GSM OnBoard Aircrafts (GSMOBA) System

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***Abstract*— The paper presents the GSM on board aircrafts system description and a resume of ongoing activities on standardization.**

***Keywords*— On board, aircrafts, GSM, interference, Network Control Unit, Standardization**

I. INTRODUCTION

The world is becoming increasingly connected. People are adopting an “always on” attitude, where they expect to be in contact with work, friends and family on a 24 hour basis. The advent of mobile telephony and internet has made it easy to access information from anywhere in the world, with some of these services becoming an integral part of modern business life. One of the last remaining islands where mobile communications access is not available is in passenger airliners. However, this is about to change. The project “GSM on Board aircrafts” (hereafter GSMOBA), supported by Siemens AG and Nokia Siemens Networks, is working towards designs, standards and simulations to provide connectivity in flight. The technology will be based upon emerging standards including firstly GSM [2] and after also UMTS [3] and other technologies for mobile telephony. The key attraction is that passengers should be able to use their own equipment (mobile phone or laptop) to access the offered communications services.

A picocell installed within the aircraft will provide the GSM coverage and a satellite link will keep the connection between the aircraft and the existing terrestrial mobile network. In order to avoid harmful interference between onboard system and terrestrial network a Network Control Unit (NCU) is used. The NCU prevents mobile phones on board aircrafts from roaming into base stations on the ground by raising the noise floor in the cabin.

As the GSMOBA system falls under the R&TTE (Radio & Telecommunications Terminal Equipment) directive [5], which states that "[…] radio equipment shall be so constructed that it effectively uses the spectrum allocated to terrestrial/space radio communications and orbital resources so as to avoid harmful interference", the European Telecommunications Standards Institute (ETSI) has the task of creating a Harmonized Standard to obtain a license of operation in Europe.

The Harmonized Standard is being developed together with a corresponding Technical Specification in the ETSI GSMOBA group which was created in June 2006 as a joint group of the ETSI ERM (ETSI Electromagnetic Compatibility and Radio Spectrum Matters) and ETSI MSG (ETSI Mobile Standards Group) working groups. Technical work on this topic is also ongoing in the CEPT ECC PT SE7 (Conférence Européenne des Administrations des Postes et des Télécommunications, Electronic Communications Committee, Project Team Spectrum Engineering 7) group under the name Mobile Communication onboard Aircraft (MCA).

This paper has the purpose to provide a high level GSMOBA system description and to summarize the ongoing activities on European standardization.

A. *Motivation*

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. Passengers would like to act as they would do in their normal terrestrial life, without thinking on the limitations of being on a plane. Going even further and taking into account both travellers' requirements and airlines' benefits; it would be desirable to provide the usage of personal devices instead of built-in terminals on the aircraft seats. From the users' point of view, their service acceptance will be increased by the fact that they can be reached under their usual telephone number and they can access their own data stored in cell phones or laptops. From the airlines' point of view there is a huge saving of the investment related to the installation of terminals (screens, stations), together with software licenses and further investments due to hardware updating to always offer the latest technology to their customers.

II. SYSTEM ARCHITECTURE

The GSMOBA system architecture [1] consists of three segments: the cabin segment, the transport segment and the ground segment as depicted in figure 1.

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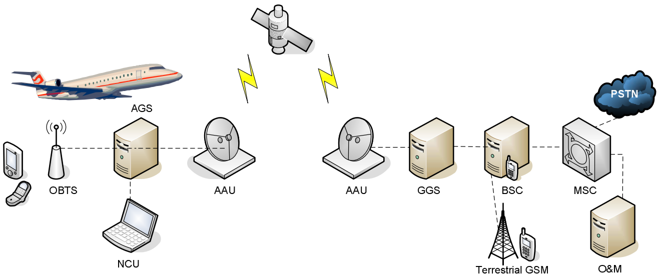

Fig. 1. GSM on Board aircraft System Architecture.

A. *Cabin Segment*

The cabin segment comprises an Onboard Base Transceiver Station (OBTS) and a Network Control Unit (NCU) which are connected to a dedicated antenna system (leaky feeder), an Air GSM Server (AGS) and an Airborne Access Unit (AAU) that connects the cabin system to the ground network via a satellite link.

The Siemens proposed OBTS is the NanoBTS [1]. It is a single transceiver Pico cellular base station utilizing Abis over IP for the network connection back to the BSC. It uses IP carried over an Ethernet connection for all communications with the network. The nanoBTS is the smallest and lightest picocell in the industry providing GSM/GPRS at GSM1800/1900 MHz. It can be expected to provide cell sizes of up to half a kilometer in uncluttered environments and around 50m or more when deployed for in building coverage, depending on the building materials.

The NCU is a component of the system that prevents direct connection of the onboard mobile terminals with mobile networks on the ground by raising the noise floor in the cabin. It transmits a wideband noise in the downlink bands of (at least) GSM400, GSM900, DCS1800 and UMTS. An example of the noise power radiated by a NCU prototype in the 900 MHz, 1800 MHz and 2 GHz bands is shown in Figure 2.

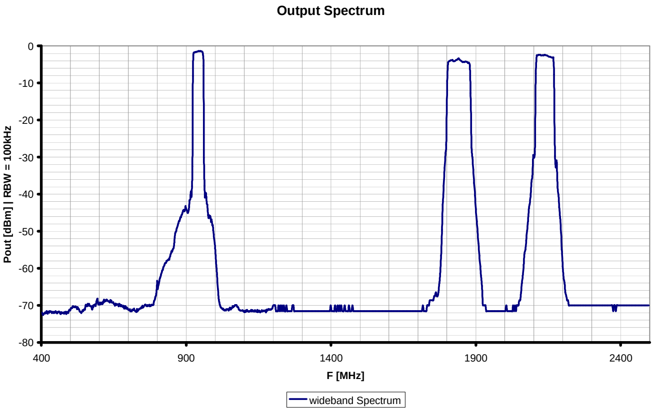

Fig. 2. Spectral characteristics of a NCU prototype

The NCU also includes a database to automatically calculate all relevant parameters based on the current position of the aircraft. The NCU power level is dependent on the aircraft altitude and geographical position. That means that the NCU will decrease the power level with increased flight altitude and vice versa. In order to ensure the correct level for the control signal the NCU will calculate the absolute height above ground, depending on the aircraft position and regulation for each country over flown.

The AGS provides service compression, control and protocol adaptation for the satellite link to the ground. It is also the aircraft Operation and Maintenance (O&M). The AGS is composed of three parts: The BSC Slave, the Satellite Transport Adaptation and the AGS Control Management. The BSC Slave adapts the airborne GSM system for the satellite connection reducing the signaling and voice traffic over the satellite bandwidth making the system cost effective. Also it provides an Operation and Maintenance interface to the GSM onboard central management and the local maintenance terminal. The Satellite Transport Adaptation realizes an IP connection from the aircraft to the ground by interfacing with the satellite system and providing a QoS scheduler for different traffic classes. Finally the AGS Control Management provides a database and implements the logic to react on stimuli received from other aircraft systems.

The AAU is the airborne modem that provides the physical interface to the satellite system.

B. *Transport Segment*

The transport segment is the Satellite System that will connect the aircraft with the ground network being the Abis interface, for example the Inmarsat [4] system. It makes the transport of signaling and user traffic from the aircraft to the ground. An active IP connection is needed by the system which will be established by satellite link modules.

The system is independent of the satellite transport network; the airlines can choose their satellite service operator. Connection to telecom networks is considered to be achieved by satellites with large coverage areas, especially over oceanic regions during long-haul flights. The service concept needs to take into account today’s peculiarities of satellite communications, thus it must cope with the available or in near future available satellite technology and interworking must be performed at aircraft interface level with the satellite segment.

Only restricted satellite data rates will be available in the near future; thus the requested bandwidth by standard interfaces of the wireless standards needs to be adapted to the available bandwidth. Furthermore, dynamic bandwidth management is needed to allocate higher bit rates from temporarily unused services to other service.

C. *Ground Segment*

The ground segment is the terrestrial GSM network (composed by BSC, MSC and O&M). The Ground GSM

Server (GGS) is incorporate to the terrestrial system working exactly as the AGS on board the aircrafts. The Ground Control Server provides service compression, control and protocol adaptation between aircraft and ground. There is also an Airborne Access Unit (AAU) to provide the physical interface between the ground and the satellite system.

One deal of the GSMOBA system is to divide the BSC into BSC Slave, installed in the aircraft, and BSC Master, installed on the ground. The BSC Slave/Master adapts the airborne/ground GSM system for the satellite connection by reducing the signaling and voice traffic over the satellite connexion. Non real-time services can be pre-processed on the aircraft by the BSC-slave reducing the usage of the satellite bandwidth making the system cost effective.

III. SYSTEM DESCRIPTION

The goal of the GSMOBA System is to enable the use of mobile phones on board of an aircraft. The passengers will be able to utilize GSM communication with their personal devices like mobile phones, PDAs, Laptops, etc. The system provides mobile visited network access, meaning that the onboard network is run by a licensed operator with roaming agreements with the passengers' home operators and that the call will be billed to the user like any roaming call. Current onboard network operator is OnAir who has a partnership with Airbus, the airplane manufacture providing the complete GSMOBA system. The Siemens/Nokia Siemens Networks is the supplier of the on board equipments as the NCU and OBTS for Airbus.

A picocell installed within the aircraft will provide the GSM coverage and a satellite link will keep the connection between the aircraft and the existing terrestrial mobile network. In order to avoid harmful interference between onboard system and terrestrial network, a Network Control Unit (NCU) is used preventing mobile phones on board aircrafts from roaming into base stations on the ground by raising the noise floor in the cabin. The OBTS and NCU share the same antenna. The typical implementation of this antenna is a leaky feeder running along the cabin ceiling. Depending on the cabin and on the desired areas of coverage, multiple feeders or point source antennas could also be implemented.

GSMOBA services are envisaged to be available during the cruise phase, currently defined above 3000 meters. During take-off and landing the system must be automatically switched off and the passengers must switch off your mobiles.

In detail, the system shall be able to perform the following functions:

- GSM mobile communication from/to inside the cabin to/from ground by using a suitable satellite system.
- GSM voice, SMS, GPRS / WAP service
- Interface to an aircraft console (for turning on/off the GSM onboard components and obtain the operational state of the equipment)
- Interface to aircraft internal systems (to obtain the position data of the aircraft and automatically configure the system according to local GSM regulatory authority's restrictions)

The challenges in the design of the GSM onboard system arise from the particular RF scenario it is intended for. There are a number of issues that set the system apart from ground mobile networks, for example the propagation model inside the cabin and the radiation generates outside the aircraft that can interfere on the ground network.

Not considering the use of the NCU, depending on the power levels and the effective shielding of the aircraft, the transmissions from equipment onboard may interfere with ground networks. Due to the altitude and line of sight propagation, the interference may reach many ground stations very far away. This is an aspect that sets the scenario apart from usual mobile ground networks analysis. RF aircraft scheduling could be a solution here. Several studies have shown, however, that current commercial aircraft bodies do not ensure sufficient RF shielding. Although the materials used in the fuselage of today's aircraft are metallic, the windows allow for considerable leakage of radio signals. Literature and experience prove that it is possible for a terminal onboard an aircraft to receive signals from base stations on the ground, to attach to the networks and even to start a call. Furthermore, theoretical simulations have shown that the combination of a leaky feeder along the cabin and the aircraft windows may act as an antenna array and thus have a gain in certain directions.

The interference level that is acceptable to terrestrial radio networks is a topic that has currently been debated in several standardization groups. The worst case of interference is not obvious to find. The relative position of the aircraft to the ground victim has great impact on the level of interference. At a given altitude the path loss determined by the distance and the antenna pattern of the ground BTS have opposite effects. The elevation angle at which the ground victim receiver sees the interfering aircraft changes as the aircraft flies, the worst-case elevation angles being in principle when the victim terminal is directly below the aircraft, or the victim base station is close to the horizon as seen from the aircraft. In addition, the radiation pattern of the aircraft is generally not isotropic.

In order to reduce this interference and prevent that onboard mobiles access the ground network, the transmit power levels used by the NCU, the OBTS and the MS have to be appropriately reduced. The transmit power level of the OBTS is tuned to result in the minimum signal to noise ratio required for ensuring proper signal reception at the MS, taking into account the wideband noise level generated by the NCU. The NCU must transmit at a sufficient level to effectively cover the signals from ground BTSs; the OBTS needs to transmit at higher power than the NCU to avoid being interfered by it. This is the connectivity margin (assumed a value of 12 dB over the NCU level). For the uplink the OBTS commands the MS – through the power control mechanism – ensuring that the MS output power is fixed at its lowest level of 0dBm which is the maximum power permitted by the regulators. In conclusion, the operational requirements and the interference requirements put a limit to the range of utilization: the transmitted power of the NCU must be sufficient to cover the ground networks inside the cabin, but at the same time it must be low enough to avoid interference to their downlink. The OBTS needs a few dB more than the NCU, but again it should not interfere at ground level. The emissions of onboard terminals, when set at 0 dB, should not interfere with the uplink of ground networks.

IV. ONGOING STANDARDIZATION ACTIVITIES

A. Normative and regulatory activities

The possibility to implement a GSMOBA system in Europe has been made possible by a decision from the Telecommunications Conformity Assessment and Market Surveillance Committee (TCAM) in July 2004 that the NCU is not a jammer (which is illegal under current regulations). It has also been decided that the whole onboard system (NCU, OBTS, leak feeder) falls under the jurisdiction of the R&TTE Directive [5], which states that "[…] radio equipment shall be so constructed that it effectively uses the spectrum allocated to terrestrial/space radio communications and orbital resources so as to avoid harmful interference". This means, to obtain a license of operation in Europe, ETSI should develop a Harmonized Standard covering the onboard system following this directive. Interference in avionic system is completely out of scope of this work and is handling by others regulatory bodies.

A work item to develop the Harmonized Standard on GSMOBA was adopted in November 2005 and following the decision by ETSI OCG (Operational Co-ordination Group) in January 2006, a joint group between ETSI MSG and ETSI ERM groups was established in June 2006 and held its first meeting in August 2006. The joint-group is called GSMOBA and is responsible to develop the Harmonized Standard (EN 302 480, hereafter HS) and its corresponding Technical Specification (TS 102 576, hereafter TS) for GSMOBA system.

The HS identifies the essential requirements to demonstrate conformity to Article 3.2 of the R&TTE Directive and refers to existing GSM technical specifications and to the technical specification under development within the GSMOBA group. The HS also makes reference to the relevant aircraft standard (RTCA DO-160E or EUROCAE40-E).

The accompanying TS provides the additional essential requirements in term of limits and methods of measurement related to the particular characteristics of the overall GSMOBA system and the operational requirement. It is separated into two subsets:

The first subset provides the additional requirements, associated limits and the methods of measurement, which are not available in any other ETSI standards in order to demonstrate that the GSMOBA system conforms to Article 3.2 of the R&TTE directive.

The second subset provides an agreed methodology in order to derive power values at the antenna output port of the GSMOBA system that can be used to demonstrate conformance to e.i.r.p. (equivalent isotropic radiated power) limits defined outside the aircraft. Given the dependence of the power levels outside the aircraft on the specific system implementation, this subset also identifies testing procedures to determine the value of the necessary parameters.

The final version of the HS and its associated first subset of the TS were considered complete at the meeting GSMOBA#6 in Munich on March 2007 at Siemens AG. The documents were finalized and submitted to ETSI MSG and ETSI ERM groups for approval and the HS to proceed for Public Enquiry.

Following the ETSI ERM#31 and ETSI MSG#14 meeting comments, it was recommended to copy and paste the relevant part of the first subset of TS 102 576 in the EN 302 480. This change was incorporated in the HS by the GSMOBA group; the TS now is composed by only its second subset.

The 3GPP GERAN group (3rd Generation Partnership Project GSM/EDGE Radio Access Network) is also involved on the GSMOBA standardization process and was asked to review the HS by an official Liaison Statement sent from GSMOBA group to the GERAN#34 meeting in China on May 14th – 18th 2007. The appropriated comments from 3GPP GERAN were incorporated in the HS.

The final version of the HS, EN 302 480 v.0006, is now considered completed. ETSI will review the document editorially and send it for public enquiry at August first 2007 (response from public enquiry within 2-3 months).

By November, the GSMOBA will hold a resolution meeting to incorporate the comments from public enquiry and send the document again for final approval. The whole process lasts approximately 6 months which means that the HS is to be available around the second quarter of 2008.

The next step of GSMOBA group is to finalize the TS. This is a methodology document that can be completed a part from the HS. A possible deadline for the completion of the TS is December 2007.

B. *Other Technical activities*

Technical work on GSMOBA topic is also ongoing in the CEPT ECC PT SE7 group under the name MCA (Mobile Communication onboard Aircraft) in order to evaluate the interference caused by onboard GSM radio equipment to terrestrial radio systems and in general to look at all the radio compatibility and spectrum issues. The work is carried out under mandate from the European Commission. In particular, three interference paths are considered to be critical: from onboard screening device (NCU) to terrestrial MS, from onboard BTS to terrestrial MS and from onboard MS to terrestrial BTS (see Figure 3).

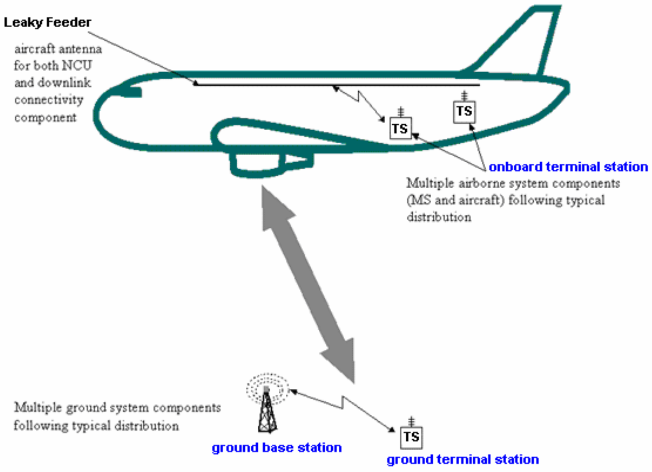

Fig. 3. GSMOBA and terrestrial cellular system interference scenario

The fine description of these interference scenarios is out of scope of this contribution. More details can be found in [6].

CEPT WGSE Project Team SE7 commenced the compatibility study on GSMOBA topic in January 2005. The result of the work is an ECC Report [6], published in September 2006. This Report specifically addresses the impact of the GSMOBA system on terrestrial GSM, UMTS (WCDMA (UTRA FDD)), FLASH-OFDM and CDMA2000 technologies. On the basis of the regulatory developments and the report produced by SE7, CEPT WG RA produced and submitted for public consultation a draft ECC Decision on GSMOBA. The Decision [7], which was published in December 2006, allows operation of a GSMOBA system, compliant with the requirements laid out in its Annex, according to the licensing conditions for the use of spectrum in the country of registration of the aircraft. It also requires that the equipment onboard complies with the R&TTE Directive (with the HS).

An important result highlighted on the ECC Report concerns the effective attenuation of the aircraft (shielding, attenuation by windows, chairs, etc.). The e.i.r.p. limits and certain assumptions regarding the aircraft and the leaky feeder antenna, the CEPT SE7 report has concluded on a set of requirements for the effective attenuation of the aircraft. The effective attenuation is the factor that relates the power radiated from the transmitters inside the aircraft (NCU, OBTS and user terminals) to the e.i.r.p. values outside the aircraft. It is a notoriously difficult parameter to assess and to measure: it depends on factors particular to each aircraft, such as hull attenuation, cabin characteristics and installation of the onboard leaky feeder. A number of theoretical and practical studies of this factor were presented to CEPT SE7, showing a large spread of results. CEPT SE7 found it impossible to define a precise relationship, analytical or empirical, that could be applicable to a broad range of aircraft types and GSM onboard installations. Further work on this issue is been developed by the GSMOBA group and results will be presented in the next meetings. The contributions will be reflected in the TS.

C. *Further Work*

An important issue which is still left open is related to the behavior of advanced mobiles onboard aircrafts in presence of the NCU. There is an official concern of operators that advanced mobiles (equipped with the feature MSRD - Mobile Receive Diversity [8] [9]) onboard the aircraft may be capable to eliminate the noise spectrum emitted by the NCU and may hence be capable to camp on a terrestrial GSM base station. Due to this concern from operators which was formally raised by 3GPP GERAN#25 meeting in a liaison to SE7, it seems to be necessary to investigate this point.

Although there are no MSRD capable mobiles on the market yet this is a feature already included in the 3GPP Technical Specification [8] as a release-independent feature and soon the mobiles will be on the market.

V. CONCLUSION

A lot of work is currently being carried out to allow the provision of mobile communications based on GSM inside aircraft. It is now accepted that it is technically feasible to offer a GSM service onboard civilian aircraft that is safe in terms of avoidance of interaction with aircraft systems, immune from interference with terrestrial mobile communications, compatible with current regulation (at least that of Western Europe), and capable of offering a service that responds to perceived customer demand. In order to achieve these benefits, effective management of the onboard systems (including the passengers’ mobile terminals) and of the air-ground links is imperative. It is in these areas primarily that technical standards from ETSI are making a significant contribution.

This paper has outlined work performed within ETSI, mainly from the GSMOBA group and CEPT to find regulatory and technical solutions for GSMOBA system.

Naturally, there are issues related to the offering of GSMOBA that extend beyond the purely technical and regulatory ones. There are social issues, such as how a system can be managed to prevent annoyance to other passengers. Cabin crew is likely to have to acquire new skills to deal with such circumstances, as well as for managing the use of the system in the various phases of the flight. With the support of the airlines and the GSMOBA operators, passengers may need to be taught a new 'social etiquette' for the use of mobile devices in-flight. The aviation industry will need to address issues of aircraft and system type approval, taking account of the wide variety of aircraft configurations to be accommodated. There are also security issues beyond those of system interference, such as the potential for GSMOBA to be exploited in terrorist situations. Operating procedures will need to be established by airlines and air regulators to address all these circumstances. GSMOBA will only be deemed a success if it meets passengers' demands and satisfies the commercial expectations of its promoters.

It is also worth remembering that GSM may not be the only possible technology to provide this service: some companies are demonstrating systems using cdma2000, and GAN-based systems (e.g. using WLAN) standardized in 3GPP GERAN Release 6 may also be feasible.

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