at least 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 operates several airplanes, the savings run into the millions of Euros per year due to reduced fuel burn.

A.2.2 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 components of a wired system are 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 are 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.3 Traffic evaluation

The total bandwidth needed for new larger aircraft such as the A380 will exceed 800 Mbit/s for in-flight entertainment applications.

UWB location tracking and data communication in aircrafts: in the aircraft environment the envisaged applications range from location and tracking to signalling and data communication. The spectrum masks, the mitigation techniques and activity factors which will be implemented are thought to be compatible with ECC Decisions [i.3] and [i.4]. Both options for LT are still considered, LDR-LT based on pulsed transmissions (similar to IEEE 802.15.4a [i.10]) as well as HDR-LT based on MBOFDM (similar to ECMA 368 [i.11] and 369 [i.12]).

Location and sensor system devices are generally required to be very low powered and zero-maintenance (with battery lifetimes of several years), and so tend to have inherently **relatively low activity factors.**

In summary, UWB location tracking and sensor systems are primarily to be used on moving platforms, which have indoor like parameters, by nomadic users, and are likely to have relatively low activity factors and duty cycle.

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 take-off. 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 take-off. Both of these uses of IFE on the ground are generally restricted to a single channel of content, and thus have limited network bandwidth needed.

- **At Cruise:** This is the most common use of IFE, after the aircraft has reached a high altitude, and the crew member 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 needed for conveying the content to the passenger increases.

Annex B: Technical information

B.1 Technical description

B.1.1 Transportation Systems (aircraft)

The Advisory Council for Aeronautics Research in Europe (ACARE) indicated in the latest Strategic Research Agenda [i.15] that future aircraft will have to be lighter, more flexible, more efficient, safer, easier and cheaper to maintain.

The following points have been indicated as crucial in the development of next generation aircrafts:

Environment friendly aeronautic transportation:

- Component energy consumption and weight reduction.

Increase of transportation capacity:

- Turn-around time < 10 min.
- Cabin layout change (e.g. seat-class change, introduction of new seat rows) < 30 min.
- Devices reconfiguration 50 % faster and cheaper.
- No maintenance during turn-around time by predictive system health monitoring.

Safe and passenger friendly cabin:

- Large number of sensors required to detect danger or uncomfortable conditions.
- High reliable cabin infrastructure.

Efficient Aircraft:

- Commonalities between different aircraft families (i.e. reconfigurable and flexible devices are required).
- Reduce assembly, direct maintenance and operation costs.
- Reduce time required to implement customer specific needs.

Therefore a wireless infrastructure providing location & tracking and data communication capability for devices and sensors is essential to enable the achievement of the previously indicated targets. Wirelessly connected seats, Passenger Service Unit (PSU) and other devices could be added, moved, removed or replaced much faster than in the case of wired network, also considering the fact that the installation of additional cables for any possible configuration would be impossible. The use of wireless technologies would in addition eliminate the need for data connectors, i.e. no wear parts and fewer actions by hand reducing radically the time for aircraft cabin reconfiguration and cabin layout change.

Such a wireless infrastructure should be also able to automatically localize each seat, PSU or any other wireless device in order to allow fully automated identification of the cabin layout and generation of a look-up table that associates each seat number or system device with the MAC and IP address of the wireless transceiver related to it (e.g. UWB transponder, wireless sensors, wireless controlled reading light panel etc., wireless sign, etc.).

Each seat is provided with a transceiver that will have to be localized by at least 3 anchors.

The UWB infrastructure could be then also used for the following applications:

- tracking of attendants and catering trolleys for increasing service level and coordination of the work of crew members;
- low data rate wireless communications inside the cabin.

The UWB technology has been identified as the only one which is able to provide the required accuracy for localization and tracking together with the data communication functionality and low power operation. This would enable to use one infrastructure for different applications which would normally require multiple systems working in parallel.

The aim of this application is to provide higher flexibility and lower operational costs for aircraft cabin reconfiguration, reducing radically the time for cabin layout change.

The figure B.1-1 shows the wireless system inside the cabin.

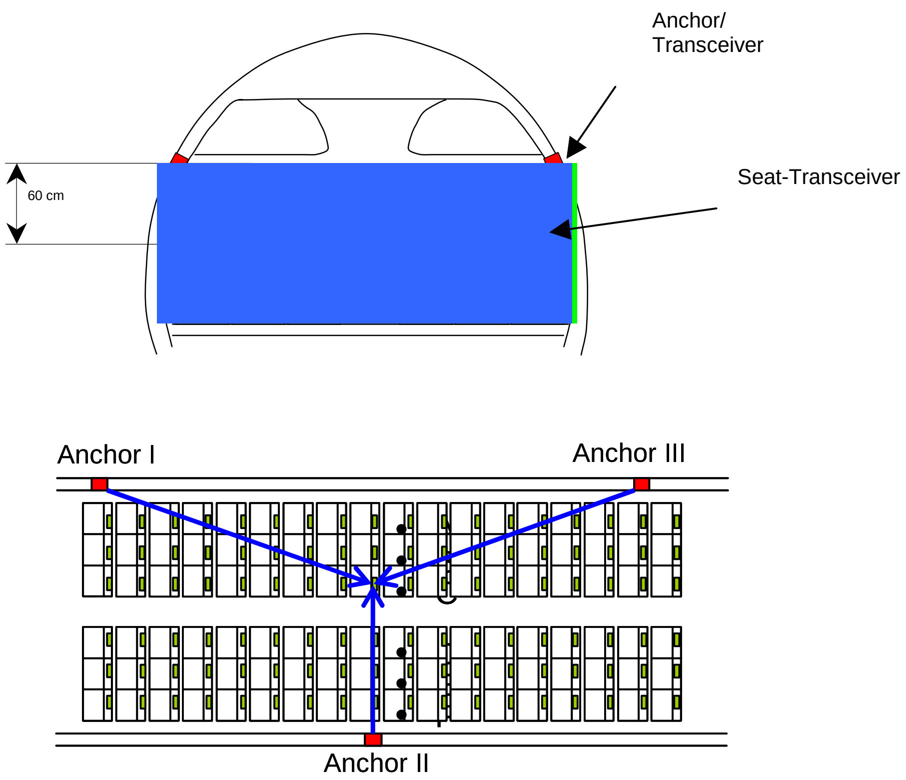

Figure B.1-1: Wireless System inside Cabin

B.2 Basic Demand

The general spectrum requested is driven by two demands. The first one is the certification of the aircraft. Before the aircraft can be used commercially it is certified by the aviation authorities. This demand is the most stringent one, as without a chance of certification the results of this project become meaningless for this application. Therefore the system is designed to meet the expectations of the authorities. But for new technologies there is no reference of allowed or critical implementations. The best approach is to guarantee the same reliability demands as an already certified system does. These demands depend on the Design Assurance Level (DAL) of the involved components or features.

The second major demand for the application is that it is usable worldwide. This means it meets the regulations of every country for aircrafts and for radio usage. Two possible approaches exist for this demand. Either the system can use the same frequencies and transmission powers throughout the world, or it automatically adapts its spectrum usage mask for each country. The latter approach is less preferable, as it increases the complexity of the system. The system would have to check permanently its current location and height to adapt every network receiver to the new regulations. Hence a consistent range of usable frequencies for the system is desired. With the current emission mask for Europe only one band group can be used completely and only four bands in total. Due to the multi-cell architecture a larger number of bands is desirable. Hence a detection and avoidance mechanism is preferred.

Besides the two general demands there are also requirements for the network resulting from the aspired system. These include the number of nodes, achievable data rates, device localization, reliability and redundancy.

B.2.1 Number of units

This clause gives an estimate of the required number of wireless nodes per aircraft. The precise number depends on the type of aircraft, its seat configuration and the features that are implemented wirelessly.

Figure B.2-1 shows the cabin reference layout of an A380 aircraft.

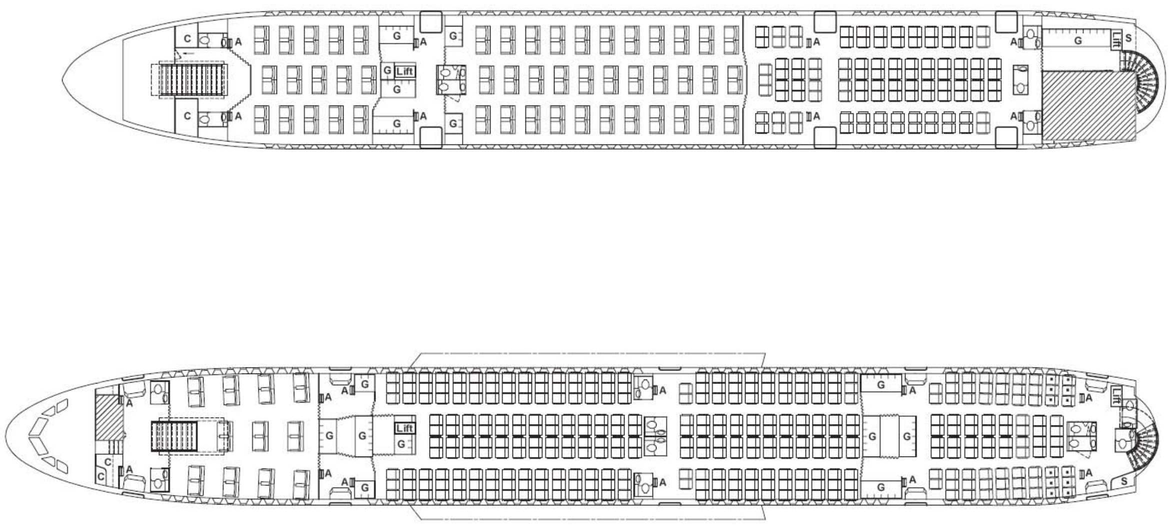

Figure B.2-1: Airbus A380 cabin reference layout

On the given layout the following numbers as shown in table B.2-1 can be expected:

Table B.2-1: Number of units

Unit type	Number	Note
PSUs	190	One per bench (2 to 3 seats) plus monuments
Sensors	200	Currently an aircraft has 70 smoke detectors
Illumination	300	Currently a single deck aircraft has about 300 illumination modules (without spots and monuments lighting). It is assumed that those modules can be grouped
Video surveillance cameras	20	
Signs and buttons	50	E.g. exits signs or crew installations
In-flight Entertainment Terminals	555	One per seat
Total	**1315**	

It may be noted that this number is for a double-deck aircraft with the maximum number of wireless units installed. It can be assumed that not all features will be implemented wirelessly. At the beginning the system should support up to 500 nodes per deck in a 70 meters long cabin.

B.2.2 Data rates

The data rates required by different data flows may differ a lot. Anyway, due to the high nodes density the aggregate datarate could reach several hundreds of Megabytes. Table B.2-2 shows data rate estimations referring to generic expectations.

Table B.2-2: Functions data rate estimation

Pos.	Function	Bit Rate / Mbps		Remarks
		DL	UL	
1.	Audio announcement	0,4	-	
2.	No. of audio channels	16 channels		Each PSU is capable to switch to any of these channels with the given synchronicity
3.	Total audio data rate for all (16) channels	6,5	-	In case of broadcast all audio channels in one cell
4.	Control traffic (lights, signs, buttons)	< 1	< 1	Bi-directional signal channel
5.	In-flight Entertainment Terminal	up to 20	up to 5	Per terminal (in-seat display)
6.	Video Surveillance	< 0,5	20	Per camera
7.	Sensors	< 0,1	< 0,5	Data rate depends strongly on sensor type and specific constraints
	No. of sensors	> 100		

B.2.3 Reliability of wireless data transmission

The reliability of the CMS functions (DAL Level) is independently from the way of data transport to the relevant front end device (e.g. PSU). The whole system has to be designed that way that the Design Assurance Level for the appropriate cabin function is met in any case and under any condition. The wireless extension system has to be protected against intentional and unintentional jamming or hacking and against EMI.

This can be done by several ways and have to be investigated and evaluated in detail within the concept phase. Below are listed some ideas which should be taken into consideration in the concept phase:

- A meaningful combination of wired and wireless components within one system (e.g. PSUs).
- A combination of different wireless standards.
- Dynamic reconfiguration and resource allocation in case of link or hardware failure.
- A combination of several PHYs under one MAC.
- Spread spectrum, frequency agile systems (frequency or band hopping).

Design objective for the wireless extension system in the end is to provide the required reliability, availability and robustness by itself, e.g. to have a wireless network which is capable to provide redundant wireless links by supporting different PHYs in hot stand-by by a common MAC Layer.

B.2.4 IFE Specific Specifications

The following specifications indicate the characteristics that a system designed to provide IFE services should have:

- The IFE system should be designed to provide Audio and Video Broadcasting and Audio and Video on Demand to all seats.
- The system shall be capable of processing and distributing all common video and audio formats. Today's common video formats are MPEG 1, 2, 4, etc.
- The IFE System shall be capable of providing HDTV (Streaming).
- The resolution of the graphic display should be 720 p.

- The downlink data rate per PAX shall be minimum 20 Mbit/s.
- The uplink data rate per PAX /transceiver shall be 5 Mbit/s.
- The needed latency should be about 300 ms (check what is required for PA override).
- The system shall be able to provide Internet / Email / Web 2.0 applications.
- The system should be able to provide interactive gaming between PAX.

B.2.5 Localization

Device localization is necessary in case of new or repaired equipments are installed or the aircraft cabin layout has been reconfigured. The location of devices can be done:

- In close co-operation with the CMS network (e.g. wired backbone).
- Using the local intelligence of the wireless access points.
- Taking into consideration expected cabin layout.

The location procedure is structured generally in three steps:

1) Identification of wireless devices.
2) Location within A/C cabin, wireless cell.
3) Assignment of a unique device identification number/code.

A preliminary estimation of the localization accuracy required in the cabin environment in order to enable the automatic seat localization and wireless network organization is between 20 cm and 30 cm.

B.3 Technical justification for spectrum

B.3.1 Technical justification for proposed power levels

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 by Boeing in 2004 [i.13] on aircraft with actual and simulated passenger loads.

Tests performed by Boeing in 2004 related to the measurements of aircraft fuselage attenuation in the 5 GHz band showed results that the aircraft fuselage can provide an average attenuation of 5 GHz signals in excess of 17 dB. This information was recently given to CEPT/ECC-SE24 when having studied usage of 5 GHz frequencies for airborne usage. Those tests were already performed on the new aircraft 787 with composite fuselage. A comparison was also made between a normal aluminium aircraft door and a composite fuselage and it was found that the attenuation of the aluminium fuselage was greater than 30 dB in the 5 GHz band. 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.

Consequently, airborne UWB can be considered to be comparable to an indoor environment and the same emission values as included in the existing UWB regulation for indoor devices are proposed.

B.3.2 Technical justification for bandwidth

For a range resolution of 10 cm, this gives a bandwidth needed of around 3 GHz. For a range resolution of 30 cm approximately BW of 1 GHz would be needed following this approach.

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 are supported.

- With MPEG-4 encoding, a viewer-acceptable video stream consumes about 1Mbit/s.

In conclusion, a total available bandwidth of about 4 GHz as provided by the two frequency bands 3,1 GHz to 4,8 GHz as well as 6 GHz to 8,5 GHz may be considered to be sufficiently covering the total bandwidth needed of all application fields.

Annex C:
Expected compatibility issues

C.1 Coexistence issues

It is noted that airborne UWB application scenarios were not discussed yet in ECC although airborne UWB can be considered to be comparable to an indoor environment. Possible new coexistence challenges with regards to other outdoor radio services and applications using the same frequencies need to be investigated.

Additionally, the ECC Report 93 [i.7] (Compatibility between GSM equipment on board aircraft and terrestrial networks) might contain valuable information.

C.2 Current ITU allocations

There is no current ITU-R allocation corresponding to these devices. The present document assumes operation according to a provision of the Radio Regulations (RR4.4) that does not require any new allocation (i.e. on a non-protected basis and causing no harmful interference).

Due to the broad range of frequencies covered, an excerpt of the European Common Allocation Table [i.2] is not reproduced here. Please see [i.2] for further details.

C.3 Sharing issues

No sharing issues have been identified.

History

Document history		
V1.1.1	May 2009	Publication