GSM ON-BOARD – OVERVIEW OF THE MOBILE TELEPHONY SYSTEM ON AIRBUS SINGLE AISLE AIRCRAFT

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ABSTRACT

On-board connectivity has been identified as growing market and field of interest for airlines. Connectivity solutions increase the passenger's comfort and also serves airline administrative and operational communication. Airbus pioneered connectivity and was the first manufacturer to receive certification for its on-board mobile phone system in June 2007. The system provides connectivity functionalities, such as make / receive telephone calls, send / receive short messages (SMS), access to emails and their attachments, mobile Internet or social networks.

The objective of this document is to provide a system architecture overview as well as the selected on-board system with the implemented control means. It will also address the major challenges during the development and certification process: The electro-magnetic compatibility of mobile phones with aircraft electronics and the requirement that mobile phone networks on ground may not be disturbed.

1. HISTORY AND BACKGROUND

The EASA and other airworthiness authorities identified any transmitting devices as potential risk for aircraft safety. Especially mobile phones have been suspected for interferences with the aircraft electronics. Thus, the authorities recommended prohibiting the use of mobile phones in the aircraft, which is reflected in the respective laws, at least in each country of the European Union.

Indeed, mobile phones may have an effect on aircraft electronics. The cruise altitude is approximately 12500 m where the mobile phones receive signals from ground base stations. The mobile phones recognize the base stations as a far away ground network and transmit with maximum power, in order to connect to the base station. This effect may result in interferences.

Mobile phones in the aircraft, which connect to base stations on ground, may also have an impact for the ground service providers. Due to the speed of the aircraft, a controlled handover from one ground base station to the next is not possible, which may disturb ground networks.

With the growing demand for connectivity systems, the expectation of the airlines towards Airbus was to offer a connectivity solution enables the use of mobile phones in the aircraft cabin, by maintaining safety standards.

The requirement from the EASA towards AIRBUS was to prove that the mobile phones would not interfere with the aircraft in any flight phase.

2. INTRODUCTION OF THE GSM ON-BOARD SYSTEM

In 2001 Airbus started to study in detail the subject of mobile telephones on board and was working on guidelines for safe use of mobile phones and evaluation technologies, with the following results:

- Mobile telephony systems on aircraft can be used safely, if specific EMC compatibility guidelines such as EUROCAE ED-130 are respected and
- The technology of „GSM On-Board“ is feasible and suits the special conditions for use in a/c.

This led to principle design as described herein.

2.1. Overview

Enabling GSM connectivity in an aircraft environment requires an onboard infrastructure ensuring the communication between the mobile phones and finally the ground station that interfaces with the public telephony network as shown below.

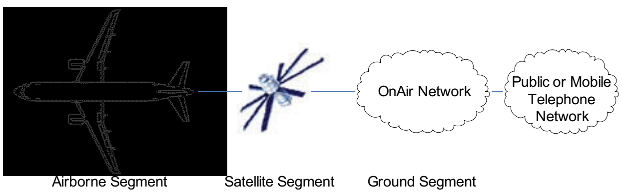

FIG. 1 System segment overview

The GSM On-Board System is located in the airborne segment. It enables mobile phone services in the aircraft. The system could be seen as stand-alone GSM cell in the aircraft. The system receives or transmits RF signals from/to the mobile phones and forwards the data traffic (IP based) via the satellite system to the ground segment.

The satellite segment enables the Air-to-Ground communication in L-Band via Inmarsat I-4 satellites. Although not further detailed here the Air-To-Ground communication systems is provided by Thales Avionics SA, published under the brand TOPFLIGHT System. This system has been designed following the new ARINC 781 standard. The GSM Onboard system benefited of the early deployment of a preliminary ‘BGAN With Wings’ Service in 2007 that was recently upgraded to Inmarsat SwiftBroadband (class 7). In this segment the data from aircraft are transmitted via satellite to the Inmarsat ground earth station (GES) and subsequently to the service provider in the ground segment via a VPN network.

In the ground segment, OnAir operates as service provider for mobile communication. This segment receives the data from the satellite segment and hosts communications controller functions that act together with the functions of the airborne segment in the aircraft.

For this purpose, a Ground GSM server (GGS) is used. Its main features are to perform the routing towards the aircraft and to interconnect the A/C traffic with terrestrial backbone networks (e.g. Public or Mobile Phone networks). The ground segment also hosts accounting and billing functions, mobility management, and routing capabilities. OnAir has a business partnership with a Monaco based telecommunication service provider.

2.2. Description of GSM On-Board System

The system is designed to fulfil the following main objectives

- The system design has to consider all airworthiness requirements
- The system design has to consider the frequency regulation and
- The system has to provide on-board GSM access to the passengers during cruise flight phase (altitude > 3000m).

In order to meet these requirements, Airbus and KID Systeme (100% subsidiary of Airbus), developed the GSM On-Board System, consisting of a

- Base Transceiver Station (BTS), providing the onboard GSM cell (picocell)
- On-Board Control Equipment (OBCE), providing RF network control features
- Airborne GSM Server (AGS), providing a host for the applications controlling the systems function and most of the aircraft interfaces
- Control Panel, for managing the system’s operation
- RF antennas for receive and transmit paths.

The location of the components is shown in FIG. 2.

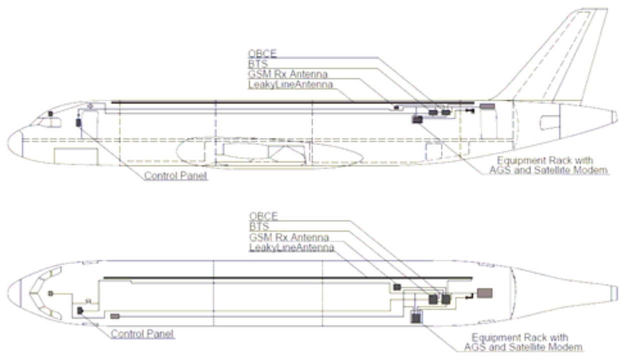

FIG. 2 System components and location

2.2.1. BTS – Base Transceiver Station

The Base Transceiver Station establishes the communication pipe to the mobile phones and supports all necessary system features like radio access, power level control and frequency configuration. It is controlled and configured by the AGS.

2.2.2. OBCE – On-board Control Equipment

The On Board Control Equipment ensures that mobile phones in the cabin cannot access terrestrial networks and that mobile cell phones do not transmit any signal without control of the GSM On-Board system. The OBCE controls mobile stations in all frequency bands in over flown areas (e.g. GSM 900, GSM 1800 and UMTS) and transmits a noise floor, as described in section 2.3.2.

The OBCE holds a database containing geographical data that are used to keep the system's operation within regulatory boundaries.

2.2.3. AGS – Aircraft GSM Server

The Aircraft GSM Server forwards the data streams between BTS and satellite segment. The AGS contains a communication management function for the satellite link and controls the BTS and the OBCE. Communication management function means to manage bandwidth capacity, resources and prioritisation to the satellite modem.

In order to address the latency caused by the signal delay in the communication via geostationary satellite link (approx 36000km) the AGS operates in conjunction with the ground station as classical Base Station Controller (BSC) and additionally onboard network controller for the BTS.

2.2.4. Cabin Antennas

The cabin antennas distribute the RF signals in the cabin. As transmission antenna, a radiating coaxial cable (also known as leaky line) has been selected. It is installed along the cabin behind the ceiling panels. This type of antenna has a very uniform but low field distribution inside the cabin. Therefore the electromagnetic radiation to aircraft equipment, crew and passengers will be very low. The second antenna is a dipole only for reception of the GSM signals emitted from the mobile phones.

2.2.5. Control Panel

The control panel is the physical interface from where the system can be manually accessed by the cabin crew. For this functionality, the design of the control panel includes buttons and system indication lights.

The control panel provides the following means to control the system.

- Service on/off
- Activate/deactivate voice calls, enabling smooth night flights without disturbing ring tones when the people onboard relax
- Information signs 'NO MOBILE' manually
- A forced reset of the system (rarely used)
- System fault and service ready indications

2.3. System Functions

The following subsections will provide a brief overview about the different system functions mobile communication, frequency control, cabin information and system control.

2.3.1. Mobile Communication

The GSM On-Board System provides service to mobile phones according to the GSM 1800 MHz standard, which includes GSM voice telephony service, point-to-point and broadcast SMS services, GPRS data services and supplementary GSM services. These services will be available on commercial available passenger owned mobile phones.

Any other mobile without GSM 1800 capability may also be switched on, but will not work with the system. This means passengers can use all non-communication functions (i.e., calendar or MP3 player) on this type phone. The cabin crew does not have to be able to distinguish between different types of phones.

Other transmitting devices like satellite phones or walkie-talkies are not controlled by the system and have to remain switched off.

2.3.2. Frequency Control Principle

An overall introduction of the communication process between a mobile phone and a base station is drafted here. FIG. 3 shows a simplified access procedure for mobiles stations.

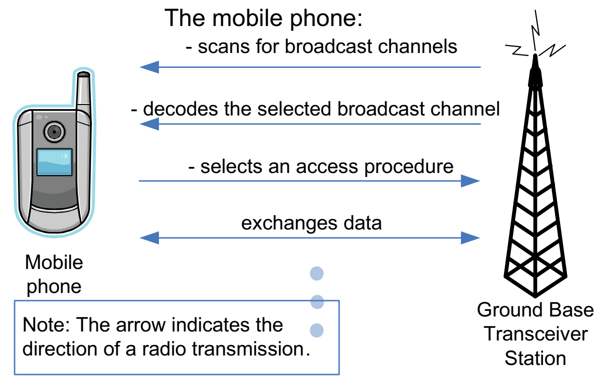

FIG. 3 Mobile access procedure schema

After a GSM mobile phone is switched on, it will scan for broadcast channels from the BTS. Once the broadcast channels are found, the one being received with highest power included in the preferred operators' list of the mobile's phone SIM card will be chosen; if no channel included in the preferred operators' list is found, the one received with more power from the roaming operators list will be chosen. If no channels are found included in any of the lists, the mobile phone will remain in idle mode without starting any transmission. Once the broadcast channel is selected, the data broadcasted by the BTS in this channel is decoded, an access procedure is selected and the exchange of data between mobile phone and BTS can begin.

In summary control of mobile phones is possible due to the property of mobile phones not to transmit without having received and decoded a BTS signal. The idea was borne to influence or overwrite the low level (due to the altitude of the aircraft above ground) telecommunication signals from terrestrial network. This can be achieved by generating a noise signal with slightly higher power level than the receivable ground stations.

Such a noise floor is generated by the OBCE affecting that the terrestrial signals are hidden for the mobiles in the aircraft. And in consequence, the mobile phones on board will not transmit and are fully controlled regarding feared interferences. The only signal that may be received and decoded by phones in the aircraft is the signal coming from the onboard BTS. Once this signal is detected and decoded, the communication between mobile phones and the aircraft BTS begins as described above.

However the important requirement related to this method is not creating any harmful interference to terrestrial networks.

FIG. 4 shows the spectrum measured in the aircraft in which the signal coming from the BTS on board the aircraft is received with more power than the unwanted signals from the terrestrial stations. The 'Noise Floor' line indicates the required power level of the noise floor, which is to be generated by the OBCE, in order to hide the base transceiver stations on ground.

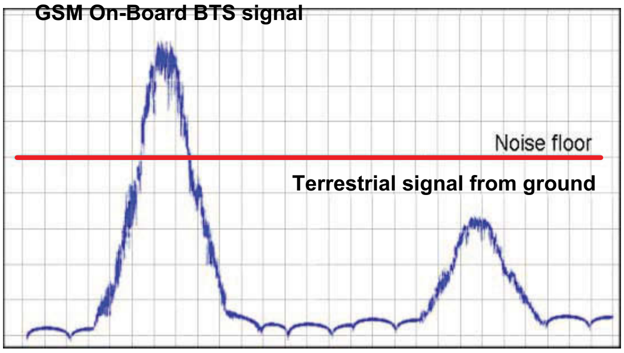

FIG. 4 Measured power levels of the BTS on board, a BTS on ground and the indicated OBCE power level.

The power level of the noise signal should be as low as possible but as high as needed to sufficiently suppress the visibility of the terrestrial station.

Similar applies to the BTS on board output power. It is adjusted in a way that the level is as low as possible to avoid interferences but still high enough to make the onboard cell visible for mobile phones on ground.

Influencing parameter are signal levels and location of ground stations, free space loss between the aircraft and ground as well as attenuation by the aircraft shielding.

As a consequence the GSM on Board system offers service only in flight above a certain altitude. This altitude adds some required attenuation to the signals coming from the BTS on board for potential receivers on ground. The signal should not be detectable on ground. And vice-versa the mobile phones on ground may not be able to connect the on board system.

For the adjustment of the power levels and extensive measurement campaign has been performed including ground and flight tests. One of the flight tests has been performed to evaluate possible interferences between the GSM On-Board system and terrestrial networks under real flight conditions. For this test, ground-based transmitters have been installed on mountain "Brocken" (lat.: 51° 48′ 2″ N, long.: 10° 37′ 2″ E, altitude: 1141.1m above sea level). During the in-flight measurements the aircraft performed a predefined flight pattern above the ground transmitters in order to simulate real flight conditions. The flight pattern included varying altitudes and approach angles.

The actually applied power level of the mobile phones used onboard is approximately 30dB lower compared to its typical usage on ground.

2.3.3. Operation of the System

The system is designed to operate automatically. However interaction between cabin crew and passengers and eventually also cockpit crew is required.

The conditions for the operation can be summarised as

- The aircraft altitude is above a certain altitude, in Airbus A320 family: 3000m above ground position, see FIG. 5
- The aircraft flies in the air space of countries where the GSM on-board service is licensed
- The system operates with all equipment in healthy condition
- The cabin or cockpit crew has not manually switched on the 'NO MOBILE' signs in the supply channel (see below)
- The cabin or cockpit crew has not deactivated the system

A typical flight profile is shown in FIG 5. As long as the aircraft is on ground the service has to stay off. During critical flight phases such as take-off, landing or descent, approach the mobile phones are also not permitted and have to be switched off. The system is automatically switch on reaching altitude level higher than 3000m. The 'NO MOBILE' signs are off during cruise.

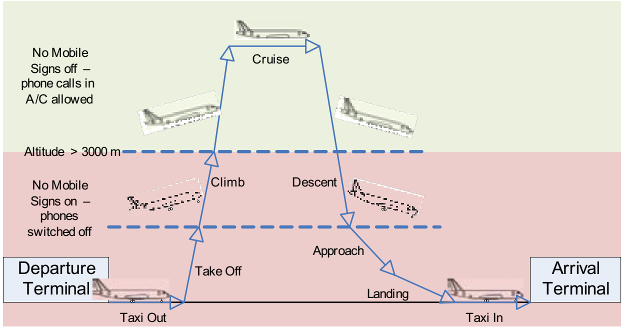

FIG. 5 Passenger signs during flight phases

Airbus designed a dedicated 'NO MOBILE' signs to indicate clearly when it is not allowed to use the mobile phones. This new sign is located above the passengers seat along the cabin.

FIG. 6 No-Mobile signs

Once the signs are illuminated the GSM service is shut down until neither the BTS nor the OBCE contribute to mobile phone control.

Further to the control means at Control Panel the cockpit crew is also in the position to shut down the service. Therefore a dedicated switch is installed. This function should be used just in case of the pilots do not trust their displays assuming interferences caused by mobile phones.

Maintenance advice is provided by a dedicated cabin plug for connection of a mobile computer such as laptop. A variety of maintenance actions, including reading of failure reports and software loading (via laptop) is possible via built-in graphical user interface.

3. ELECTROMAGNETIC COMPATIBILITY WITH AIRCRAFT ELECTRONICS

Beside the requirement that mobile phone networks on ground may not be disturbed, another major challenge had to be considered, the electromagnetic compatibility with aircraft electronics. As of today, electronic equipment in the aircraft was qualified against the standards, established by the RTCA and EUROCAE committees (see [DO160]).

These standard are sufficient for aircraft environment qualification but they do not reflect the most recent frequency allocation for telecommunication networks. That means for the flight critical systems and equipment the qualification levels may be sufficient but were never tested for the mobile phone network frequencies. So this means an unknown compliance to the RF susceptibility.

Further with the installation of the GSM On-Board system, an RF network is provided in the aircraft with mobile phones transmitting on relatively low power levels thanks to the controlled environment. In consequence we added a new source for RF emission as intentional transmitters to the qualification bases of the aircraft equipment. Also here additional attention was required.

However discussions with the EASA showed scenarios where the EMI controlled environment is not given:

- In undetected failure case that means the system does not work without any action to switch off the mobiles
- When the aircraft is approaching ground and people simply do not switch off their mobile phones.

Then the mobile phone could either interfere with the aircraft electronics (safety issue) or terrestrial telecommunication network (regulatory issue). The important finding was: There was no designed-in safety feature on system level possible that mitigates the interference risk caused by mobile phone.

For the justification derived worst-case scenario had been defined as the maximum of mobile phones are uncontrolled and would connect to the ground stations. The impact is a very high level of EMI emission that is generated by many mobile phones trying to communicate with maximum power simultaneously.

At the end Airbus followed the requirement from EASA to provide an assessment for each and individual aircraft that is equipped with GSM On-Board stating the EMC compatibility of the aircraft.

The justification assessment includes an analysis of safety relevant equipment, usually an aircraft level EMC test and appropriate technical.

In summary with the installation of the GSM Onboard system Airbus proved once more that the risk of interferences caused by mobile phones is negligible.

4. CONCLUSION

Airbus pioneered to enable mobile phones on aircraft. Airbus developed and installed the GSM On-Board applying the first time Inmarsat's SwiftBroadband service (started as "BGAN with wings"). The baseline for certification has been set and proofed, that the use of mobile phones in the aircraft will not interfere with base stations on ground.

Airbus performed a specific assessment considering aircraft level EMC test and proved that mobile devices will not interfere with aircraft electronics.

In the meantime the system has been introduced on Airbus aircraft of about 15 airlines.
The equipment is flying on around 50 aircraft and was already committed by 40 airlines worldwide.

5. REFERENCES

[LuftEBV] Luftfahrzeug-Elektronik-Betriebs-Verordnung vom 22. Februar 2008 (BGBl. I 2008 S. 266)

[ED130] EUROCAE ED-130, Guidance for the use of Portable Electronic Devices (PEDs) on board Aircraft, Malakoff, 2006

[DO160] RTCA DO-160, Environmental Conditions and Test Procedures for Airborne Equipment

6. ABBREVIATIONS

A/C	Aircraft
AGS	Aircraft Ground Server
BGAN	Broadband Global Access Network
BSC	Base Station Controller
BTS	Base Transceiver Station
EASA	European Aviation Safety Agency
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
GES	Ground Earth Station
GGS	Ground GSM Server
GPRS	General Packet Radio Service
GSM	Global System Mobile
OBCE	Onboard Control Equipment
RF	Radio Frequency
RX	Receiver
SMS	Short Message Service
TX	Transmission