Evolution of Aeronautical Communications for Personal and Multimedia Services

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ABSTRACT

The demand to make air travel more pleasant, secure, and productive for passengers is one of the winning factors for both airlines and the aircraft manufacturing industry for which aeronautical communications is one of the enablers. This article describes current trends in the area of aeronautical passenger communication toward personal and wireless in-cabin communications and multimedia data networks. Technological challenges are summarized as well as market potentials and regulatory issues.

INTRODUCTION

Today, airplanes seem to be the last remaining islands where mobile communications and Internet access are not available. While security and passenger safety have always been of prime concern, recent acts of international terrorism have clearly demonstrated the need for major improvements and new initiatives in in-flight communications. Such developments can be brought about by the use of the latest communications technologies. The R&D effort to establish broadband aeronautical communication (AirCom) has received overwhelming feedback by announcements of global players introducing "email and Internet above the clouds." Inspired by enthusiastic estimations envisaging a multibillion-dollar market a few years ago, several steps have already been taken to bring aeronautical communications systems toward a broadband infrastructure for airline passengers. For instance, the introduction of new global broadband systems by Inmarsat to provide broadband access in the sky or the collaboration between Lufthansa and Connexion by Boeing in the FlyNet project to provide Internet connectivity aboard aircraft reflect this market potential. Since Inmarsat introduced its first aeronautical satellite communications systems in the early 1990s the development of AirCom has been exciting. While in the past aircraft operators could only rely on quasi-global communications service with only a few kilobits per second used for voice and low-rate communications, now links of several hundred kilobits per second up to some megabits per second are available to allow new variety in services and applications. Thus, a promising new market is opened for communications service providers/operators and airline operators. Design studies for airlines and market surveys of in-flight network providers show the necessity for high-data-rate communications services for airliners, with an obvious trend toward in-flight entertainment (IFE), Internet applications, and personal communications. Moreover, people are becoming more and more used to personalized equipment, such as mobile phones, laptops, and PDAs, all accommodated in their personal environment. From a user perspective, there is a clear demand for a *wireless access* solution for multimedia and personal communications services through users' own equipment. Besides, a wireless network may also support airline personnel (cabin crew, maintenance crew) during their daily work (e.g., for mobile data access) and at the same time save the cost of installing a massive wired network inside an aircraft.

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TODAY'S PASSENGER COMMUNICATIONS

Today, aeronautical in-cabin communications consists mainly of basic telephony with back-seat-installed equipment. Passenger acceptance of such systems is low due to the mental barrier of credit card registrations, user-unfriendly interface and handling, and high cost. Various aeronautical communications services are currently offered to the civil aviation market, including the Inmarsat Aero system for aeronautical mobile satellite services (AMSS) and other systems for aeronautical mobile terrestrial services (AMTS) such as North American Terrestrial System (NATS). Currently, the Inmarsat Aero satellite communications system provides two-way voice, fax, and data services for aircraft operating virtually anywhere in the world.

THE EVOLUTION OF AERONAUTICAL COMMUNICATIONS

Existing systems suffer from bandwidth limitations; the trend toward bandwidth-consuming Internet services currently cannot be satisfied. Two paths are followed in the evolution of aeronautical services:

- To improve aircraft cabin technology with a user-friendly environment for personal and multimedia communications
- To improve space segment technology to allow higher-bit-rate services

The development of aeronautical communications is very much driven by European activities. The European Space Agency (ESA) typically funds technology development and pilot projects. In its BRAHMSS/THALES project [1, 2] the requirements for a wideband service demonstrator were determined. Recently antenna technology and multimedia pilot systems were addressed in the ABROAD project. The European Commission complements these activities with projects that aim to integrate aeronautical networks within the terrestrial infrastructure. In particular, new concepts for aircraft information technologies and infrastructure have been investigated by the ABATE project where a technology demonstration for aeronautical satellite communications at higher frequencies was performed [3]. Currently, the project *WirelessCabin* (www.wirelesscabin.com) aims to provide aircraft passengers and crew members with heterogeneous wireless access solutions for in-flight entertainment, Internet access, and mobile/personal communications. It is expected from these initiatives that aircraft passengers will be offered the same wireless services for personal and multimedia communications as on the ground, consisting of different overlaying cellular access networks, such as Universal Mobile Telecommunications System (UMTS), IEEE 802.11x wireless LAN (WLAN), and Bluetooth.

In the space segment, several parallel activities target the aeronautical market. Inmarsat will increase the data rate of its aeronautical services and system capacity using about 200 spotbeams with its fourth-generation satellites. In the B-GAN™ system to be deployed in 2004, the available bandwidth typically ranges up to 432 kb/s. Such systems will use omnidirectional antennas at L-band frequencies in which aircraft installation requirements are low and existing aero antennas can be used. A service mix with email Internet access and voice services can be offered. Since the available spectrum at L-band is limited, higher bit rates can only be provided with Ku-band or K/Ka-band satellite systems as are used for analog TV broadcasting, digital video broadcast with return channel (DVB-RCS) with additional IP data support, or transparent services to augment the L-band systems (Fig. 1). Due to a small number of spotbeams and poor frequency reuse, current Ku-band systems cannot provide sufficient capacity to serve large aircraft fleets with two-way multimedia communications, but distributing the same content in broadcast/multicast mode to many aircraft in the wide coverage zone seems advantageous. The L-band system can be used as return link.

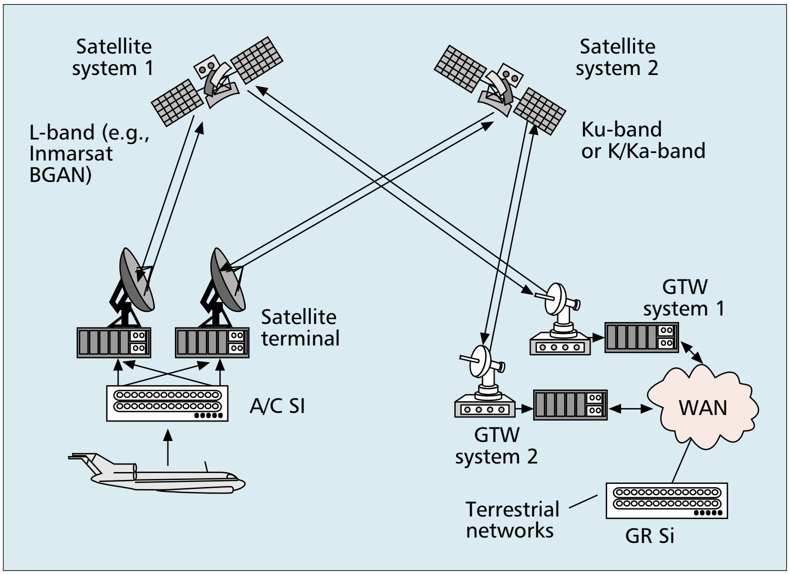

Figure 1. *Satellite evolution scenario with L-band two-way communications augmented by a Ku-band satellite system for downlink streaming.*

New agile aircraft antennas are needed to provide high-gain characteristics at Ku band and above. Connexion™ by Boeing is one potential candidate using such Ku-band satellites for two-way communications; European airlines British Airways, Lufthansa, and SAS have run early trials of this approach.

AERONAUTICAL SERVICE ARCHITECTURE

The improvement of the cabin communications infrastructure tackles several communications segments. A variety of services is needed, each with different bandwidth demand and types of communication protocols. Many of the services will be available to the passenger by means of cabin-installed equipment, such as TV screens, a rescue compartment with telemedicine equipment, or fixed installed satellite phones. Since

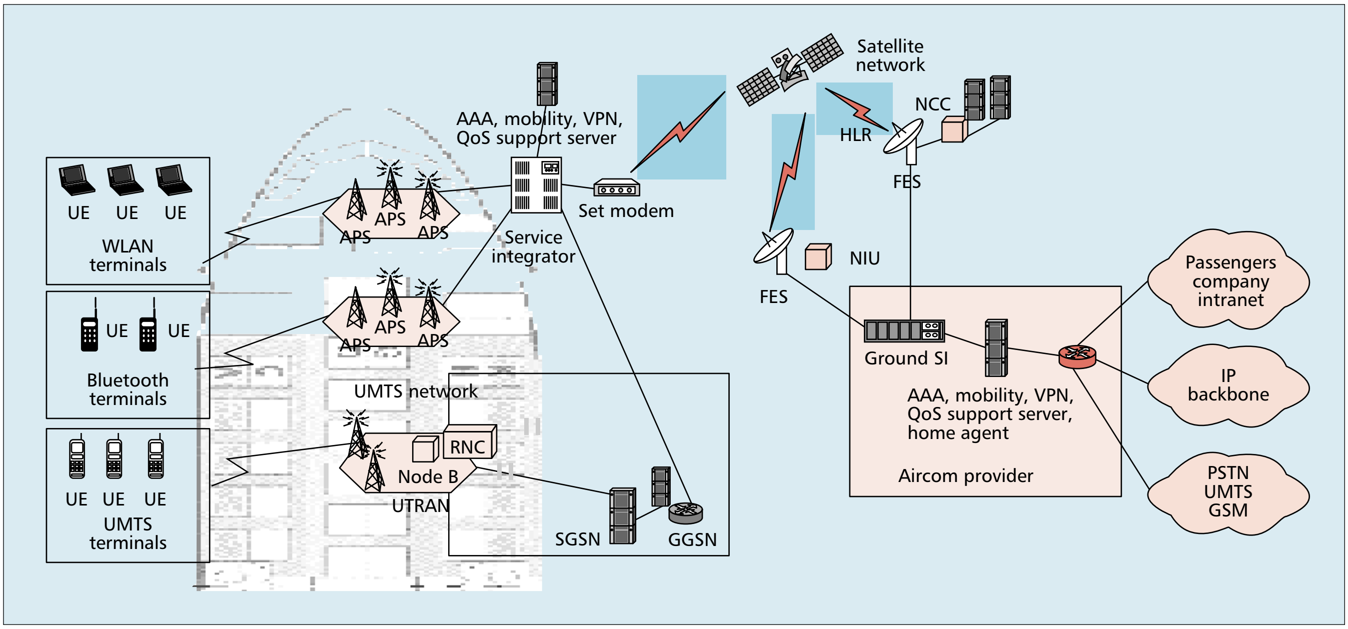

Figure 2. *Aeronautical communications network architecture.*

people are becoming more and more used to their own communications equipment (e.g., mobile phones and laptops with Internet connection through either a network interface card or dial-in access via modems), business travelers will soon be demanding wireless access to communications services. While WLAN is planned to be rolled out by some airlines, cellular phones are still prohibited in commercial aircraft due to the uncertain certification situation. Airframe manufacturers, however, are currently tackling this issue. The most important wireless access technologies are GSM, UMTS with UMTS radio access network (UTRAN) air interface, Bluetooth, and WLAN IEEE 802.11x. Of course, these access technologies need to coexist with each other and wired IP installations. The architecture and its components are conceptually depicted in Fig. 2. Such an infrastructure comprises:

- Several wireless access segments in the aircraft cabin, namely a WLAN according to IEEE 802.11b for IP services, a GSM/UMTS picocell for personal and data communications, and Bluetooth™ 1.1, as well as a standard wired IP LAN.
- A satellite segment for interconnection of the cabin with the terrestrial telecom networks. The different cabin services must be integrated and interconnected using a *service integrator* that allows separation and transportation of the services over a single or several satellite bearers.
- An aircom service provider segment supporting the integrated cabin services. The aircom provider segment provides interconnection to terrestrial personal and data networks as well as the Internet backbone. For the GSM/UMTS cabin service, part of the core network must be available.

Integration of Services

The different wireless access services of GSM/UMTS, WLAN, and Bluetooth require different architectures from a protocol and networking point of view. The central part of service portfolio provisioning is a service integrator. The service integrator will provide the interfaces for the wireless and wired service access points in the cabin, as well as the interface to the terrestrial networks at the aircom provider site. All services will be bundled and transported between a pair of service integrators (SIs). For the UMTS access network, a Node-B is required in the cabin. This Node-B is controlled by an onboard radio network controller (RNC). If content onboard the aircraft is wanted, it is attractive to also have a SGSN/GGSN and even a mobile switching center (MSC) in the aircraft.

The SIs (in-cabin and on ground) provide QoS monitoring mechanism for the Wireless-Cabin network, although each individual access network may have its own QoS support mechanism. The in-cabin SI prioritizes the packets received from different access segments by implementing sophisticated scheduling mechanisms together with statistical multiplexing techniques. Packets in the SI can be segregated into different queues based on the type of services.

One important characteristic of this architecture is the design of the network architecture in the ground segment. Here, the satellite gateway is expected to be connected to the ground SI, which belongs to an aircom service provider (Fig. 3). The aircom service provider is used to support the integrated cabin services and provides interconnection to the IP backbone, private intranet, and the public switched telephone network (PSTN). In order to provide global satellite coverage, constellations of satellites from different systems are preferable. Aircraft belonging to the same fleet can be located in several service areas of different satellite pro-

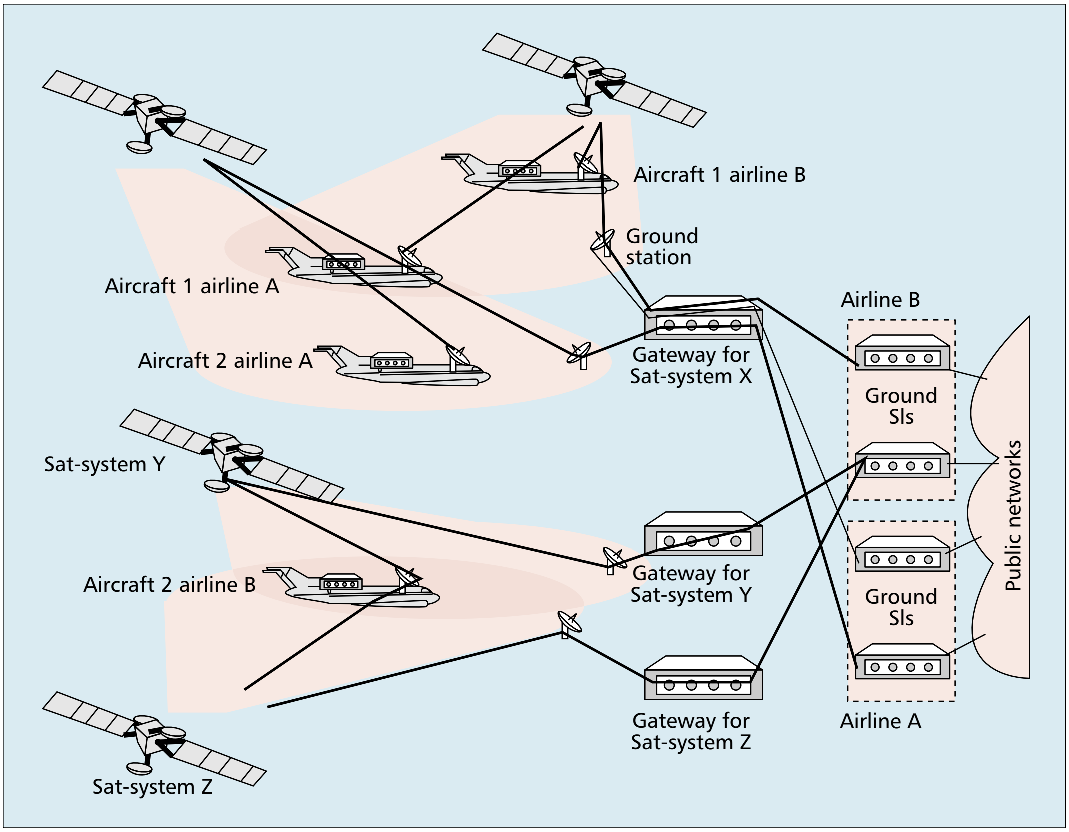

Figure 3. *Satellite and service provider architecture.*

Approximately 80 percent of the respondents travel using standard class airfares, highlighting the fact that wireless services should not be solely directed at business and premium class passengers.

viders.

Therefore, the SI in the aircraft must maintain its connection to the ground SI even when the aircraft moves into another satellite system coverage. Handover must be supported between different satellite systems under the following conditions:

- When the aircraft moves outside the coverage area of the current satellite system but into the coverage area of another satellite system
- When the aircraft is in the coverage area of the current satellite system but needs to change to another satellite system due to adverse network or operating conditions

The SI pairs must initiate handover. As the SI acts as the intelligence unit onboard the aircraft, no modification is required on the user equipment. The SI can predict the location of the plane and perform any intersatellite handover procedures before leaving the coverage area of its present satellite system.

Aeronautical Market

A variety of economic experts announced AirCom market analyses and estimations in the past, unfortunately mostly not detailing the basis for their estimations in literature. While enthusiastic market estimations envisaged a US$70 billion, all these estimations were revised due to the decline of the air travel market.

Boeing estimated (May 2001) the number of customers to evolve to about 1.7 billion in 2010. In October 2001 this forecast was confirmed but with a delay of two years. The estimation of the number of passengers was based on the OAG forecast for the number of passengers worldwide of May 2000. Early 2001 annual user fee revenues were expected to be US$45 billion in 2010 (Connexion by Boeing), based on a statement of the World Airline Entertainment Association (WAEA) for 2000. A more recent (and credible) estimate was produced by Northern Sky Research in October 2001. There the annual user fee revenues are expected to be “only” US$2.5 billion in 2007. A detailed revenue and traffic analysis focusing only on IP and voice services in an aircraft is given in [4] resulting in revenues of about €2000 depending on the aircraft size.

A recent passenger survey has been performed [5] to estimate the demand of wireless services. The passenger survey had nearly 300 respondents, mostly located in Europe but with significant numbers of respondents located in the United States or Asia Pacific. Approximately half of the respondents regarded themselves as business travelers, typically making 10 flights a year. Approximately 80 percent of the respondents travel using standard class airfares, highlighting the fact that wireless services should not be solely directed at business and premium class passengers. The respondents of our survey were asked to identify which of a long list of potential services were important to them. Figure 4 provides the answers from our survey.

The results presented in Fig. 4 show that email, Internet access, and video on demand are among the services in greatest demand. Interestingly, the information most sought after relates to the passenger’s destination and general news services. Services least demanded by passengers included e-commerce and videoconferencing.

A correct business model is essential for the success of services onboard aircrafts. In general, the AirCom business model is very complex since more actors are involved. Licensing aspects of UMTS and international mobility further complicate the situation.

Actors

In Fig. 5, the actors potentially involved in the business model are shown. Not necessarily all parties will be present in all situations.

The *customers* are the prime members of the value chain. They will probably have an existing business relationship with a service provider (UMTS operator, Internet service provider, ISP, or wireless services operator) and the airline (ticket sales).

Airlines are promoting the service in order to collect revenues directly from charges levied for service access or indirectly through increasing market shares (i.e., creating "shareshift" where passengers will change airlines to access the services). The airline may also become a major user of the services, for non-mission critical communications, crew, maintenance, and additional security. The airline may choose to own the infrastructure. Alternatively, third parties can operate the onboard network. The latter option represents a major business opportunity for mobile telephone operators and ISPs.

Airport operators are already offering WLAN communications access at major international airports for passengers. The provision of such services will undoubtedly play a role in stimulating demand for wireless access on the aircraft.

The *aircraft manufacturer* is an important part of the overall business model. Manufacturers can expect to sell more aircraft that are certified to operate with wireless systems. The aircraft manufacturer may operate the telecom infrastructure onboard the aircraft (e.g., Connexion by Boeing).

The *service provider* can be a terrestrial service provider such as a mobile or WLAN operator or a specialized aircom provider.

The *satellite operator* is an essential part of the value chain as it provides the communications link between ground and air.

The *content provider* provides multimedia content to passengers and crew, and maybe material for use in the onboard in-flight entertainment system.

Tax entities are there to collect tax on services.

Finally, *terrestrial network operators* are the gateways to terrestrial networks.

Business Relationships and Billing

The generally accepted model for the business relationship is *interconnect*, with revenue sharing between parties. Billing for services can be done according to a number of parameters: content and transport, the latter further subdivided into airtime, satellite connection time, volume, and so on [6]. Clearly, the customer will have to pay for services. Charging can be of three possible types: flat rate (all included), flat rate up to a certain amount plus excess traffic, or only traffic. Since quality of service (QoS) issues are likely to arise in this complex scenario, they should be correctly taken into account in the billing system. It is also likely that part of the communications costs may be absorbed by companies wishing to advertise to flying passengers (e.g., offering low-rate rented cars or hotels at passenger destinations). Incoming calls on UMTS may be charged to the originator up to national borders and to the recipient beyond them.

Regulatory Aspects

Besides the challenges of GSM/UMTS licensing for use within the aircraft cabin, a major concern in the use of wireless *passenger-carried electronic devices* (PEDs) aboard aircraft is their electromagnetic compatibility with aircraft electronic systems. The following approach covers several aspects of disturbance. Specifically, as PEDs can emit disturbing energy, two different features of the emission have been investigated:

Intentional emission, if present, is usually lim-

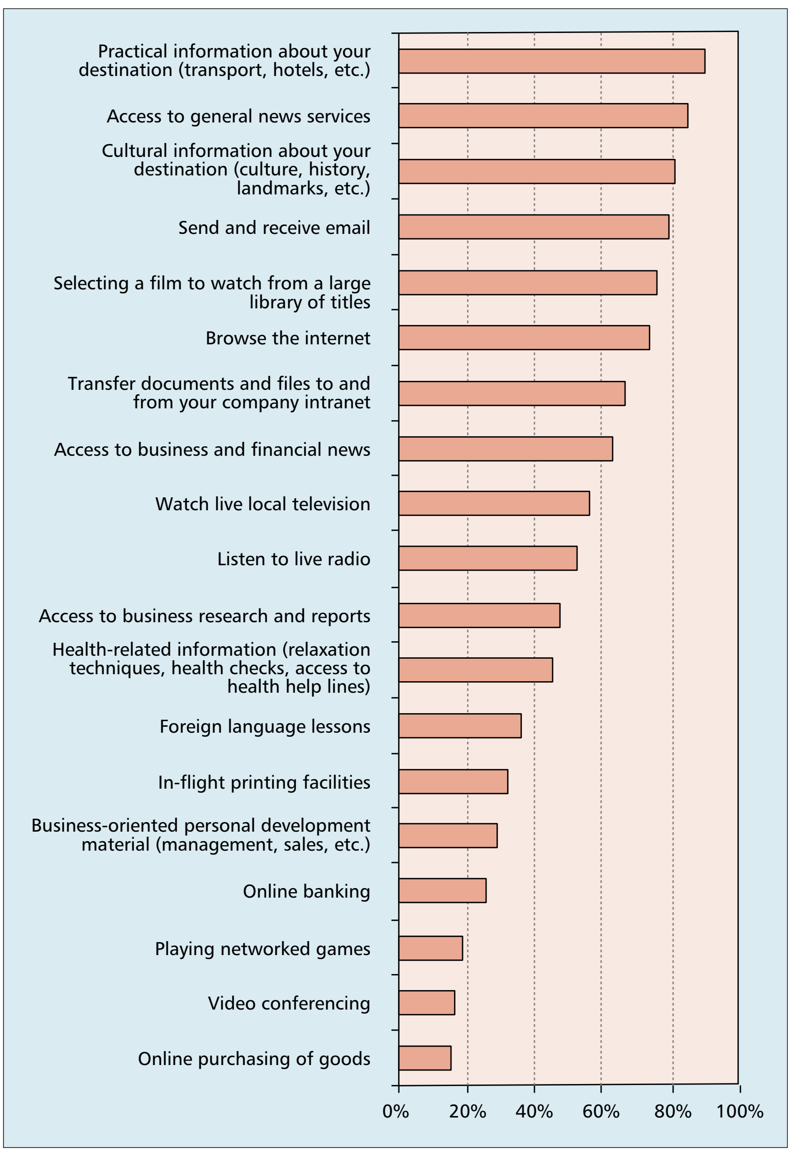

Figure 4. *Services passengers thought important to use onboard an aircraft.*

ited in the frequency band. However, the power level is higher than the noise or spurious emission level for normal operation.

Spurious emission is unintentional and contributes to the noise floor in the vicinity of a device. In Europe this spurious emission is regulated by means of EN standards (e.g., [7]), limiting the allowed electromagnetic emission. They are different from acknowledged aircraft standards such as EUROCAE ED 14D (RTCA DO160D) [8, 9] in both limits and measuring procedure.

Hence, any PED emitting exhibiting spurious emission — regardless of whether or not it is providing wireless functions — is considered a potential candidate for interference.

For sufficient signal-to noise-ratio the PED usually must produce intentional emissions that exceed the noise floor in the aircraft. A good signal-to-noise ratio, exceeding some minimum value, is essential for proper function, whether conducted or wireless. On the other hand, signal levels for good SNR must not be exaggerated to unacceptable levels. Two different aircraft systems need to be investigated.

Electronic systems for essential functions that do not receive radio spectral energy: These systems are designed and qualified for high intensive radiated fields (HIRF) environments [10]. This way, any system performing essential functions is protected against field strength levels of several hundred volts per meter. Its high qualification level protects it against anticipated levels of intentional or spurious PED electromagnetic field emission, so it is expected that these systems will not be affected by electromagnetic interference.

Navigation and communication (NAV/COM) systems sensitive to electromagnetic signals: Intentional PED emitters are protected by frequency separation regulated by the International Telecommunication Union (ITU). Therefore, any intentional emission from an arbitrary PED is out of band for any aircraft NAV/COM system today.

However, NAV/COM systems may be sensitive to spurious emissions in their operational frequency band. The spurious PED emission from intentional emitters can be controlled by the same means as that from spurious emitters. During takeoff and landing, for example, when the instrument landing system (ILS) is in use, passengers are obliged to switch off their PEDs. This countermeasure prevents both intentional and spurious emission of PEDs.

Due to frequency separation WLAN 802.11b should not be a candidate to interfere with sensitive aircraft navigation and communication systems (Table 1). WLAN is out of band to any current aircraft navigation or communication system. This applies for any currently available wireless service today on the market. Consequently, Bluetooth, for example, currently is exempt from restrictions on wireless emitters inside the cabin [11].

Intentional emitters can be allowed aboard aircraft according to RTCA/DO233 recommendations if their safe use is demonstrated [12]. For A4340-600 the safe use and compatibility of WLAN has been demonstrated in the aircraft environment at a power level artificially increased 250 times.

Bluetooth has been investigated by Intel [10].

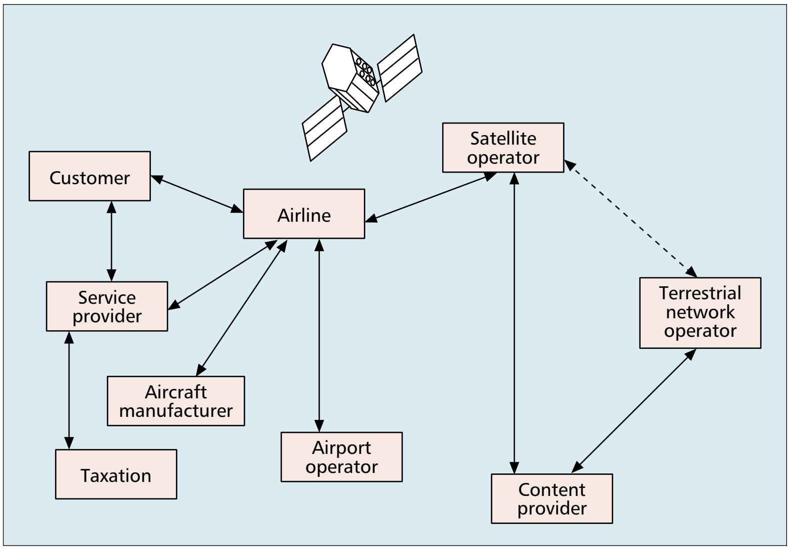

Figure 5. *The participants in one possible value chain for provision of wireless in-cabin services.*

Omega navigation 10…14 kHz	ADF 190…1750 kHz	HF 2…30 MHz	Marker beacon 74.85, 75, 75.15 MHz	VOR, localizer 108…118 MHz	VHF COM 118…136 MHz	Glide slope 328…335 MHz
GSM 400 450.4…467.6 MHz 478.8…496 MHz	GSM 850 824…894 MHz	GSM 900 876…960 MHz	DME 960…1220 MHz	TCAS/ATC 1030,1090 MHZ	GPS 1575 MHz	SATCOM 1529, 1661 MHz
GSM 1800 1710…1880 MHz	European UMTS 1880…2025 MHz 2110…2200 MHz	GSM 1900 150…1900 MHz	IMS band: WLAN 802.11b,g Bluetooth, Home RF 2446.5…2483.5 MHz	Low-range altimeter 4.3 GHz	Microwave landing system 5.03, 5.09 GHz	WLAN 802.11a 5150…5350 MHz
Weather radar 5.4 GHz	WLAN 802.11a 5725…5825 MHz	Weather radar 9.3 GHz	Sky radio 11,700 MHz	DBS TV 12.2…12.7 GHz	Frequency separation regulated by International Telecommunication Union, Geneva, Switzerland	

Table 1. *Frequency separation; the aircraft NAV/COM frequencies are indicated in blue; other radio services do not interfere with these frequencies.*

During tests conducted up to now even non-essential systems such as in flight entertainment, that are qualified to low susceptibility levels, have not been observed to be disturbed. From a technical point of view there is no general objection against the use of these services.

Lufthansa already provides a certified wireless service in the cabin in combination with portable electronic devices.

During tests conducted thus far, even nonessential systems such as in-flight entertainment that are qualified to low susceptibility levels have not been observed to be disturbed. From a technical point of view there is no general objection to the use of these services. Additionally, telephony standards (GSM, UMTS, and other wireless services) are being investigated within Airbus and the WirelessCabin project. It is one of the major aims of the WirelessCabin project and other studies conducted by Airbus to ensure aircraft safety and quality standards. This will be done by calculations, analysis, design, and compatibility demonstrations.

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Biographies

Axel Jahn [SM'90] (Axel.Jahn@dlr.de) received Ph.D. and Dipl.-Ing. degrees in electrical engineering in 1999 and 1990 from Fern University at Hagen and University Fridericana at Karlsruhe, Germany, respectively. Since September 1990 he is with the Institute of Communications and Navigation of the German Aerospace Center (DLR) as a research scientist, project manager, and group leader. Since 2003 he is also a managing partner of TriaGnoSys GmbH. He is a lecturer at the Carl-Cranz-Gesellschaft for Mobile Satellite Communications since 1993 and in 1995–/1996 he was a lecturer at Technical University at Ilmenau. He received the DLR Science Award 2002 and the Best Paper Award of the ITG Mobile Communications Conference in 1993, and is listed in *Who's Who in Science*. He has authored and co-authored numerous publications on satellite communications, with two scientific textbooks and 15 scientific journal papers.

Matthias Holzbock received a Dipl.-Ing. degree in electrical engineering and information technology in 1996 from Technical University of Munich, Germany. From 1995 to 1996 he was with the Optical Networks Group of the German Aerospace Research Establishment (DLR). Since 1996 he is with the Institute of Communications and Navigation of the German Aerospace Center (DLR) as a research scientist and project manager. Recently, he is also a managing partner of TriaGnoSys GmbH. He has authored and co-authored more than 50 publications and several patent applications.

Jan Müller received his Dipl.-Ing. degree from the University of Applied Sciences Cologne in electrical engineering in 1999, specializing in communications and information technologies. After graduation he worked for Bosch Telecom and Siemens Mobile on several mobile phone development projects from RF stage to integration tests. This work was research for UMTS projects and integration tasks for GSM/UMTS intersystem functions. He has a thorough understanding of most aspects of terrestrial mobile communication. Since 2002 he is with Airbus as a system engineer for WirelessCabin communication systems. He is responsible for design, development, integration, certification, and support of Cabin Wireless Communication Systems in Airbus aircraft.

Robert Kebel [M] studied electrical engineering at Hanover University where he specialized in control systems engineering and electromagnetic compatibility. From 1995 to 1998 he was a research assistant at the university's institute for basic electromagnetics. During this period he also was with Hanover University of Applied Sciences, where he lectured on transmission line theory. In 1997 he prepared an emc test laboratoriums accreditition. After his Ph.D. in 1999 he joined EADS Germany's military aircraft section, where his responsibilities were in the field of signature technology. Since August 2001 he is with Airbus in Hamburg, where his responsibilities lie in electromagnetic compatibility and lightning protection. He is the author of numerous publications in the field of electromagnetic compatibility.

Massimo De Sanctis received a degree in electronic engineering from Rome University in 1977. Since then he has been involved in advanced communications projects around Europe, with major telecom equipment manufacturers (ITT, Alcatel, AEG Telefunken, Bosch Telekom). In the early '80s he was involved in early broadband trials in Germany (BERKOM, BIGFON, BIGFERN), owning patents in video codecs and multiplexing. After a period of three years at NATO Shape Technical Center as a senior scientist, where he designed the network management system for the NATO transmission network, he joined Ericsson in 1987 and participated in ATM switching and early IP projects, and in the development of advanced telecom systems platforms. He was program manager of the Ka band broadband satellite program Astrolink. Currently his research areas include satellite systems, billing, CRM, and business models for advanced communication networks. He has authored and contributed to several papers in advanced communications, and contributed to two textbooks.

Andrew Rogoyski started his working career as an academic, working at King's College London and later at the Rutherford Appleton Laboratory in Oxford on the applications of high-energy lasers to xray science. He worked with a number of internationally renowned research groups, including the Naval Research Laboratory, Washington, the Ecole Polytechnique, Paliseau, France, and several major universities in the United Kingdom. He then made the transition to industry, working for Logica in their space and defense division. Initially involved with a number of government research projects, he went on to take responsibility for the management of a business group within the division, servicing a number of different government clients. Following this, he was asked to supervise the majority of the division's projects, later taking full responsibility for the overall operational control of the 350-strong space and defense division. He then decided to explore new industries and took a position within the financial services divisionof Logica. There he oversaw a group of industry experts originating market-leading business propositions, several of which were then taken up and implemented as technical solutions for some of the United Kingdom's leading financial institutions. He now focuses on technical and business consultancy, working for ESYS Consulting plc, a company with a strong reputation in the space and satellite communications sector. Since joining ESYS, he has led a number of projects including ESYS' contribution to the WirelessCabin project. Other projects have included analysis and research of airborne telemedicine, navigation systems (EGNOS and Galileo), prototype development of a system for multimedia content distribution via satellite, satellite system simulation, and, most recently, working with the Open University on a new project to develop novel designs for interplanetary probes. He is the author of 17 refereed and conference papers.

EYAL TRACHTMAN received a B.Sc. in electronics engineering in 1982 and an M.Sc. in telecommunications in 1989 from Tel-Aviv University, Israel. In 1990 he joined Inmarsat Ltd., London, United Kingdom. Since 1994 he has been leading the R&D activities at Inmarsat. His technical expertise covers various disciplines in the field of mobile satellite systems, including modulation and coding, source coding, satellite multiple access, wireless packet, circuit networking, and IP networking. He holds six patents in the field of telecommunications.

OLIVER FRANZRAHE received a Dipl.-Ing. degree in electrical engineering in 1999 from the University of Hannover, Germany, where he specialized in information processing and communication systems. From 1996 to 1998 he was involved into research and technological development projects dealing with image processing technologies at Laser Zentrum Hannover and Lawrence Livermore National Laboratory, United States. Following his graduation he joined the Airbus subsidiary KID-Systeme GmbH in Buxtehude as system engineer in the predevelopment department. In this function, he is working on the development and evaluation of new applications, technologies, and systems dedicated to use inside the aircraft cabin.

MARKUS WERNER [SM] received a Dipl.-Ing. degree from Darmstadt Technical University, Germany, in 1991, and a Ph.D. degree from Munich Technical University, Germany, in 2002, both in electrical engineering. Since 1991, he has been with the Institute of Communications and Navigation of the German Aerospace Center (DLR), Oberpfaffenhofen, Germany, as research scientist, project manager, and group leader. Since 2002 he is also managing director of TriaGnoSys GmbH, Wessling, Germany, a consulting company for satellite and aeronautical communications. His project experience includes several national and ESA studies, and various projects in the framework of European ACTS and IST research programs. He has been national delegate to the recent COST 227 and COST 252 Actions, and is currently national delegate to the COST 272 Action. His main research activities are in the areas of multiservice traffic engineering and capacity dimensioning for satellite systems in general, and system design issues for aeronautical satellite systems in particular. He lectured on mobile satellite communications at Ilmenau Technical University, Germany, from 1995 to 1996. He is also a lecturer at the Carl-Cranz-Gesellschaft (CCG), Oberpfaffenhofen, Germany, teaching satellite communications courses for telecommunications professionals. He is co-author of the textbook *Satellite Systems for Personal and Broadband Communications* (Springer-Verlag, 2000). He is a member of VDE/ITG.

Y. FUN HU received a first class B.Sc. degree in mathematical sciences and a Ph.D. degree in information systems engineering, both from the University of Bradford, United Kingdom. In 1990 she joined the University of Leeds, United Kingdom, as a research rellow after working two years in the satellite communications industry. In 1994 she was appointed lecturer at the University of Bradford. She is now a senior lecturer at the same university. She has been involved in several defense, ESA, and European Union funded projects, including SAINT, SINUS, SUMO, VANTAGE, SECOMS, and SUITED. She is a co-author of the book *Mobile Satellite Communications Networks* (Wiley). She was a national delegate to the EU COST 253 and COST 256 Actions. She is now a national delegate to the EU COST 272 Action and a member of the Executive Committee of the IEE Satellite Systems and Applications Professional Network.

It is one of the major aims of the wireless cabin project and other studies conducted by Airbus to ensure aircraft safety and quality standard. This will be ensured by calculations, analysis, design and compatibility demonstrations.