ECC Report 214

Broadband Direct-Air-to-Ground Communications (DA2GC)

Approved 30 May 2014

0 EXECUTIVE SUMMARY

Mobile customers expect to be connected everywhere, every time, with all kind of mobile devices. This includes the provision of broadband services on-board aircraft and European airlines have great interest to offer internet services to their flight passengers in their continental fleets as soon as possible.

The connection link between the aircraft and the global broadband network can be established either via satellites or by means of Direct-Air-to-Ground Communications (DA2GC). Satellite and DA2GC can be seen as alternative technical solutions which are in competition. On the other hand, both solutions could also be seen as complementary to each other. It should be noted, although it is outside the scope of this ECC Report, that MSS systems (1980-2010 MHz / 2170-2200 MHz) are being developed and such systems may include a Complementary Ground Component (CGC). In Europe, MSS systems might also be used to provide communication to aircraft in the future, for which technical studies and further regulatory considerations are required.

A Broadband DA2GC system constitutes an application for various types of telecommunications services, such as internet access and mobile multimedia services. It aims to provide access to broadband communication services[1] during continental flights on a Europe-wide basis[2]. The request for spectrum is related to the direct-air-to-ground radio solution. The connection with the flight passengers' user terminals on-board aircraft is to be realised by already available fixed or Wi-Fi-based on-board connectivity network and/or via GSM, UMTS or LTE on-board aircraft.

This ECC Report provides the basis for frequency designation and respective regulation for Broadband DA2GC. It takes also into account the outcome of the relevant compatibility and sharing studies as provided by ECC Reports 209 [14], 210 [16] and the ECC Report 220 on Compatibility and sharing studies of DA2GC, PMSE video links, SRD and DECT in the 2 GHz unpaired bands [15].

The implementation and operation of more than one pan-European Broadband DA2GC system in the same frequency band (either in the unpaired 2 GHz bands or in the 5.8 GHz band) was considered as unlikely. Therefore intra-service sharing studies (e.g. for two Broadband DA2GC systems in the unpaired 2 GHz bands) were not carried out. However, by looking at the results as described under section 6 of this ECC Report it appears obvious that co-channel operation of different Broadband DA2GC systems would not be possible in the same geographical area.

The work on this ECC Report was initiated by three different ETSI System Reference Documents [1], [2] and [3] and is also relevant for the Mandate from the European Commission [24] on the frequency bands 1900-1920 MHz and 2010-2025 MHz.

Various frequency bands below 6 GHz were identified which could be suitable for fulfilling the spectrum requirements for the Broadband DA2GC systems when the activities within CEPT started. This list is available in ANNEX 2: of this ECC Report. It contains 4 categories which had, at the point of time when it was created, reflected the potential for each identified frequency band to be harmonised within CEPT countries and to be retained as a frequency band for Broadband DA2GC. Some frequency bands were selected for detailed investigations and for conducting compatibility and sharing studies. Some bands were considered less suitable after initial studies or considerations. A short term solution for Broadband DA2GC (by end of 2017) could not be realised in a frequency band above 6 GHz. However, higher frequency bands can be considered in the future for next generation Broadband DA2GC systems.

A future spectrum designation for Broadband DA2GC should be technology neutral as far as possible taking into account the three different system descriptions as described in section 5 of this ECC Report. However, the system proposals are based on different technologies, different assumptions and different business models. Therefore it was not possible to define only a single set of parameters for the Broadband DA2GC spectrum designation/regulation.

[1] "Broadband" in this context refers to a service providing data rates between several hundred kbit/s up to several Mbit/s per end-user, depending on the traffic load within a communication cell.

[2] Precise geographical coverage will be determined by flight traffic density considerations and airline demand and hence some regions within CEPT might not be covered.

Five different options have been considered (the order does not indicate any prioritisation):

1. An FDD system according to ETSI TR 103 054, frequency bands: 1900-1910 MHz (FL) and 2010-2020 MHz (RL);
2. A TDD system according to ETSI TR 101 599, frequency band: 5855-5875 MHz;
3. A TDD system according to ETSI TR 101 599, frequency band: 1900-1920 MHz;
4. A TDD system according to ETSI TR 103 108, frequency band: 5855-5875 MHz;
5. A TDD system according to ETSI TR 103 108, frequency band: 1900-1920 MHz.

Especially by taking into account the pan-European character of Broadband DA2GC, which results in a significant requirement for harmonisation, it was concluded that (an) ECC Decision(s) would be more appropriate than (an) ECC Recommendation(s). The three system proponents consider an EU harmonisation measure to be important for a European wide implementation of Broadband DA2GCS.

Currently, all or parts of the frequency band 1900-1920 MHz is licensed to mobile operators for the provision of electronic communications services in 36 CEPT countries, whereby the licences are mainly limited to UMTS/IMT-2000 TDD technology. On the other hand, the frequency band 2010-2025 MHz, or parts of it, is licensed to mobile operators in 13 CEPT countries for the provision of electronic communications services, mainly limited to UMTS/IMT-2000 TDD technology and in some cases in a technology neutral way. Even if not used, the duration of those licenses vary from country to country, from 2014-2029 (or even unlimited duration, in United Kingdom). In addition it has to be mentioned that licences have already been surrendered in some countries.

Licensing constraints, similar to the ones described above, do not exist for the frequency band 5855-5875 MHz. The key issues considered in relation to this band were those related to coexistence with other radio applications in or adjacent to the band 5855-5875 MHz.

The regulatory parameters for the five options as indicated above are provided in ANNEX 6: (for No. 1), ANNEX 7: (for No. 2), ANNEX 8:(for No. 3) and in ANNEX 9: (for Nos. 4 and 5) to this ECC Report. They should be considered as core elements for a future frequency designation/regulation for Broadband DA2GC, i.e. for the technical Annex(es) to (a) new ECC Decision(s). However, these regulatory masks should not prevent future developments of Broadband DA2GC systems nor the roll-out of a system with similar characteristics to those assumed for the technical studies.

Network investment and deployment costs as well as aircraft equipment costs are high for Broadband DA2GCS, especially when considering the first roll-out of Broadband DA2GCS. The implementation of such a system is only reasonable if a gap-free and continental-wide coverage is achieved, thus a CEPT wide harmonised radio spectrum designation and harmonised licensing conditions would be essential. In addition, a European harmonised authorisation framework is considered necessary to provide the regulatory certainty that network operators and airlines require to invest in a Broadband DA2GCS.

Given the need for substantial financial investment, together with the requirement to protect other spectrum users, it is reasonable to envisage individual authorisation for the ground stations in Europe and that the aircraft stations are exempted from individual licensing. Free circulation and use is required for Aircraft Stations which are under the control of the Broadband DA2GC network and this could be achieved under the umbrella of an ECC Decision. In addition it is important that the chosen forms of regulation and licensing do not impose unreasonable restrictions on competition.

The deployment of a European wide Broadband DA2GC network on a harmonised basis is urgent and a decision regarding spectrum and licensing conditions needs to be made quickly for a start of operation by end of 2017. Otherwise European airlines could only implement satellite solutions which may be more expensive.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
3G	Third Generation
3GPP	Third Generation Partnership Project
4G	Fourth Generation
AAC	Airline Administrative Communications
ACARS	Aircraft Communications Addressing and Reporting System
AM(R)S	Aeronautical mobile service (route)
AMS	Aeronautical mobile service
AOC	Airline Operational Communications
APC	Air Passenger Communications
AS	Aircraft Station
ATC	Air Traffic Control
ATM	Air Traffic Management
BBDR	Broad Band Disaster Relief
BEM	Block Edge Mask
BFWA	Broadband Fixed Wireless Access
BWA	Broadband Wireless Access
CAGR	Compound Annual Growth Rate
CCL	Cordless Camera Link
CEPT	Conférence Européenne des Administrations des Postes et des Télécommunications (European Conference of Postal and Telecommunications Administrations)
COTS	Commercial off-the-shelf
DAA	Detect-And-Avoid
DA2GC	Direct-Air-to-Ground Communications
DA2GCS	Direct-Air-to-Ground Communications System(s)
DECT	Digital Enhanced Cordless Telecommunications
DSRC	Dedicated Short-Range Communications
EC	European Commission
ECC	Electronic Communications Committee
ECS	Electronic Communications Services
EESS	Earth Exploration-Satellite Service
e.i.r.p.	Equivalent Isotropically Radiated Power
ENG/OB	Electronic news gathering / Outside broadcasting
EPS	Evolved Packet System
E-s	Earth-to-space
ESOMP	Earth stations on mobile platforms
ETSI	European Telecommunications Standards Institute
EU	European Union
E-UTRA	Evolved UMTS Terrestrial Radio Access
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
FCC	Federal Communications Commission (USA)
FDD	Frequency Division Duplex
FL	Forward Link
FS	Fixed service
FSS	Fixed-satellite service
GBR	Guaranteed Bit Rate
GS	Ground Station
GSM	Global System for Mobile communications
GSMOBA	GSM On-Board Aircraft

IFE	In-Flight Entertainment
IFR	Instrument Flight Rules
IMS	Internet Protocol Multimedia Subsystem
IP	Internet Protocol
ISD	Inter-site distance
ISM	Industrial, scientific and medical applications
ITS	Intelligent Transport System
ITU-R	International Telecommunication Union – Radio sector
LTE	Long Term Evolution
MCA	Mobile communication services on aircraft
MES	Mobile Earth Station
MFCN	Mobile/fixed communications networks
MIMO	Multiple input multiple output
MLS	Microwave Landing System
MS	Mobile service
MSS	Mobile-satellite service
MVL	Mobile Video Link
NGMN	Next Generation Mobile Network
O&M	Operation and Maintenance
OPEX	Operational expenditure
PMSE	Programme Making and Special Events
P-P	Point-to-point
PVL	Portable Video Link
QCI	QoS Class Identifier
QoS	Quality of Service
RDSS	Radiodetermination-satellite service
RF	Radio frequency
RFID	Radio frequency identification device
RL	Reverse Link
RLAN	Radio Local Area Network
RLS	Radiolocation service
RSC	Radio Spectrum Committee (of the EC)
R&TTE Directive	Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 *on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity*
SAB	Services Ancillary to Broadcasting
SAE	System Architecture Evolution
SAP	Services Ancillary to Programme making
s-E	Space-to-Earth
SINR	Signal to Interference plus Noise Ratio
SISO	Single input single output
SRD	Short Range Device
SRS	Space research service
TDD	Time Division Duplex
TRA-ECS	Terrestrial radio applications capable of providing Electronic Communications Services
TTT	Transport and Traffic Telematics
UE	User equipment
UMTS	Universal Mobile Telecommunications System
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
WAPECS	Wireless Access Policy for Electronic Communications Services
WIA	Wireless Industrial Application
Wi-Fi	Wireless Fidelity
WRC	World Radiocommunication Conference (of ITU)

1 INTRODUCTION

A Broadband DA2GC system constitutes an application for various types of telecommunications services, such as internet access and mobile multimedia services. It aims to provide access to broadband communication services[3] during continental flights on a Europe-wide basis[4]. The request for spectrum is related to the direct-air-to-ground radio solution. The connection with the flight passengers' user terminals on-board aircraft is to be realised by already available fixed or Wi-Fi-based on-board connectivity network and/or via GSM, UMTS or LTE on-board aircraft.

The main application field would be Air Passenger Communications (APC). In addition a Broadband DA2GC system could also support Airline Administrative Communications services (AAC) and thus improving aircraft operation, resulting in particular in reduced OPEX for the airlines. Safety-relevant communications such as Air Traffic Control (ATC) and related services are not intended to be covered. However, it would also be advantageous to have a broadband connection to aircraft in cases of emergency.

Various satellite technologies are today available for Europe for providing on-board connectivity. Satellite systems, typically operating in L-band, Ku-band and Ka-band[5] are currently providing communication to aircraft for passenger connectivity. Furthermore, MSS systems (1980-2010 MHz / 2170-2200 MHz) are being developed and such systems may include a Complementary Ground Component (CGC). Such MSS systems might also be used to provide communication to aircraft in the future, for which technical studies and further regulatory considerations are required[6]. These solutions are outside the scope of this ECC Report. Satellite and DA2GC can therefore be seen as alternative technical solutions which are in competition. On the other hand, both solutions could also be seen as complementary to each other.

However, no spectrum has been designated so far specifically for Broadband DA2GC in Europe. In order to promote competition with regard to on-board connectivity market and to allow European citizens and airlines to profit from the social and economic benefits of the implementation of such a radio application (intended to provide broadband connectivity between the aircraft and a terrestrial based network), a harmonised spectrum designation within CEPT would be necessary. In order for Broadband DA2GC operators to offer a viable solution then there would need to be widespread implementation of any harmonisation measure(s) throughout CEPT countries. Any harmonisation measure(s) would also need to include some sort of agreement to allow the free circulation and use of the Broadband DA2GC aircraft stations throughout CEPT countries.

It should also be noted that in North America an air–to-ground system has been established with more than 2 000 commercial aircraft and 6 300 business aircraft equipped so far. In addition, the FCC considers a proposal for DA2G Communications at 14.0-14.5 GHz (sharing with the FSS uplink whereby ground stations avoid transmissions into the geostationary arc). This information, dated 12 October 2012, informs about the considerations for the next generation direct-air-to-ground communication system which may be under consideration for the USA and Canada. The system would support high speed broadband connectivity for airplane passengers using smartphones, tablets, and laptops - the full range of wireless devices that are used intensely on the ground. The existing license period in the USA ends in 2016. In addition, besides using DA2GC, the existing North American DA2G provider has also plans to use Ka-Band satellites as was announced in December 2012 (this relates to the ECC/DEC/(13)01 [20] on ESOMPs). A short term solution for Broadband DA2GC (by end of 2017) could not be realised in a frequency band above 6 GHz. However, higher frequency bands can be considered in the future for next generation Broadband DA2GC systems.

The Civil Aviation Administration of China (CAAC) announced in October 2012 that the China's Civil Aviation Air-ground Broadband Communications System project will be able to provide individualised communications services to more than 300 million travellers per year. It was stressed that the connection of satellite links and terrestrial communications networks can be employed, and ground-based dedicated base stations can be used to cover the sky, directly achieving mobile communications between base stations and aircraft. Currently, the satellite communications method is more mature, but bandwidth is severely limited and

[3] "Broadband" in this context refers to a service providing data rates between several hundred kbit/s up to several Mbit/s per end-user, depending on the traffic load within a communication cell.
[4] Precise geographical coverage will be determined by flight traffic density considerations and airline demand and hence some regions within CEPT might not be covered.
[5] Briefly addressed in ECC Report 184 (for ESOMPs) [53]
[6] On-going work within CEPT and EU at the time of adoption of this ECC Report.

communication costs are high. The announcement said that using the surface-to-air base station method requires constructing a network of base stations covering each flight route, which can better ensure communications bandwidth and lower communication costs.

China is currently testing CDMA EV-DO to cover all of China's air routes. The industry is also studying the use of the fourth-generation mobile communications standard LTE, which provides higher download speeds, for route coverage. Trials for DA2G communications are underway under the direction of CAA China and other Chinese Government entities to operate in 1785-1805 MHz band (20 MHz total bandwidth for DA2GC) and using TD-LTE technology. At present, China Telecom has constructed four surface-to-air base stations on the Beijing-Chengdu route, and has a total of 17 base stations completed as of early 2012. Under the plan, China will construct up to a thousand surface-to-air base stations in the next few years. China's Civil Aviation Air-Ground Broadband Communications System will cover all routes of the major domestic airlines.

European companies represent an important force in the aeronautical market. The European aircraft industry holds about 50% of the world market for aircraft manufacturing. In the field of Air Passenger Communications services, however, Europe has room for improvements when compared to other parts of the world.

European Airlines are following the CEPT activities on Broadband DA2GC. So far Lufthansa / Swiss / Austrian airlines, KLM / Air France, Air Berlin and British Airways have sent letters to CEPT showing their interest in a solution for Broadband DA2GC in Europe.

2 DEFINITIONS

For the purpose of the present document the following definitions apply.

Table 1: Definitions for Broadband DA2GC

Term	Definition
Broadband	“Broadband” in this context refers to a service providing data rates between several hundred kbit/s up to several Mbit/s per end-user, depending on the traffic load within a communication cell
Direct-Air-to-Ground Communications	Direct radio link between an Aircraft Station (AS) and a Ground Station (GS).
Ground Station (GS)	Entity on the ground providing the radio, control and telecommunication functionalities for DA2GC.
Aircraft Station (AS)	Entity on-board aircraft providing the radio, control and telecommunication functionalities for broadband DA2G communication.
Forward Link (FL)	Within the DA2GC system the link from the Ground Station (GS) to the Aircraft Station (AS).
Reverse Link (RL)	Within the DA2GC system the link from the Aircraft Station (AS) to the Ground Station (GS).

3 MOTIVATION AND SPECTRUM DEMAND FOR BROADBAND DA2GC

It was decided by ECC that for the compatibility and sharing studies only those parameters for Broadband DA2GC should be used which are based on / derived from the following three system descriptions as provided by ETSI:

- “System Reference Document on Broadband Direct-Air-to-Ground Communications operating in part of the frequency range from 790 MHz to 5150 MHz“, ETSI TR 103 054 V1.1.1 (2010-07), see [1];

- “System Reference Document on Broadband Direct-Air-to-Ground Communications System employing beamforming antennas, operating in the 2.4 GHz and 5.8 GHz bands“, ETSI TR 101 599 V1.1.3 (2012-09), see [2];

- and "System Reference Document on Broadband Direct-Air-to-Ground Communications System operating in the 5.855 GHz to 5.875 GHz band using 3G technology", ETSI TR 103 108 V1.1.1 (2013-07), see [3].

3.1 MOTIVATION FOR BROADBAND DA2GC

Mobile customers expect to be connected everywhere, every time, with all kind of mobile devices. This includes the provision of broadband services on-board aircraft and European airlines have great interest to offer internet services to their flight passengers in their continental fleets as soon as possible.

The connection link between the aircraft and the ground can be established either via satellites or by means of Direct-Air-to-Ground Communications (DA2GC). Using satellites for on-board aircraft internet access may also provide intercontinental coverage.

For future broadband services, it can be foreseen that the service provision via satellite will be conducted by using Ka-band satellite capacity and a considerable number of Ka-Band satellites have already been put into operation or are under procurement. Satellite operators also consider mobile platforms such as aircraft and vessels as a considerable part of the addressable market and the ECC adopted a new Decision on Earth Stations on Mobile Platforms (ESOMP), ECC/DEC/(13)01 [20]. Alternatively, DA2GC services are already well established in other frequency bands than considered in this ECC Report in North America (USA and Canada) and are also being considered for introduction in other parts of the world, e.g. in China.

Ka-band satellite and DA2GC can therefore be seen as alternative technical solutions which are in competition. On the other hand, both solutions could also be seen as complementary to each other.

The establishment of a pan-European regulatory environment for Broadband DA2GC would provide ample benefits for the users - i.e. airlines and passengers - in Europe:

- As an alternative service provision which by fostering competition (between DA2GC and satellite solutions) might lead to a lower cost for airlines and airline passengers;
- The technical implementation of DA2GC and also the stimulus of competition may lead to a provision of services at improved cost structures - including non-safety-relevant administrative communication services - and hence create a benefit to end customers and airlines resulting in higher and earlier service take-up;
- DA2GC avoids the round trip delay that is typical and unavoidable for geostationary satellite service provision and hence can provide low latency services;
- The costs for aircraft installations and maintenance are a key issue for airlines. The fact that DA2GC equipment can be installed overnight on a plane is seen as an advantage by airlines. In particular with regard to the aircraft antenna (e.g. smaller size and weight and hence lower fuel consumption), a terrestrial solution has a clear advantage compared to existing satellite usage.

A further motivation arises from the expected growth of the air traffic. A forecast from Eurocontrol[7] published in October 2011 estimates 11.5 million movements under Instrument Flight Rules (IFR) in Europe in 2017. This is 21% more than in 2010.

About two thirds, i.e. the main part of the airline business, of the European air traffic consist of domestic or continental flights. The addressable market in Europe for DA2GC is currently consisting of about 160 airlines with more than 4 500 aircraft expected in 2014 (without business aviation). In general a strong increase in percentage of aircraft fleet equipped with internet connectivity solutions is expected during the next years. According to a market research approximately 50% of the world's fleet will have been equipped with Wi-Fi connectivity by 2020[8].

[7] http://www.eurocontrol.int/statfor/public/subsite_homepage/homepage.html
[8] IMS research: http://imsresearch.com/news-events/press-template.php?pr_id=1981

An introduction of a Broadband DA2GC solution would not only increase Europe's competitive position, but it could also bring Europe into a leading position in this market segment. Studies on airline passenger demand for on-board connectivity are currently not publicly available[9].

The introduction of a new Broadband DA2GC system providing mobile services would contribute to the development of the internal market and enhance competition by increasing the availability of pan-European services and end-to-end connectivity as well as encouraging efficient investment. DA2GC constitutes an innovative alternative platform for various types of pan-European telecommunications services provided to airline passengers.

The provision of broadband services including also all kinds of transportation sectors is a declared goal under the European Digital Agenda 2020 plans.

DA2GC networks provide such services without the round trip delay that is a limitation of the competing geostationary satellite service solutions. In addition, these networks can provide services to aircraft by using antennas that are considerably more efficient in terms of weight, size, aircraft installation costs and air drag when compared to aircraft mounted satellite antennas.

3.1.1 Evolution of air traffic

Based on studies of e.g. Airbus, Boeing, and Eurocontrol (see [4], [5] and [6]), the expected air traffic increase in the European area is estimated to be in the range of about 3% per year for commercial aircraft at least for the next ten years. 3400 commercial aircraft were in operation for pan-European continental connections in 2009. Considering the estimated increase, about 4500 aircraft will be available in the European continental market in 2020.

In addition also a significant part of business aviation is expected to use Broadband DA2GC, if available. In 2009 the number of registered business aircraft was in the same range as the commercial continental aircraft, but in contrast to commercial aviation most business aircraft operators have only a low number of flights per week (see [6] and [7]). Therefore, the air traffic amount is primarily dominated by the commercial aircraft market.

This is demonstrated in Figure 1 which shows the share of flights of the main aviation market segments in Europe in 2009 [7]. With Broadband DA2GC the segments of traditional scheduled, low-cost, charter and business aviation are targeted, i.e. 92% of the overall market.

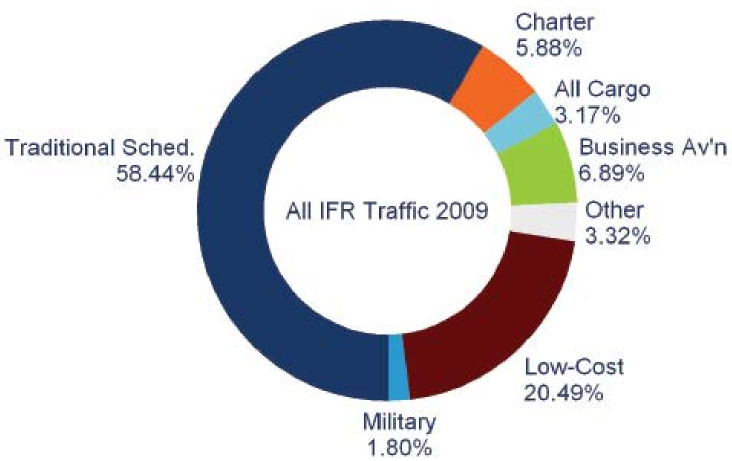


Figure 1: Market shares of flights of the main market segments

[9] See document FM50(12)017_Air_passenger_survey_results at http://www.cept.org/ecc/groups/ecc/wg-fm/fm-50/client/meeting-documents; 2012; M5 – 6-9 March; Input documents

According to Figure 1 it is clear that the focus of Broadband DA2GC is on the commercial aircraft market. However, also a significant part of business aviation is expected to use Broadband DA2GC, if available. In 2009 the number of registered business aircraft was in the same range as the commercial continental aircraft, although the number of flights operated by business aircraft was very much lower than for the commercial airline sector.

A study carried out by TriaGnoSys on statistical evaluation of commercial continental aircraft traffic in Europe based on flight schedules of a typical day in 2009 shows that during main daily flight time about 1900 aircraft are on average en-route in the European air space [8].

Assigning the traffic according to location and time to a hexagonal cellular grid on the pan-European area allows assessing the traffic density over time Broadband DA2GC would have to cope with (see Figure 2)

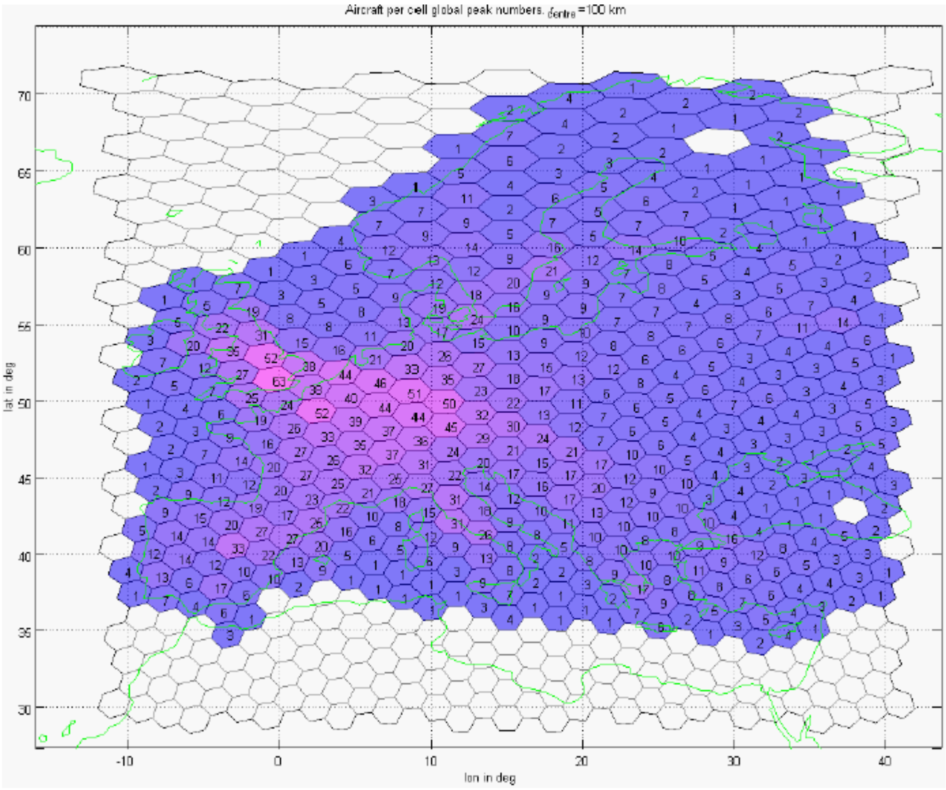


Figure 2: Peak values of commercial continental aircraft per cell during a day in 2009 in the European area (cell radius of 100 km assumed) [8]

3.1.2 Evolution of internet service usage by end customers

It is expected that the usage of internet-based services in aircraft will strongly increase during next years following the trends already seen in terrestrial mobile radio networks and in Wi-Fi hot spots.

This assumption is confirmed by the following facts:

- Passengers want to be able to use the same applications in the air as on the ground in fixed and wireless networks. Especially the upcoming generation of digital natives is accustomed to be always online in social networks (Twitter, Facebook, etc.);
- During their journeys business travellers require more and more to get informed by phone and/or by data exchange about relevant issues with impact to their commercial activities;
- The data throughput per customer (here per passenger) will also increase due to changes in service usability (higher percentage of video services, larger web page sizes because of more multimedia elements, lower price per Megabyte, …);
- The end user equipment is drastically changing from classical voice-centric mobile phones and laptops for data services to smart phones and tablet PCs, which is simplifying especially the use of services on-board aircraft in spite of limited space.

As an example Figure 3 shows the global mobile data traffic forecast of Cisco until 2015 with a CAGR of 92% [9]. Especially the strong impact of mobile video services is clearly seen (about 2/3 of overall data volume in 2015).

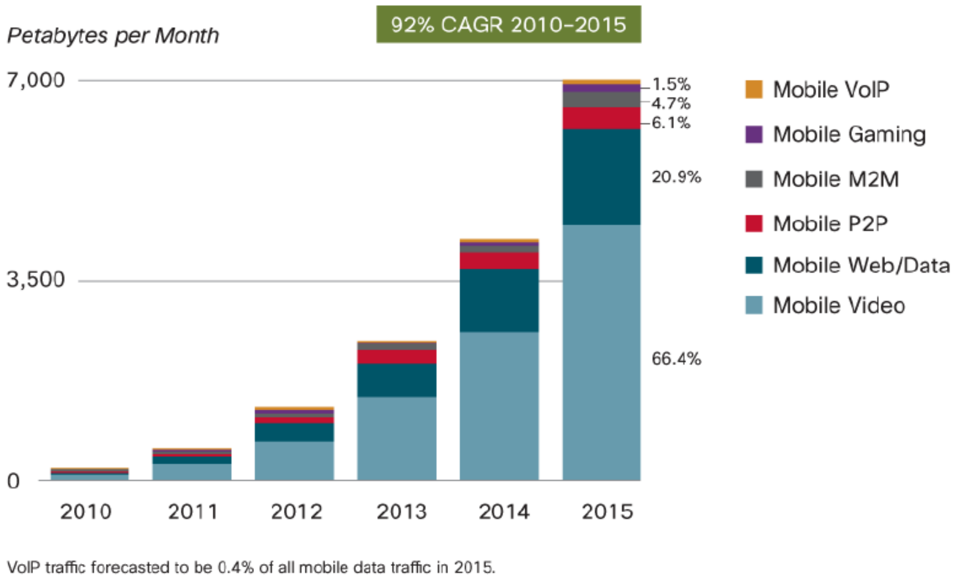


Figure 3: Global mobile data traffic forecast until 2015 [9]

A summary of similar forecasts can be found e.g. in [10], including also values until 2020.

The EU Radio Spectrum Policy Programme is targeting access to wired or wireless broadband at a speed of not less than 30 Mbit/s for all EU citizens by 2020, which will have an impact on the customers' expectations and behaviour related to these kind of services. The typical data rate per user in a plane is not comparable with the data rate on the ground (terrestrial or wired systems) due to a shared medium within a larger coverage area and the long links between GS and AS but nevertheless it provides the ability for a range of broadband applications to users on aircraft.

3.1.3 Evolution of airline related services

In addition to passenger service evolution, airlines are expected to change their strategy particularly with respect to Airline Administrative Communications (AAC) in the future if a broadband link is available at lower cost compared to existing satellite systems (for non-safety relevant applications) (see e.g. [11]).

3.1.4 Example of DA2GC/IFE architecture

The in-flight entertainment (IFE) distribution system makes use of wireless networking technology to enable passengers to use their personal devices such as laptops during the flight to access the internet, watch videos, communicate via e-mail and take advantage of the multitude of web-based applications which are already available via terrestrial fixed and mobile broadband networks. The system also allows for airlines to make these services available via in-seat displays.

The IFE element of this system has been installed and successfully tested on commercial airliners. Tests inside the aircraft proved the usability of the wireless IFE solution under full load conditions and with other communication channels in use.

Figure 1 Illustrate the basic concept of the IFE system, together with the connection to the air-to-ground radio equipment and, in this example, four aircraft mounted antennas.

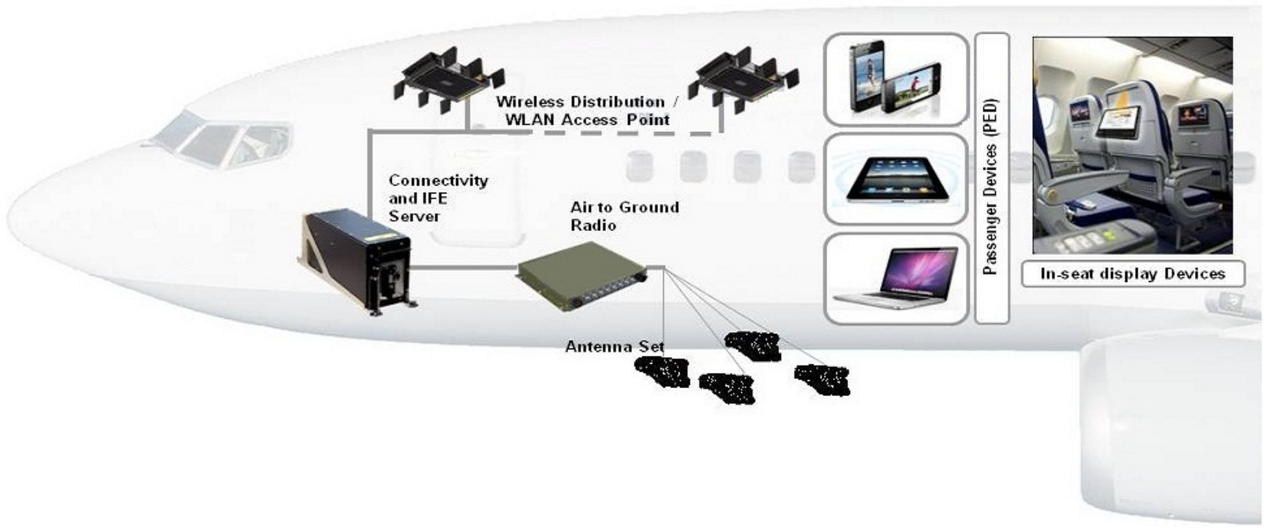


Figure 4: In-flight Entertainment System and airborne DA2G equipment connectivity

Specifically tailored passenger information services could also be provided, such as arrival-, transfer-, customs- and airport-related information, Moving Map flight information, In-flight Shopping, travel advice, destination tourist information, weather forecasts, etc.

Airline information data (non-safety relevant) could include localised real-time weather information to better inform the pilot of immediate weather conditions as well as the ability to relay real-time flight systems data from the aircraft to the ground to assist in diagnostics and other flight-related requirements.

3.2 SPECTRUM DEMAND FOR BROADBAND DA2GC

The spectrum demand for Broadband DA2GC is derived from a summary of relevant factors essential to cope with future capacity demand as well as from results achieved by system performance evaluations.

The statistical traffic evaluations show that there is an average number of more than 26 aircraft simultaneously within one cell with coverage radius of 100 km in dense air traffic areas which are concentrated in Western/Central Europe (mainly Germany, France, Benelux, Switzerland, Austria, England, Northern Spain and Northern Italy). It has to be mentioned that there are also areas at the edge of the flight zones, where the cells have only a low traffic density in the range of 1 - 2 aircraft simultaneously. The approach used assumes that about 60% of the fleets are covered. More details are provided in ANNEX 1:

Based on these calculations, paired spectrum of 2 x 10 MHz for FDD operation is agreed to be necessary for a single network to cope with short- to medium-term demand. Unpaired spectrum of 20 MHz for a single TDD network would also be an alternative.

3.3 FREQUENCY BANDS PROPOSED FOR CONSIDERATION

A list of candidate frequency bands had been established in order to identify bands which are suitable for fulfilling the spectrum requirements for the Broadband DA2GC systems under consideration. This list is available in ANNEX 2: of this Report. It contains 4 categories which had, at the point of time when it was created, reflected the potential for each identified frequency band to be harmonised within CEPT countries and to be retained as the executive frequency band for Broadband DA2GC. Some frequency bands were selected for detailed investigations and for conducting compatibility and sharing studies. Some bands were considered less suitable after initial studies or considerations.

The frequency bands selected for compatibility studies are listed in Table 2. More detailed information on the conclusions derived from the compatibility studies" is given in section 6.

Table 2: Candidate bands for which compatibility studies have been performed

Frequency band	Results	ECC deliverables
1900-1920 MHz, 2010-2025 MHz	See section 6.1.3	Response to the EC Mandate [24] under development. ECC Report 209 [21] ECC Report 220 [15]
2400-2483.5 MHz	Withdrawn as candidate band after initial compatibility studies (see ANNEX 2:).	ECC Report 210 [16], ANNEX 3:
3400-3600 MHz	Withdrawn as candidate band after initial compatibility studies (see ANNEX 2:).	ECC Report 210, ANNEX 4:
5855-5875 MHz	See section 6.2	Response to the EC Mandate [30] under development ECC Report 210

4 GENERAL REGULATORY ASPECTS

A future spectrum designation for Broadband DA2GC should be technology neutral as far as possible by taking into account the three different system descriptions as developed by ETSI (TR 103 054 [1], TR 101 599 [2] and TR 103 108 [3]).

The implementation and operation of more than one pan-European Broadband DA2GC system in the same frequency band (either in the unpaired 2 GHz bands or on the 5.8 GHz band) was considered as unlikely. Therefore intra-service sharing studies (e.g. for 2 Broadband DA2GC systems in the unpaired 2 GHz bands) were not carried out. However, by looking at the results as described under section 6 of this Report it appears obvious that co-channel operation of different Broadband DA2GC systems would not be possible in the same geographical area. Even in the case of different systems in adjacent frequency blocks (in the same geographical area) a guard block in between seems to be necessary if TDD is considered.

If more than one Broadband DA2GC system were to be deployed in Europe, most likely they would be implemented in different frequency bands (one within the unpaired 2 GHz bands and another within the 5.8 GHz range). Therefore no aggregate effect with regard to other radio applications in or adjacent to those bands may occur.

The roll-out of a European wide Broadband DA2GC system will most likely be realised step by step. The timeframe will depend on the availability of the regulatory framework and then on the selection process and on commercial/financial decisions. Cross-border coordination amongst European countries is considered not to be an issue because the unpaired 2 GHz bands are not in use, although licences are issued in many CEPT Member States. Coordination with services in adjacent bands - either within a country or between neighbouring countries - is expected to be based on the results of the compatibility studies.

The results of the compatibility and sharing studies provide a basis for cross-border coordination at the outer European borders, such as separation distances between DA2GC GS and other radio stations in the neighbouring country or for appropriate measures for the AS (e.g. power reduction over relevant countries without a DA2GC service). Although the situation - i.e. non-utilisation of the spectrum - outside of CEPT in ITU Region 1 is most likely similar because of the current IMT identification of the unpaired 2 GHz bands, such coordination would also support that a pan-European Broadband DA2GC service would not be subject to operational restrictions at border areas in the future.

4.1 REGULATORY FRAMEWORK FOR THE USE OF THE RADIO SPECTRUM

This section proposes an overview of the regulatory framework for the use of spectrum. It distinguishes the 3 key levels: international, regional and national levels. An emphasis is put on the main regulatory and legal instruments that govern the use of spectrum.

For some decades CEPT has carried out reviews of spectrum use with the objective of identifying and designating appropriate frequency bands to services and applications in response to demands from its members and from the industry. CEPT will continue to work on spectrum issues, either in cooperation with the EC in the frame of the RSPP [48] and the Spectrum Decision 676/2002/EC [22] or on its own work programme. CEPT process for designating spectrum to new applications is described in the RSPG opinion on review of spectrum use [25] published in 2012.

Among key features of a European harmonisation measure, the nature of the recommended “regulatory regime” should be well specified, in view of the objectives in terms of quality of service, coexistence and efficient use of the spectrum.

4.1.1 International context: International Telecommunication Union (ITU)

The agreements binding the Member States within the framework of ITU lay the foundation for spectrum management world-wide. ITU international agreements recognise that utilisation of the radio frequency spectrum is a matter of State sovereignty. Moreover, in order to be efficient the use must be regulated and therefore this sovereignty should be given a framework. The basic global instruments by virtue of which States undertake to respect common rules for sharing and using the spectrum constitute this framework. The goal is the efficient utilisation of spectrum and equitable access.

Further information is provided in Annex 5.

4.1.2 European context

4.1.2.1 Harmonisation measures

Regional organisations also play a major role in the management of the radio spectrum resource. The prime objective of the ECC is to develop harmonised European regulations for the use of radio frequencies. The implementation of ECC Decisions and Recommendations by national administrations is made on a voluntary basis. With 48 administration members, CEPT covers almost the entire geographical area of Europe.

Industry also consistently asks for harmonised spectrum to ensure development of innovative systems. Permanent negotiation on conditions of use of spectrum is critical over Europe as it enables adapting spectrum use conditions to industry requirements and national situations.

In accordance with the “Radio Spectrum Decision” [22], the Commission is assisted by the Radio Spectrum Committee (RSC) and issues mandates to the CEPT, setting out the tasks to be performed and corresponding timetable. The RSC shall then approve CEPT Reports and associated technical implementing measures prepared by the Commission, which implementation by the administrations of EU Member States is mandatory.

EC harmonisation measures provide legal certainty to industry stakeholders on the availability of identified spectrum for a given usage and under specified conditions. Deviations are possible but necessitates that the EU member state request derogation to be granted by Commission, expectedly for a limited duration. Due to the pan-European nature of Direct-Air-to-Ground Communication Systems, an EC harmonisation measure isconsidered as highly advantageous.

Finally, the legislation that applies to “radio equipment” should be distinguished from the regulation on the “use of spectrum”. The conditions for the placing on the market of radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity are governed in the EU by the “R&TTE” Directive [23][10]. It should be noted that the RSPG opinion on “streamlining” published in 2008 proposes

[10] to be replaced by the Radio Equipment Directive 2014/53/EU [54] of 16 April 2014

solutions to improve decision mechanisms, cooperation or legislation so as to ensure consistency in the different part of the regulatory environment for the spectrum use, namely CEPT, EC and ETSI.

Further information is provided in ANNEX 5:.

4.1.3 National legislation

Authorising the use of the spectrum is a national prerogative, subject to international obligations and community law in the case of EU member states as mentioned above.

According to current national telecommunication laws in the EU Member States the competence to issue licenses for radio communications services is restricted to NRAs. Thus any framework set by the European Commission needs to take into account licensing by NRAs in EU28 as well as by NRAs beyond EU28. Nevertheless to ease the work of NRAs, to prevent fragmentation and to speed up the licensing and deployment process, the conditions set by the Commission Decision should be as precise as possible.

Further information is provided in ANNEX 5:

4.1.4 Management of evolution in spectrum demand and usage

Spectrum management activities may be simplistically seen as a set of many parallel projects, each addressing how to fit in some specific case for spectrum demand from new or evolving radio systems within current and foreseen plans for spectrum use. Those projects normally develop through series of subsequent steps, making up what may be called a spectrum management cycle.

The investigations presented in ECC Report 016 [32] highlights that “refarming” often is a “last-thought” option of spectrum management, because it is likely to cause the most problems to set up and usually is the most lengthy to implement. Therefore the option of spectrum sharing, that is co-location of old and new uses or radiocommunication systems within the same frequency band, is perceived as a natural preference and will always be extensively considered first. If not workable in a first instance, it might be re-considered with amended operational requirements and system parameters for a newcomer.

Spectrum sharing is the approach which is proposed for the operation of Broadband DA2GCS in the 5855 – 5875 MHz band, which would further increase the efficient use of that band. For the unpaired 2 GHz bands, the licences which are still in force and the possible sharing with the other candidate applications under consideration have to be taken into account.If co-frequency sharing is not feasible, a solution may be found by applying some kind of frequency separation, e.g. by using the interleaved channels for incumbent and new PMR-like services.

However sharing might not always be feasible and use of refarming might become an option. In such cases, the spectrum manager will have to evaluate whether refarming is absolutely necessary, e.g. whether the identified spectrum demand may not be accommodated elsewhere and, if not, whether introduction of newly proposed use or radio system will provide sufficient benefits to justify the refarming.

4.1.4.1 Spectrum refarming

Refarming is a national spectrum management tool, which can be used to cater for new market demand, increase spectrum efficiency or work towards international harmonisation of spectrum usage. Refarming in its traditional meaning involves the recovery of spectrum from its existing users for the purpose of re-assignment, either for new uses, or for the introduction of new spectrally efficient technology.

Most of the refarming processes are taking place as a natural migration, usually from older obsolete technologies towards the newer more advanced ones. In those cases refarming is either in the interest of incumbent users of frequency bands or incumbent users leave that band with removal of their old systems (e.g. upon cessation of licence duration in the absence of further demand). In both of these cases refarming will, in most cases, not cause noticeable problems to spectrum management authorities and therefore the use of incentives or other refarming measures will not be necessary in most cases.

It is when refarming involves some forced removal of existing frequency assignments, not in the interest of the incumbent user, when the refarming becomes problematic and requires application of a number of specific refarming measures, such as refarming funds, pricing incentives, etc. It is expected that the last mentioned refarming processes would need to be performed more often in some countries in the future and will also have to be performed within a shorter timeframe. The kind of “forced” refarming, may be an option for some administrations which can repeal existing licenses based on the individual license conditions of non-use/implementation (roll-out obligations), lack of credibility of the license holder or that the license holder has still plans to implement a network under the current license, where the existing licenses will expire or expire soon in the coming years (i.e. no licence or simply in the public interest to repurpose the spectrum earlier than to wait for the expiration of the license).

4.1.4.2 Spectrum transferring

The EU “Framework” Directive sets in Article 9b paragraph 2 (see annex 5) some requirements for the transfer of frequency usage rights. That is, the intention to trade as well as the effective transfer are to be notified to the competent national authority responsible for granting individual rights and are to be made public. This therefore sets up the possibility for national authorities to approve (or not) the transfer (since the authorities have been notified of the intention to trade), though such an approval step is not made mandatory by the Directive.

ECC Report 169 [33] presents the various trading procedures described in the answers to a questionnaire. The procedures can be broken up in several steps, essentially what happens before the transaction and what happens immediately after the transaction. In general approval of transaction by NRA is mandatory, a fact which imply that there can be circumstances where a transaction can be refused.

Beyond the administrative requirements that the licensee and transferee must meet, there are more qualitative criteria like impact on competition that may require a detailed assessment by the NRA.

The possibility of trading rights of use of spectrum is highlighted in the RSPP [48] as a tool to promote innovation and investment through enhanced flexibility. Article 6 of the RSPP also specifies the harmonised bands where Member States shall allow the transfer or leasing of rights of use of spectrum (790-862 MHz, 880-915 MHz, 925-960 MHz, 1710-1785 MHz, 1805-1880 MHz, 1900-1980 MHz, 2010-2025 MHz, 2110-2170 MHz, 2.5-2.69 GHz, and 3.4-3.8 GHz).

The understanding of the baseline structure of national legislations on the use of spectrum (see Annex 5 figure 2) actually determines the applicability of the concept of “spectrum trading/leasing”.

It is first of all essential to understand that the concept of “spectrum trading/leasing” implemented in Europe can apply only to licensees’ having access to spectrum under an “individual authorisation”.

A right of use issued by a NRA applies for a certain category of electronic communication service, for limited duration and under specified conditions (technical, operational, coverage obligations…) and the amount of “licensing fee” is expectedly connected to the level of flexibility of the authorisation and the set of obligations. National rules on spectrum trading/leasing and role of NRA have to account for risk of market distortion or possible conflict with the obligations resulting from the transfer.

Such commercial users’ have tradable rights which have been granted through competitive or comparative selection procedures. They can obviously trade or lease only a right that they detain, which means that the concept works only for the delivery by the transferee of electronic communications services that are consistent with the frame of the initial “individual authorisation”. It is therefore questionable whether the concept can be applied in the 2 GHz Unpaired bands for the introduction of Broadband DA2GC systems.

4.1.4.3 Repurposing of spectrum

The purpose of the UMTS Decision of 1999, which covered the frequency bands 1900-1980 MHz, 2010-2025 MHz and 2110-2170 MHz ('terrestrial 2 GHz band'), was to initiate the introduction of UMTS in the EU in a coherent manner. The UMTS Decision expired on 22 January 2003 and fulfilled its objectives. Any outstanding or related issues after 2003 such as on spectrum allocation, licensing or re-farming have been governed by the EU regulatory framework in electronic communications as well as the Radio Spectrum Decision 676/2002/EC [22] since 2002.

Even if licences for the unpaired terrestrial 2 GHz band, comprising the TDD bands 1900-1920 MHz and 2010-2025 MHz, have been granted to mobile operators in the EU for many years, the proven lack of use of these bands [26] necessitates new harmonisation measures in order to ensure effective and efficient spectrum use in line with the EU regulatory framework and the "use it or lose it" approach endorsed by the Commission to the extent possible under the existing regulatory framework. Therefore, CEPT received a Mandate to undertake studies on the harmonised technical conditions for the 1900-1920 MHz and 2010-2025 MHz frequency bands in the EU [24].According to the mandate, Broadband Direct Air-to-Ground Communications (BDA2GC), preferably in a paired spectrum arrangement, is one of the applications that should be studied for the unpaired 2 GHz bands.

Regarding the unpaired 2 GHz bands, the decisions to be taken would need to be supplemented by a procedure to obtain access to spectrum that is still licensed to mobile network operators if withdrawal of current licences is not possible due to legal conditions in some Member States. This optional approach could be a repurposing procedure. In these cases, it would be under the responsibility of the NRA to set up a sharing framework to set out the precise rules that apply to the repurposing of the spectrum. It could include a provision for not renewing or not awarding new licences to terrestrial MFCN operators in the band. For example, the sharing framework could foresee to operate Broadband DA2GC systems on a no harmful interference basis regarding the existing MFCN licence holder until the expiration of the licence.

This repurposing procedure can provide predictability and certainty in the regulatory framework which is key for investments in technologies and innovation such as Broadband DA2GC in the unpaired 2 GHz bands case.

The repurposing procedure compatible with current EU Regulatory Framework and provides an opportunity for licensed DA2GC use of spectrum based on the assignment of individual rights of use enabling the DA2GC licensee exclusive spectrum rights of use where and when the spectrum is not used by the incumbent.

In addition, the repurposing creates an opportunity for mobile broadband applications based on DA2GC to get access to unutilised 2 GHz unpaired bands in a timely manner under the terms of the Authorisation Directive for Electronic Communication Services.

The Repurposing complements the preferred traditional exclusive authorisations of individual rights of use when re-allocation / clearing of spectrum is deemed lengthy, especially in situations where the incumbent licence holder paid a price for spectrum as a result of an award procedure;

The NRA remains entitled to deliver the individual rights of use of spectrum to the DA2GC licensee. It is essential for the repurposing to leverage interests of both parties involved, the incumbent licensee and the DA2G licensee, and maybe to some extent incentive based. This can be a consideration in cases where the remaining lifetime if the existing right of use is still quite long.

Such a repurposing of the spectrum targets underutilised spectrum bands such as the 2 GHz Unpaired Bands. It could utilise this spectrum more efficiently supporting the objectives of the Radio Spectrum Policy Programme therefore significantly contributing to Europe 2020 policy goals. It may therefore be seen as in the public interest.

A repurposing strategy needs to be accompanied by an announcement of the NRA to not intend to renew existing licenses or issue new licenses. It may be the strategy of those NRAs which have no possibility to repeal a license. The concept is less forcing than spectrum refarming in terms of legality but can help to free unused spectrum earlier to make it available for DA2GC system operation in a country in support to reach a wider coverage over Europe.

5 SYSTEM DESCRIPTIONS

All systems as described below addresses similar markets.

5.1 SYSTEM ACCORDING TO ETSI TR 103 054 V1.1.1 (2010-07)

The Broadband DA2GC system described in this chapter is based on the ETSI System Reference Document “Broadband Direct-Air-to-Ground Communications operating in part of the frequency range from 790 MHz to 5150 MHz” [1].

5.1.1 General System Description

The overall end-to-end system architecture of this Broadband DA2GC system is illustrated in Figure 5.

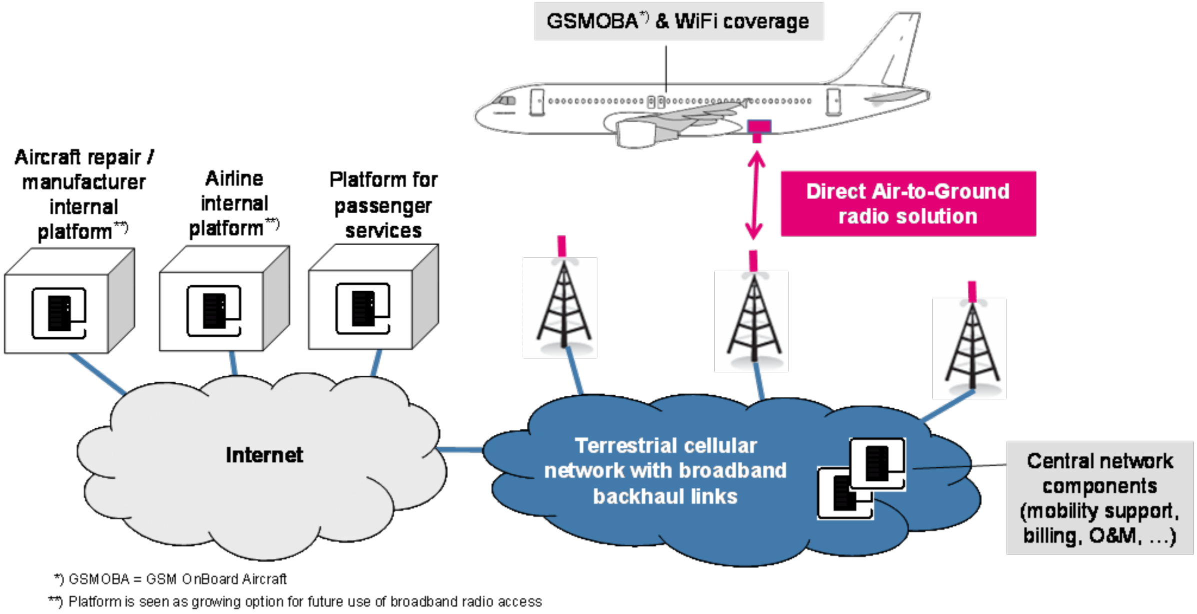


Figure 5: Overall end-to-end system architecture for Broadband DA2GC

The major building blocks of the end-to-end system architecture are:

1. Service access network infrastructure on-board the aircraft, e.g. Wi-Fi coverage and GSMOBA (both already standardised and certified for on-board implementation);
2. Broadband DA2GC network infrastructure on-board aircraft, e.g. external antenna, modem, cabling, interface to on-board network(s);
3. Terrestrial radio access network for Broadband DA2GC with broadband backhaul links, which would preferably be based on existing infrastructure, but with modifications (e.g. with regard to antenna types and base station implementation) to establish high-performance radio links to aircraft in Broadband DA2GC environment;
4. Mobile core network for session, mobility, subscriber and security management providing IP connectivity to external packet data networks (e.g. intranet, internet, IMS);
5. Central network components required for O&M, billing, etc. in the Broadband DA2GC network;
6. Various IP-based service delivery platforms e.g. for passenger services or for airline or aircraft repair / manufacturer internal applications.

Modern broadband wireless access technologies as specified for next generation mobile networks (NGMN) are a sound technological basis for such a Broadband DA2GC solution, capturing mainly items 2) and 3) in the list above.

Therefore, this terrestrial Broadband DA2GC system is based on the 3GPP LTE (also called E-UTRA) standard (Rel. 8 or higher), as described in more detail in ETSI TR 103 054 [1]. The user equipment (UE) would refer to the Broadband DA2G aircraft station (AS), and the base station (BS) would refer to the Broadband DA2G ground station (GS). An overview as well as an overall description of E-UTRAN is given in [55].

The general characteristics of the Broadband DA2GC RF and digital baseband signals are also based on the LTE specification. To adapt the LTE system functionalities to the Broadband DA2GC link specifics, some modifications are required. In particular synchronisation algorithms as well as the maximum AS Tx power are to be modified compared to terrestrial mobile radio usage in order to cope with high Doppler frequency shift caused by aircraft speed and large cell sizes. In addition the GS antenna adjustment has to be matched to cover typical aircraft heights above ground between 3 and 12 km by up-tilt of vertical diagrams. The main parameters of the radio access part are provided in ECC Report 209 [14].

5.1.2 Quality of Service (QoS)

QoS for this Broadband DA2GC system is ensured due to the use of sophisticated mobile technology, namely the 3GPP LTE (Long Term Evolution, also called E-UTRA) standard (Release 8 or higher), together with the innovative core network infrastructure known as SAE (System Architecture Evolution).

QoS refers to a broad set of capabilities and parameters for controlling service differentiation within the Broadband DA2GC network in terms of:

- RL/FL bandwidth: the amount of communication pipe capacity allocated or allowed per service class;
- Latency and jitter: consistent response times crucial to a smooth real-time service;
- Service quality: Information loss, service response time and continuity.

In this flat-IP DA2GC network, end-to-end QoS will be achieved by coherent configuration in all transport bearers. An overview of the bearers and their relation to the network elements is shown in Figure 6.

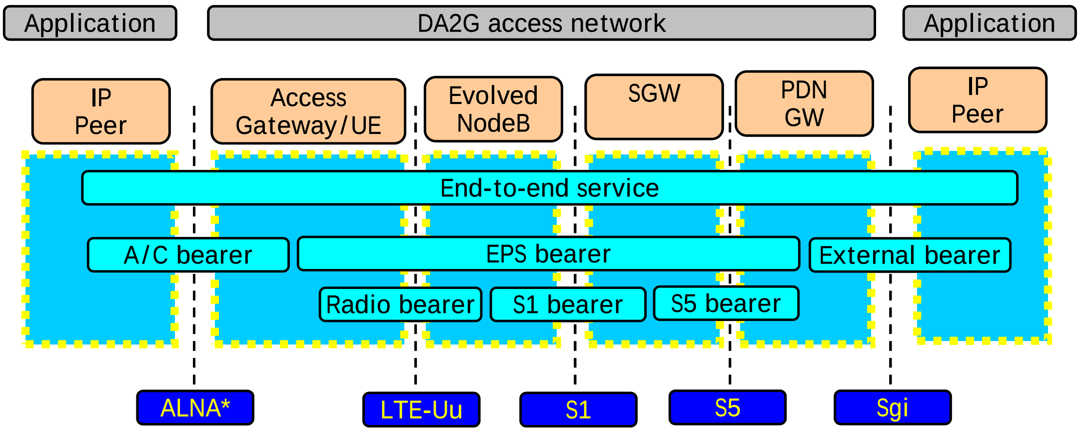


Figure 6: QoS model for the LTE/SAE based Broadband DA2GC

In Release 8 of the 3GPP standard QoS Class Identifier (QCI) are introduced in order to ensure a minimum level of QoS. Each EPS bearer is assigned one QCI at bearer establishment. The QCI is further used within the LTE access network to define the control packet-forwarding treatment from an end-to-end perspective. As shown in Figure 7, the following parameters characterise a given QCI:

- Resource Type: defines whether the bearer is GBR (Guaranteed Bit Rate) or non-GBR;
- Priority: defines a level of differentiation between service data flow aggregates of the same or different AS;
- Packet Delay Budget: defines an upper bound delay that a packet is allowed to experience between the BDA2G AS and the PCEF (Policy and Charging Enforcement Function);
- Packet Error Loss Rate: defines an upper bound for the rate of IP packets that have been processed by the sender, but not successfully delivered to the receiver. Packet losses due to network congestion are excluded.

The purpose of these parameters is to properly configure the scheduling in the eNB (i.e. in the DA2G GS), the SGW (Serving Gate-Way) and the PDN GW (Packet Data Network Gate-Way), e.g. scheduling weights, admission thresholds, queue management thresholds and link layer protocol.

QCI	Resource Type	Priority	Packet Delay Budget	Packet Error Loss Rate	Example Services
1	Guaranteed Bit Rate (GBR)	2	100 ms	10^{-2}	Conversational voice
2		4	150 ms	10^{-3}	Conversational video (live streaming)
3		3	50 ms	10^{-3}	Real-time gaming
4		5	300 ms	10^{-6}	Non-conversational video (buffered streaming)
5	Non-GBR	1	100 ms	10^{-6}	IMS signalling
6		6	300 ms	10^{-6}	Video (buffered streaming) TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc.)
7		7	100 ms	10^{-3}	Voice, video (live streaming), interactive gaming
8		8	300 ms	10-6	"Premium bearer" for video (buffered streaming), TCP-based (e.g., www, e-mail, chat, ftp, p2p file sharing, progressive video, etc) for premium subscribers
9		9	300 ms	10-6	"Default bearer" for video, TCP-based services, etc. for non-privileged subscribers

Figure 7: QoS profile of the standardised QCI

QoS will of course also be supported by using radio spectrum with predictable frame conditions and suitable sharing/compatibility conditions.

5.1.3 Specific spectrum needs

In order to allow for the highest flexibility for ECC in the designation of suitable spectrum, the frequency range from 790 MHz to 5150 MHz is proposed by the corresponding ETSI System Reference Document TR 103 054 V1.1.1 [1]. For this system spectrum above 6 GHz is not considered to be appropriate due to wave propagation aspects (e.g. increased path loss and Doppler shift). Basically, all candidate frequency bands discussed in section 3.3 could be considered for the implementation of this Broadband DA2GC system.

The signal bandwidth depends on system characteristics (e.g. operating frequency, frequency reuse, spectrum efficiency) and service data rate required per aircraft and per cell/sector.

5.1.4 Timeframe for equipment availability

The baseline access technology of this Broadband DA2GC system is the 3GPP evolved packet system (E-UTRAN+EPC) that is already commercially available (Release 8), known as LTE, and higher releases, i.e. the ground station equipment is in conformity with 3GPP specifications. The RF unit would need to be adapted to the operational frequency. Broadband DA2GC specific enhancements required correspond mainly to operational aspects, e.g. antenna up-tilt at the Ground Station (Base Station), and network management issues. These modifications do not require standardisation efforts. Adaptations of the ground components are expected to be completed ten months after spectrum designation / authorisation. The build-up of the ground network which is assumed to last about one year could be started in parallel with the backhaul and site preparations.

The Aircraft Station (AS) acts as a mobile station (MS) in this Broadband DA2GC system. Compared to a MS used in a usual mobile network, increased output power is required due to the higher path loss (larger cell sizes) in the Broadband DA2GC network. Also improved synchronisation features, e.g. to compensate the high Doppler shift, will be implemented. Time necessary for manufacturing the specific aircraft installation kits and for the corresponding type approval by aviation authorities is estimated to be about one and a half year.

Thus the service rollout with first aircraft can be expected about 18 months after the spectrum designation/authorisation. The estimated timeline for equipment availability for this BDA2GC system is illustrated in Figure 8.

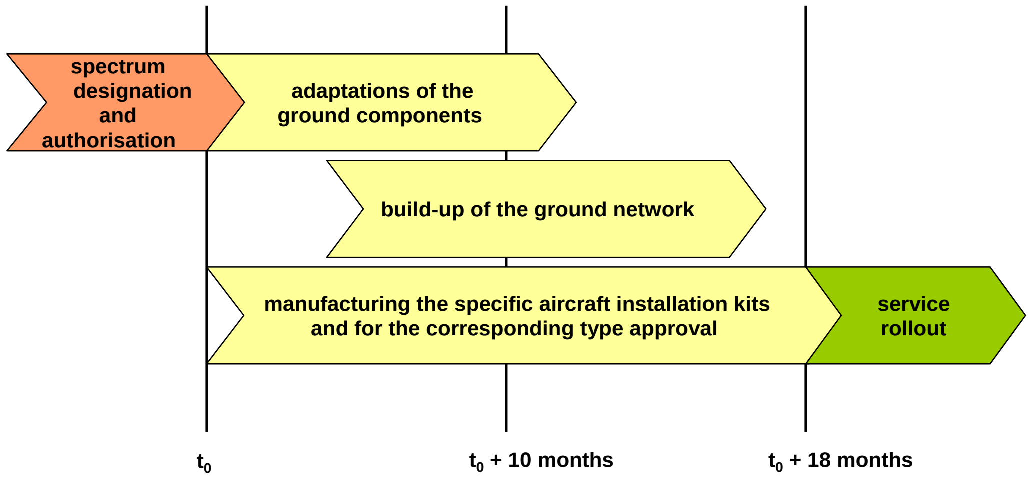


Figure 8: Timeline for equipment availability for an LTE/SAE based Broadband DA2GC system

Suitable connectivity systems (Wi-Fi / GSMOB) on-board aircraft are already available on the market, used today for connectivity solutions via satellite or DA2G in the US. The data interface to the Broadband DA2GC on-board unit – which acts as a modem - is usually Ethernet-based, using special cables and connectors.

5.1.5 System Implementation

The roll-out of this Broadband DA2GC network would be based on a hexagonal cell structure, taking into account real air traffic (position, height and direction of aircraft dependent on day time). As the number of aircraft equipped with Broadband DA2GC will be lower in the beginning the roll-out would start with a reduced number of ground stations covering large areas (up to 100 km cell radius) in order to provide a basic coverage. In areas with high aircraft density additional ground stations would be installed. Highly frequented routes over sea could be served by usage of directional high gain antennas.

The flight density across European area for the year 2006 is presented on the left side of Figure 9. This figure also includes a long-term forecast for the year 2025.

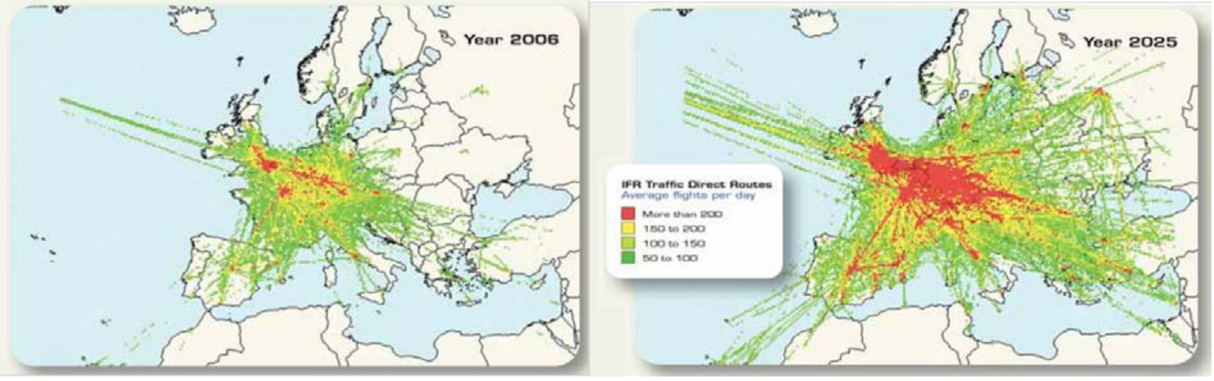


Figure 9: Growth of European flight density (source: Eurocontrol / 2007)

The density patterns in Figure 9 might be used to define basic rollout coverage scenarios for the terrestrial Broadband DA2G communication network, which could be extended during the following years to cover main flight routes and areas in Europe and neighbouring countries according to increasing air traffic demand. Based on this flight density forecast, a coverage extension to North Africa and Middle East could also be considered, provided the same spectrum as harmonised in CEPT could be made available there.

The rollout of Broadband DA2GC will start with about 200 to 250 ground stations, covering the high density air traffic area in Europe, followed by a subsequent deployment to cover the remaining areas. In the final state, the network will encompass 400 to 500 ground stations.

5.2 SYSTEM ACCORDING TO ETSI TR 101 599 V1.1.3 (2012-09)

The Broadband DA2GC system described in this chapter is based on the ETSI System Reference Document on “Broadband Direct-Air-to-Ground Communications System employing beamforming antennas, operating in the 2.4 GHz and 5.8 GHz bands” [2]. The described technology has some important features (namely the use of adaptive beamforming at the ground stations and on the aircraft) which enable consideration of the option for licence-exempt or lightly licensed operation within the 2.4 GHz and/or 5.8 GHz bands. However, the tuning range of the technology extends from 790 MHz to 6 GHz and the antennas would require only minor changes to optimise for any band within that extended range. The use of beamforming antennas on the ground and at the aircraft permits the production of shaped and dynamically steerable beams in both the forward link (ground-to-air) and reverse link (air-to-ground) directions, thereby enabling the desired system performance objectives to be maintained as the aircraft traverses its route whilst, at the same time, minimising interference into other co-frequency systems. This is achieved through the benefits of tailored radiation patterns which can be optimised to reduce interference and allow operation at lower transmit powers (on the ground and in the air) than would otherwise be necessary if more conventional fixed antennas were deployed. In respect of the underlying modulation and coding schemes used, etc., the system has much in common with other existing and proposed mobile broadband backhaul technologies.

5.2.1 General System Description

5.2.1.1 Overall system architecture

Figure 10 gives a high-level overview of how the DA2G system fits within the end-to-end system architecture. The elements which constitute the DA2G link are those elements which provide connectivity between the Air Network and the Ground Network, including the Air Station and Wireless Base Station shown in the top left hand corner of the figure.

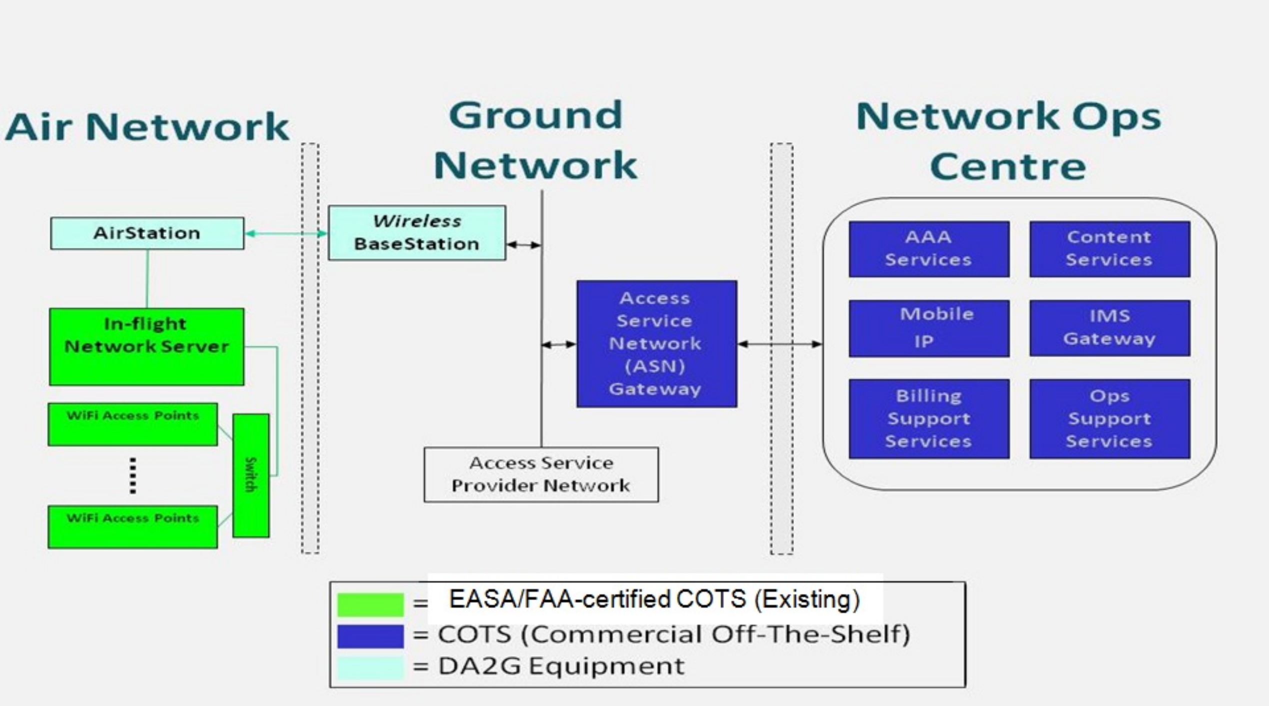


Figure 10: Broadband DA2G system (ETSI TR 101 599), as part of overall end-to-end architecture

The system has been designed to keep the airline information and passenger data completely separate by means of the physical hardware layout as well as through the use of secure encryption and data routing software, as illustrated in Figure 11 below.

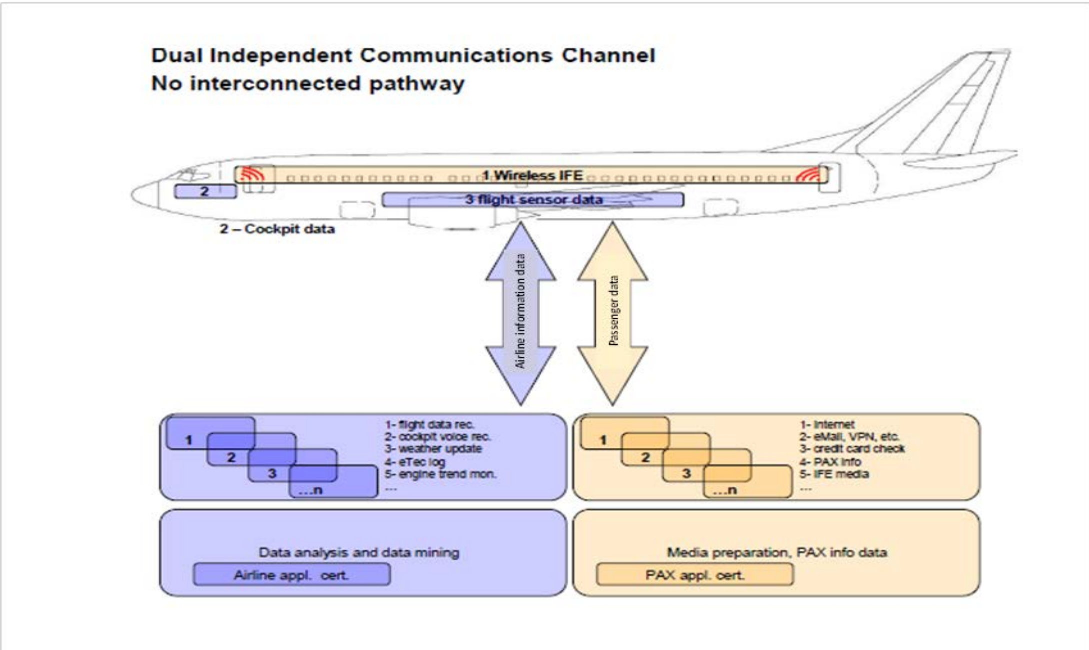


Figure 11: Dual Independent Communications

5.2.1.2 Ground station equipment

A feature of this Broadband DA2GC system is the simultaneous use of four separate integrated radio transceivers/phased array antenna assemblies at the ground station. Such an arrangement enables each ground station to cover the entire visible air space, from horizon to horizon, at all azimuths. Each integrated 8-element antenna array is capable of simultaneously producing multiple co-frequency shaped beams which need to maintain sufficient spatial separation to avoid self-interference, such that three simultaneous beams per sector (or quadrant), or twelve beams per ground station can be assumed operationally. This is shown diagrammatically in Figure 12 below.

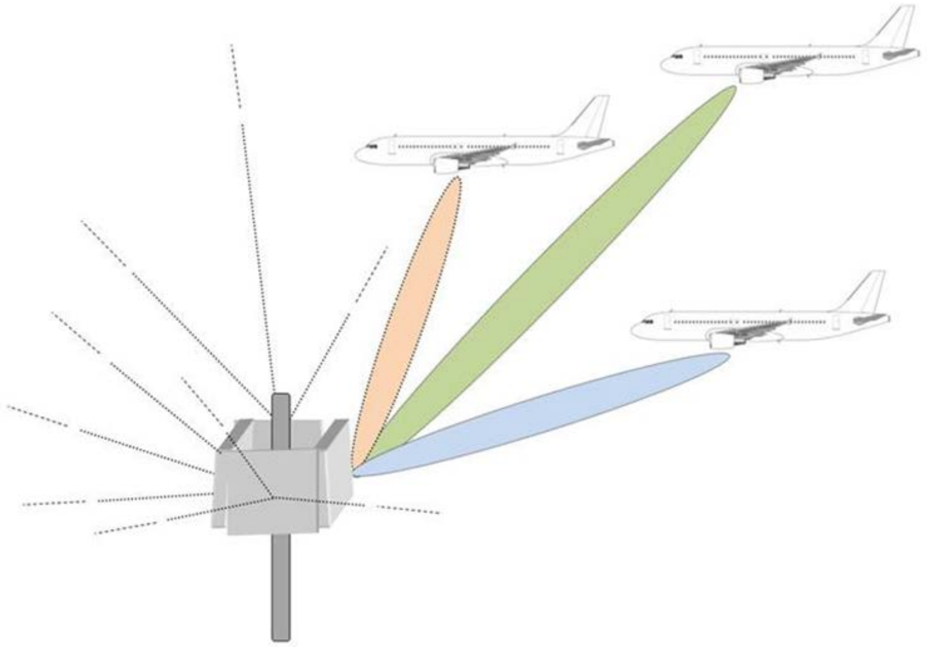


Figure 12: Typical Ground Station antenna arrangement showing three beams per quadrant (simplified depiction)

5.2.2 Quality of Service (QoS)

The quality of service objectives will be broadly commensurate with that provided by other wireless broadband services based on similar 3GPP standards. High levels of system availability will be ensured through, e.g., the ability to switch between ground stations as necessary and the extra resilience offered by the use of beamforming and unwanted signal cancellation techniques at the air and ground-based receivers.

5.2.3 Specific spectrum needs

Whatever frequency band is ultimately chosen, the system can operate with variable bandwidths in any sub-band within the relevant frequency range. For optimum performance, in TDD mode, the system would require a contiguous block of spectrum of 20 MHz.

5.2.4 Timeframe for equipment availability

The ground station and aircraft equipment (radio and antenna assemblies) optimised for operation in the 2.4 GHz band are fully developed products and variants capable of operating in the 5.8 GHz band are currently undergoing FCC certification in the United States.

Initial roll-out of the ground network and installation of aircraft equipment can be commenced within 6 months of receiving the necessary regulatory approvals.

5.2.5 System implementation

Future operations would entail partnerships with selected network operators who would provide ground station facilities including backhaul to the core terrestrial network.

5.3 SYSTEM ACCORDING TO ETSI TR 103 108 V1.1.1 (2013-07)

The importance of connectivity between aircraft and ground for the airline business is growing fast. Passengers have made clear that they would benefit from on-board high quality internet access and that they are prepared to pay for the service provided that the price is considered reasonable. Apart from passenger related applications, airlines would also benefit from a high capacity communications link for non-safety of life operational data. Many applications to reduce operating costs and increase efficiency are denied airlines because of the present costs of providing an adequate link.

There have been several attempts to provide connectivity but these have been frustrated mainly due to the cost of deploying and operating the necessary infrastructure; especially the cost of aircraft installation and operation.

Consumer devices, such as smart phones, are developing rapidly and offer easy Wi-Fi connectivity. More and more passengers are carrying pocket devices that are convenient to use during even the shortest of flights.

5.3.1 General System Description

The system provides a direct air to ground communications link using the transparent Internet Protocol.

The system is essentially based on 3G UMTS TDD Release 7 standards, developed for the bands 1900-1920 MHz and 2010-2025 MHz that have been adapted to include operation in the 5.8 GHz band as well. It uses multi-sector antennas to optimise the ground infrastructure performance by providing coverage when and where required while reducing interference. Essentially the signal in space is compliant with 3GPP standards apart from the operating frequency when used in the 5.8 GHz band.

Flight testing of UMTS technology has been successfully conducted in the 2 GHz band and also the 5091-5150 MHz band. Among other things, aircraft sorties were used to validate simulations. These simulations were subsequently used to provide performance predictions for the 5855-5875 MHz band.

Through simulation it is estimated that the number of base stations required to provide pan-European coverage is 225. The normal cell radius is approximately 140 km but this may be extended to over 250 km, using directional antennas, to support continuous coverage over sea.

The overall end-to-end system architecture of the broadband DA2GC system is illustrated in Figure 13 below:

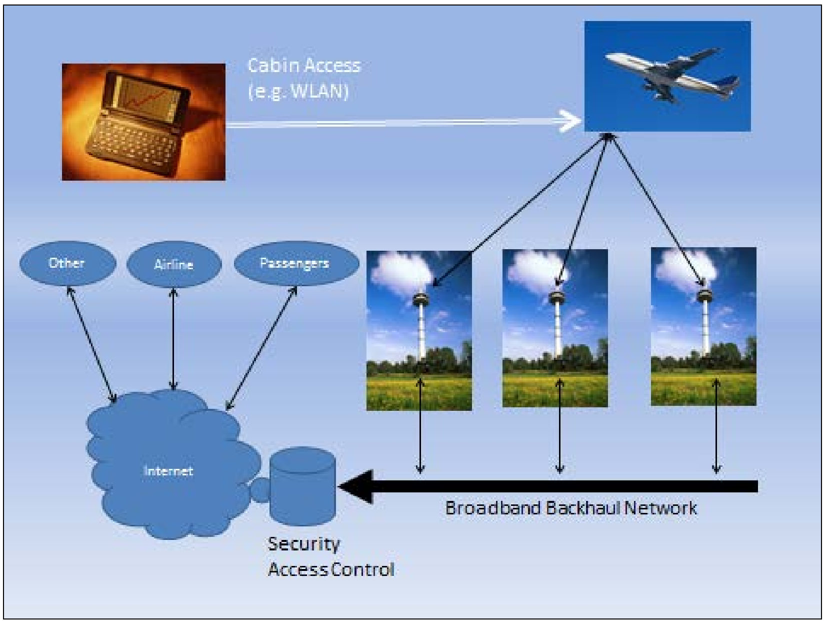


Figure 13: System Architecture for Broadband DA2GC

The major building blocks of the end-to-end system architecture are:

- service related network infrastructure on-board the aircraft such as WLAN;
- DA2GC infrastructure on-board the aircraft (external antenna, avionics with modem, cabling, interfacing to on-board network);
- terrestrial radio access network for DA2GC with broadband backhaul links, which would preferably be based on existing infrastructure, but with modifications (e.g. with regard to antenna types and ground station implementation) to establish high-performance radio links to aircraft in DA2GC environment;
- mobile core network for session, mobility, subscriber and security management providing connectivity to external packet data networks (e.g. intranet, internet, IMS);
- central network components required for O&M etc. in the DA2GC network;
- various IP-based service delivery platforms e.g. for passenger services or for airline or aircraft repair / manufacturer internal applications.

The system uses standardised equipment (ETSI 3GPP standards) for the Broadband DA2GC link. The user equipment (UE) is installed in the DA2GC aircraft station (AS), and the ground station (GS) is the DA2GC ground station (GS).

The airborne equipment is designed to meet the standardisation requirements of EUROCAE ED-14E.

5.3.2 Quality of Service (QoS)

Availability: The system is designed to be available (24/7/365) every year with a probability greater than 98%. The average monthly availability will be better than 99%.

Capacity: The system will provide a forward link capacity per ground station sector per 10 MHz channel of about 14 Mbps and a reverse link of about 2 Mbps. The division of capacity for Internet applications is about 85% for the forward link and 15% for the reverse link.

Latency: The system latency will be less than 100 milliseconds.

5.3.3 Specific spectrum needs

The system can use switch-selectable bandwidths of 5 or 10 MHz. Although single channel operation is possible, the use of additional channels reduces potential inter-cell interference and also any interference of other systems.

The preferred candidate band is 5855-5875 MHz but, as stated in TR 103 108 [3], the system may operate within extended band of 790 MHz to 6 GHz, e.g. in the bands 1900-1920 MHz and 2010-2025 MHz which were designated for terrestrial mobile systems based on UMTS-TDD technology.

The required spectrum is 20 MHz thereby enabling 2x10 MHz or 4x5 MHz channels.

This requirement has been validated through simulation studies and static capacity tests involving, among other things, a commercial aircraft with about 80 concurrent users.

UMTS-TDD Release 7 has an operational system efficiency of about 1.6 bit/s/Hz. However, when considering shared spectrum, the effective efficiency for Europe is much higher because Broadband DA2GC can use spectrum in the large volume of airspace where many other systems do not operate.

Moreover, it is anticipated that the technology would not impose any significant constraints on any future introduction of additional terrestrial services such as RLAN.

5.3.4 Timeframe for equipment availability

The planned implementation is over a two year timescale following the appropriate regulatory permission. The critical path includes the phased installation of aircraft systems which would commence 18 months after the start.

5.3.5 System Implementation

Both airlines and operators have been involved with the development of specifications and validation of business planning. There is a keen desire to implement the system and detailed planning has been made through several non-disclosure agreements.

Retrofit was always an important issue for airlines and the system has been designed to enable installation over a series of night stops thereby ensuring that the aircraft need not be taken out of operational service.

Finally, the necessary investment and operating finance for the project is available subject to certain conditions including regulatory permission to use the available candidate band.

The planned implementation is over a two year timescale following the appropriate regulatory approval. It is expected that the critical path will be the certification and installation of aircraft systems.

5.4 TYPICAL PERFORMANCE EXPECTATIONS FOR BROADBAND DA2GC

The performance metrics as described below should be considered as typical performance to be expected independently of the technical solution / of the duplex mode.

Table 3: Typical performance metrics for Broadband DA2GC

Metric	
“Broadband” DA2GC	“Broadband” in this context refers to a service providing data rates between several hundred kbit/s up to several Mbit/s per end-user, depending on the traffic load within a communication cell
Availability of the service (average target)	99 %
Latency	Less than 100 ms (compared to e.g. geostationary satellite solutions which are typically in the area of 500 ms)
Data rate for one aircraft link	Typically 15 Mbit/s in either direction
Operational system efficiency	Typically between 1.5 and 3 bit/s/Hz

The end-to-end Quality of Service for a Broadband DA2GC system (link between the GS and the AS) also depends on the network configuration, not only on the characteristics of the chosen technology (spectrum efficiency of the system). E.g. it depends on number/density of GS, frequency band (2 GHz / 5.8 GHz), mitigation measures (to ensure coexistence with other radio applications), antennas (SISO, MIMO, different polarisations, adaptive beam forming antennas), link budget, No. of aeroplanes within a sector/beam.

The QoS for the end-user in the plane additionally depends on the configuration of the on-board system and on the number of users on board aircraft.

6 SUITABILITY OF CANDIDATE FREQUENCY BANDS

Compatibility and sharing studies have been carried out with regard to the relevant radio applications in different candidate bands and adjacent to them. The results are provided in ECC Reports 209 and 210. Sharing between different Broadband DA2GC systems within a specific candidate band (intra-service sharing studies) was not considered necessary.

6.1 UNPAIRED TERRESTRIAL 2 GHz BANDS (1900-1920 MHz AND 2010-2025 MHz)

Currently, all or parts of the frequency band 1900-1920 MHz is licensed to mobile operators for the provision of electronic communications services in 36 CEPT countries, whereby the licences are mainly limited to UMTS/IMT-2000 TDD technology. On the other hand, the frequency band 2010-2025 MHz, or parts of it, is licensed to mobile operators in 13 CEPT countries for the provision of electronic communications services, mainly limited to UMTS/IMT-2000 TDD technology and in some cases in a technology neutral way. Existing licences in the unpaired 2 GHz bands have been awarded on an exclusive basis in some countries. In addition, some administrations use the band 2010-2025 MHz for short term licences, in particular for wireless cameras.

The mobile licenses (UMTS TDD) in force on the unpaired 2 GHz bands are not in use in Europe, noting also that the lack of interest of mobile operators for spectrum in the unpaired terrestrial 2 GHz band has been demonstrated during the auctions in some CEPT countries in 2011. The duration of those licenses vary from country to country, from 2014 - 2029 (or even unlimited duration, in United Kingdom).In addition it has to be mentioned that licences have already been surrendered in some countries.

6.1.1 Response to the Mandate from the European Commission

In October 2012, the European Commission issued a Mandate to CEPT to undertake studies on the harmonised technical conditions for the 1900-1920 MHz and 2010-2025 MHz frequency bands (unpaired terrestrial 2 GHz bands) in the EU.

The European Commission identified the following shortlist of potential harmonised uses of the 1900-1920 MHz and 2010-2025 MHz frequency bands to be given priority in the Mandate:

1. PPDR, most likely with preference to ad-hoc (non-permanent) PPDR networks.
2. PMSE, preferably for use by wireless cameras.
3. Short-range devices (SRD), preferably for improving energy saving and/or energy efficiency.
4. DECT, preferably in the 1900-1920 MHz band.
5. Broadband Direct Air-to-Ground Communications (BDA2GC), preferably in a paired spectrum arrangement.

The Commission had noted that also other frequency bands are currently under investigation in CEPT for some of the radio applications above. It can be assumed that some of the applications above being temporary or local in nature would not utilise exclusively the total available spectrum in the unpaired terrestrial 2 GHz bands. Therefore, shared use between the different applications should be studied in order to ensure efficient spectrum use. In this regard, appropriate least restrictive technical conditions should be developed both for the identified specific application and for any possible sharing arrangement.

For the implementation of Broadband DA2GC and PMSE (wireless cameras) in the frequency bands 1900-1920 MHz and 2010-2025 MHz, a 2x10 MHz FDD deployment for Broadband DA2GC was taken as a basis.

In both implementation options under consideration, the placement of the Broadband DA2GC frequency block in the band 1900-1920 MHz was based on the preliminary results of the compatibility studies, respectively. Co-frequency sharing between DA2GC forward-link (FL) and PMSE was assumed to be feasible, subject to confirmation by corresponding co-existence studies.

Studies demonstrate that DA2GC FL operated in the 2010-2025 MHz band is not compatible with Space Services (Earth-to-space) in the 2025-2110 MHz band. Therefore it is concluded that the DA2GC FL transmission direction should be in the band 1900-1920 MHz.

This information is considered useful to support the work in ECC groups in response to the Commission Mandate on the 2 GHz unpaired bands. The options presented are in principle applicable also to other radio applications mentioned in the Mandate.

As a result of the synergies between PMSE and PPDR, as well as between DECT and SRD, the shortlist indicated in the EC Mandate, composed of five potential harmonised uses of the 1900-1920 MHz and 2010-2025 MHz frequency bands (Broadband DA2GC, PMSE, PPDR, DECT and SRD), is considered to be adequately studied by using 3 usage blocks as presented in the following Figure 14.

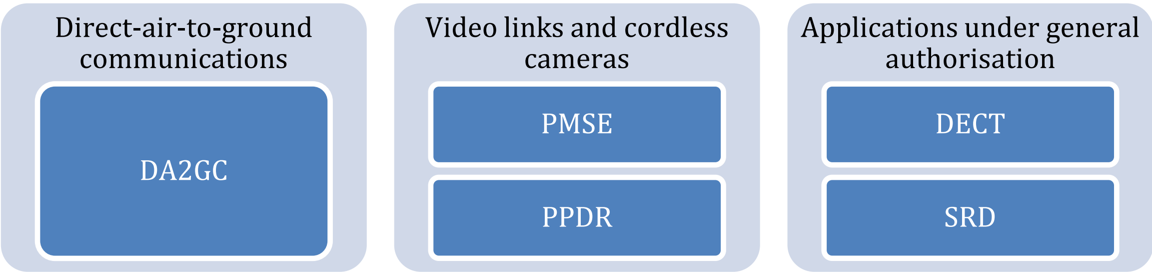


Figure 14: Synergies among the proposed short list of selected use

As a result, the on-going compatibility / sharing studies consider the three usage blocks above.

The response to the Mandate will be provided to the European Commission by a CEPT Report (*Report from CEPT to the European Commission in response to the Mandate "To undertake studies on the harmonised technical conditions for the 1900-1920 MHz and 2010-2025 MHz frequency bands ("Unpaired terrestrial 2 GHz bands") in the EU"*) [17].

A high level of support was expressed in the responses to the 'Call for Inputs' [17] for placing the shortlist of potential harmonised uses of the 1900-1920 MHz and 2010-2025 MHz frequency bands (as proposed for further study in the EC Mandate) into the above three categories, although it became visible from the contributions that it was desirable to further investigate and clarify the technical characteristics and usage conditions for specific candidate applications during the development of the final CEPT Report. The majority of contributions supported Broadband DA2GC as an application in the unpaired 2 GHz bands.

For the time being the possibilities for a TDD DA2GC system in the frequency band 2010-2025 MHz will not further be considered. During the 'Call for Inputs', no preference for a TDD solution in the 2010-2025 MHz band for Broadband DA2GC has been indicated by any responder. The 2010-2025 MHz band can only provide up to 15 MHz for DA2GCS using TDD, although it is seen as technically possible to operate such a system also within less than 20 MHz. However, as long as not all results on the on-going compatibility and sharing studies are available (especially the results regarding sharing with PMSE and other candidate applications as mentioned in the mandate) no other option should be completely excluded.

TDD within 2010-2025 MHz might be revisited in the future or a technologically neutral approach enabling either FDD or TDD usage within 1900-1910 MHz and 2010-2020 MHz.

6.1.2 Implementation options

OPTION 1: DA2GC FL (GROUND-TO-AIR) IN THE BAND 1900-1910 MHZ AND DA2GC RL IN THE BAND 2010-2020 MHZ

For a system according to ETSI TR 103 054, the implementation of a Broadband DA2GC FL in the band 1900-1920 MHz would only be feasible within the sub-band 1900-1910 MHz, with a 10 MHz frequency separation (guard band) to protect the UMTS UL above 1920 MHz. This would offer to consider deployment of other candidate applications in the sub-band 1910-1920 MHz, and possible sharing with DA2GC FL in the sub-band 1900-1910 MHz.

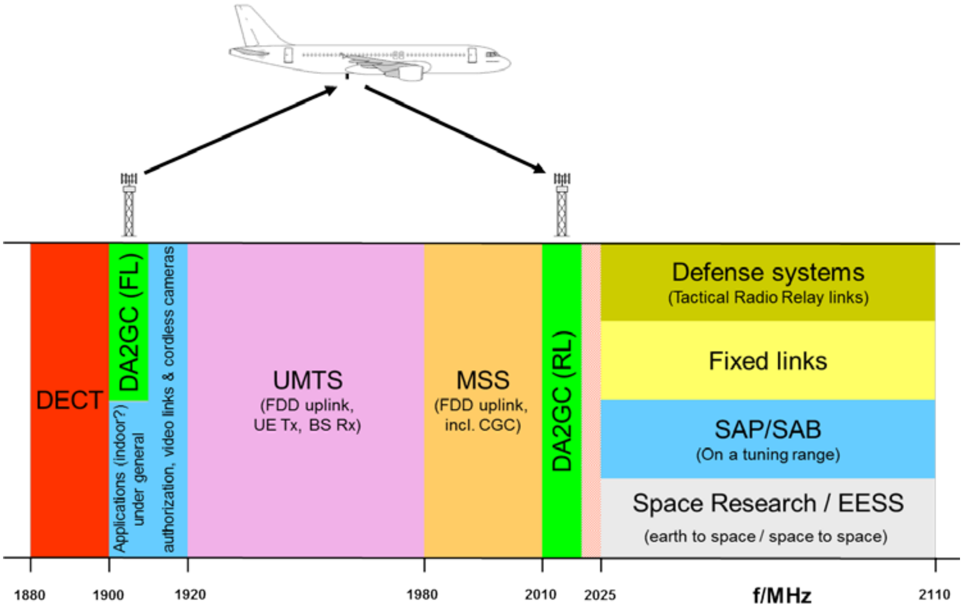


Figure 15: DA2GC FL in the band 1900-1910 MHz and DA2GC RL in the band 2010-2020 MHz

OPTION 2: Broadband DA2GC systems with TDD

For the implementation of the system according to ETSI TR 103 054 [1] in TDD mode, the outcome of the compatibility and sharing studies has shown that a guard band would be required in the lower band (1900-1920 MHz) between Broadband DA2GC and the UMTS uplink band to protect UMTS, so this band is not sufficient to fulfil the required spectrum demand (20 MHz) for such a TDD mode operation. Also the upper band (2010-2025 MHz) cannot fulfil the required spectrum demand for a TDD mode operation.

For the implementation of a TDD system according to ETSI TR 101 599 [2] or ETSI TR 103 108 [3], the outcome of the compatibility and sharing studies has shown (see ECC Report 209) that within the unpaired 2 GHz bands the band 1900-1920 MHz provides suitable conditions, assuming appropriate mitigation measures are applied.

6.1.3 Conclusion

Detailed descriptions of all relevant compatibility and sharing aspects are described in:

- ECC Report 209 [14] on compatibility/sharing studies related to Broadband Direct-Air-to-Ground Communications (DA2GC) in the frequency bands 1900-1920 MHz / 2010-2025 MHz and services/applications in the adjacent bands.
- ECC Report 220 [15] on compatibility and sharing studies of DA2GC, PMSE video links, SRD and DECT in the 2 GHz unpaired bands.

Results for Forward Link and Reverse Link in both parts of the unpaired 2 GHz band are available. Adjacent-channel operation of Broadband DA2GC and PMSE video links (CCL, MVL and PVL) is feasible with separation distances and with some mitigation techniques depending on the PMSE scenario. Co-channel operation of DA2GC FL and PMSE CCL is feasible with limited CCL Tx/Rx antenna gain and/or limited CCL. Co-channel operation of DA2GC RL and PMSE video links (CCL, MVL and PVL) is not feasible due to the high exceeding of the protection criterion of the CCL Rx.

Compatibility studies have been performed with UMTS and DECT systems adjacent to the lower 2 GHz unpaired band and with MSS (including CGC), FS, TRR and SRS/EESS/SOS adjacent to the upper 2 GHz unpaired band.

The implementation of the DA2GC RL in the lower 2 GHz unpaired band would have no impact on UMTS and DECT systems.

In case the DA2GC FL is deployed in the lower 2 GHz unpaired band appropriate separation distances between the DA2GC Ground Station (GS) and the UMTS BS and/or a guard block between Broadband DA2GC below 1920 MHz and UMTS above 1920 MHz is required, and careful radio network planning for DA2GC in combination with site coordination with UMTS operators is required. These appropriate mitigations (i.e. separation distance, size of a guard band) will be dependent upon the DA2GC system characteristics (e.g. e.i.r.p. etc.).

The implementation of the DA2GC RL in the upper 2 GHz unpaired band is considered to be feasible.

The operation of the DA2GC FL in the band 2010-2025 MHz would not allow for FS/TRR operations at the lower edge of the band 2025-2110 MHz. Concerning the impact of SRS earth stations on DA2GC AS, calculations have shown that DA2GC AS, regardless of the system characteristics, will experience significant level of interference from earth stations emissions. By applying mitigation techniques to DA2GC systems the impact of these interference events could be reduced although not totally eliminated.

In conclusion, implementing the DA2GC FL in the lower 2 GHz unpaired band (1900-1910 MHz) and the DA2GC RL in the upper 2 GHz unpaired band (2010-2020 MHz) would offer a reasonable compatibility solution with regard to the radio services/applications in adjacent bands for the system according to ETSI TR 103 054. An operation in the lower 2 GHz unpaired band (1900-1920 MHz) would offer a suitable compatibility solution for a TDD system according to ETSI TR 101 599 and ETSI TR 103 108, assuming appropriate mitigation measures are applied.

The deployment of a Broadband DA2GC FDD system with 2x10 MHz in the 2 GHz unpaired bands would leave 10 MHz available in the sub-band 1910-1920 MHz for the implementation of alternative radio applications like PMSE (wireless cameras). In the case sharing with the DA2GC FL is feasible, additional 10 MHz could be used on a shared basis.

During the public consultation of this ECC Report, some mobile operators and mobile equipment manufacturers expressed their support for the FDD option.

6.2 FREQUENCY BAND 5855-5875 MHz

This frequency band has been designated to various radio applications.

The 5.8 GHz band is a worldwide ISM band according to provision No. 5.150 of the ITU Radio Regulations. Therefore the developments in other regions should also be taken into account. It should also be noted that, according to the provision mentioned above, radiocommunication services operating in the band 5725-5875 MHz must accept harmful interference which may be cause by ISM applications.

The FCC in the USA has announced a new proposed rulemaking (FCC 13-22) and has started spectrum investigations to be performed by the NTIA for additional RLAN spectrum in the 5 GHz frequency range services which do also cover the 5855-5875 MHz frequency range.

In regard to the work on DA2G the EC has already indicated that in view of the DAE (Digital Agenda for Europe) targets spectrum availability and coherent spectrum access and/or licence conditions for high-capacity broadband connections to moving vehicles and planes are considered a priority and as a matter of principle the EC takes a technology neutral view. In regard to the use of the 5.8 GHz band, in September

2013 the EC issued a Mandate ("*Mandate to CEPT to study and identify harmonised compatibility and sharing conditions for Wireless Access Systems including Radio Local Area Networks in the bands 5350-5470 MHz and 5725-5925 MHz ('WAS/RLAN extension bands') for the provision of wireless broadband services*") to CEPT to study the designation of additional harmonised licence-exempt spectrum for RLAN services (Wi-Fi) at 5 GHz in view of a potential revision of EC Decision 2005/513/EC (amended by EC Decision 2007/90/EC) [34]. Within ECC, ECC/DEC/(04)08 [35] was set in force for Wireless Access Systems including Radio Local Area Networks (WAS/RLANs).

The tendencies in the broadband wireless access market lead to more non-stationary use and including more outdoor usage. User equipment is not bound to fixed installed equipment but increasingly small devices such as smart phones, tablets etc. DA2GC systems should therefore take into account that the usage scenario in this band may be changed in the future to be similar to the 2400-2483.5 MHz band with outdoor RLAN and outdoor non-specific SRD applications.

The results of the compatibility studies for the 5.8 GHz band can be found in ECC Report 210 [16] on compatibility/sharing studies related to Broadband Direct-Air-to-Ground Communications (DA2GC) in the frequency bands 5855-5875 MHz, 2400-2483.5 MHz and 3400-3600 MHz.

Sharing and compatibility studies were conducted between Broadband DA2GC and the following services/systems in the band 5855-5875 MHz:

1. Broadband Fixed Wireless Access (BFWA);
2. Fixed Satellite Service (E-s);
3. Non-specific Short Range Devices (SRD);
4. Intelligent Transport Systems / Transport and Traffic Telematics (ITS/TTT);
5. Radiolocation Systems.

The studies carried out in ECC Report 210 [16] show that operation of Broadband DA2GC according to ETSI TR 101 599 [2] and ETSI TR 103 108 [3] is possible in the 5.8 GHz band based on specific system parameters and if appropriate mitigation measures are applied. However, ECC Report 210 [16] has not considered in detail that other applications will also use mitigation techniques in this frequency band. For example, the harmonised European Standard for Intelligent Transportation systems, EN 302 571 [36], includes a mandatory technical requirement for Listen-Before-Talk (LBT) to improve co-existence with BFWA as indicated in ECC Report 101 [37]. When the ITS LBT is triggered the ITS radio is not allowed to transmit.

Most probably the ITS LBT is not able to distinguish between Broadband DA2GC and other non-ITS signals and therefore it is important that the DA2GC transmissions will not exceed the LBT threshold. However, it is shown in ECC Report 210 [16] that the ITS receiver interference threshold is lower than the trigger threshold for the ITS LBT and therefore there was no need to study further the impact from DA2GCS on the ITS LBT.

Also the detect-and-avoid (DAA) mitigation feature as described in ECC Report 210 [16] at the Aircraft Station for the system according to TR 101 599 [2] is not able to differentiate between signal characteristics coming from different applications because the DAA mechanism reacts on the received power level (above the threshold) and not on the signal characteristics. The situation may be improved in the future by considering more complex mitigation techniques which allow differentiating between different applications. False triggering of the DAA cannot cause interferences, but it may lead to system performance degradation. Such an impact, e.g. caused by BFWA transmissions, could be avoided by switching off DAA at the AS and - instead - by applying a greater minimum elevation angle for the beam between AS and GS which would lead to a higher number of GS. It is also assumed that received signals from ITS stations will typically be at lower power levels than signals from BFWA and by optimising the trigger power level, false triggers from ITS could be minimised. However, this possibility to avoid false triggering of DAA was not part of the studies carried out within the scope of ECC Report 210 [16].

6.2.1 Other considerations on the 5.8 GHz frequency band

A first questionnaire regarding the implementation of BFWA according to ECC/REC/(06)04 [38]. (*Use of the band 5725-5875 MHz for Broadband Fixed Wireless Access (BFWA))* had been sent out by the ECO in 2008. The responses to this questionnaire had been discussed during the 63rd WG FM meeting in Brussels, May 2008. It was assumed that the extent of implementation had been increased within CEPT since 2008, therefore WG FM decided during its 74th meeting in Bern, April 2012, to send out again a questionnaire on the use of the 5.8 GHz BFWA band to the CEPT administrations.

The responses to the questionnaire [29] were discussed during the 75th WG FM meeting in Minsk in September 2012. According to the summary, 38 CEPT administrations had submitted a response. Until that point in time 14 countries had implemented BFWA in the whole frequency range from 5725-5875 MHz, whereas some other countries had implemented BFWA in parts of this frequency range, 14 countries had not at all implemented BFWA until that point in time. However, 4 of the latter planned the implementation of BFWA. The main reasons for not implementing BFWA, partly or completely, were given by the required protection of other radio applications. With that regard, TTT, ITS, FSS uplinks and radars were mentioned in the responses. According to the implementation status in the document database as well as information in EFIS, three countries which did not submit an answer to the questionnaire had also implemented ECC/REC/(06)04 [38] (BFWA). Altogether 27 countries had implemented BFWA in the whole frequency range 5725-5875 MHz or in parts of it until that point in time.

Also the regulatory status of BFWA at 5.8 GHz was discussed. On national level, BFWA is considered as a radio application under the scope of a radio service, e. g. the Fixed Service in some countries, but in other countries, as a de facto non-protected radio application as it is the case for other radio applications which are exempted from individual licences. The regulatory status of BFWA will have an impact on the sharing arrangement between Broadband DA2GC and BFWA on national level.

All except four countries which had implemented BFWA follow the ECC/REC/(06)04 [38] which recommends that administrations should consider applying simplified authorisation procedures for BFWA in this band, e.g. licence-exempt or light licensing regime. Several countries had already made use of registration/notification procedures (light licensing) which also make it necessary to provide location details about the central station or even clients. The majority which had implemented BFWA in that point in time, had done this based on ECC/REC/(06)04 [38] and using exemption from individual licensing.

7 CONCLUSIONS

7.1 TECHNICAL AND OPERATIONAL CONDITIONS

In order to ensure the adequate protection of incumbent radio services and applications, the technical requirements for Broadband DA2GCS, based on the results set out in ECC Reports 209 [14] and 210 [16], can be summarised briefly as follows,

General requirements

- DA2GCS GS: e.i.r.p. limitations similar as for base stations for terrestrial cellular mobile networks;
- The minimum operational height above ground is 3000 metres for the DA2GC AS;
- Compliance with a relevant Harmonised European Standard or alternatively, compliance with equivalent technical specifications (to fulfil the essential requirements of art. 3(2) of the R&TTE Directive[11]);
- DA2GCS AS has to be operated under the control of a network.

Requirements for the unpaired 2 GHz bands (FDD mode, 1900-1910 MHz / 2010-2020 MHz)

- Coordination is required for DA2GCS GS operating in the frequency band 1900-1910 MHz with MFCN base stations receiving above 1920 MHz;
- To protect the DA2GCS GS reception in the band 2010-2020 MHz coordination with FS, TRR and SRS earth stations is required.

[11] to be replaced by the Radio Equipment Directive 2014/53/EU of 16 April 2014 [54]

Requirements for the unpaired 2 GHz bands (TDD mode)

- Coordination is required for DA2GCS GS operating in the frequency band 1900-1920 MHz with MFCN base stations receiving above 1920 MHz.

Requirements for the band 5855-5875 MHz

- For DA2GCS AS operating in the frequency range 5855-5875 MHz, e.i.r.p. mask limitations need to be set up in order to avoid exceeding acceptable interference thresholds (e.g. pfd limitations) for the suitable protection of the incumbent systems on the ground. In addition, the DA2GCS AS unwanted emissions into the adjacent bands need to be limited (e.g. for the protection of radars and ITS);
- For DA2GCS GS operating in the frequency range 5855-5875 MHz, e.i.r.p. mask limitations are required as a function of DA2GCS GS elevation angle. Additionally, for ETSI TR 101 599, the minimum operational elevation angle is 5 degrees. Furthermore, the DA2GCS GS (ETSI TR 101 599 and ETSI TR 103 108) unwanted emissions into the adjacent bands need to be limited (e.g. for the protection of radars and ITS);
- Coordination is required for DA2GCS GS operating in the frequency band 5855-5875 MHz with BFWA stations, where locations are known, and for the protection of ITS close proximity should be avoided to main roads;
- For DA2GCS AS in the frequency band 5855-5875 MHz additional measures are required to protect BFWA stations, by limiting emissions towards the BFWA receivers.

Detailed parameters have been identified as a basis for the regulation for the following Broadband DA2GCS options:

Table 4: Broadband DA2GCS options

For 5855-5875 MHz	For 1900-1920 MHz	For 2010-2025 MHz
	TR 103 054 (FDD) (Annex 6, FL: 1900-1910 MHz)	TR 103 054 (FDD) (Annex 6, RL: 2010-2020 MHz)
TR 101 599 (TDD) (Annex 7)	TR 101 599 (TDD) (Annex 8)	
TR 103 108 (TDD) (Annex 9)	TR 103 108 (TDD) (Annex 9)	

An aircraft station operating in the territory of one country could cause interference to terrestrial systems operating in a neighbouring country. The technical and operational conditions as described above could also be used as a basis for future agreements on cross border coordination, especially with countries outside CEPT.

7.2 COMPATIBILITY / SHARING WITH OTHER RADIO SERVICES AND APPLICATIONS

At the time of writing this ECC Report, some open issues remained concerning the compatibility / sharing of Broadband DA2GC with newly proposed radio applications:

a. in the frequency range 5855-5875 MHz:

- The studies for future WAS/RLAN usage in the frequency band 5725-5925 MHz are not completed. The schedule of the 5 GHz mandate [30] foresees a first draft Report from CEPT to the Commission in November 2014 and the review and reconfirmation of the final results by July 2016.

b. in the unpaired 2 GHz bands:

- In the Mandate on the unpaired 2 GHz bands [24] it is assumed that some of the candidate applications being temporary or local in nature and would not utilise exclusively the total available spectrum in the unpaired terrestrial 2 GHz bands. Therefore, shared use between the different candidate applications should be studied in order to ensure efficient spectrum use. In this regard, appropriate least restrictive technical conditions should be developed both for the identified specific application and for any possible sharing arrangement.

- In the point of time when this ECC Report was adopted, the studies regarding Broadband DA2GC, PMSE video links, SRD and DECT had not been completed

In relation to the open issues as described above, but also related to the schedule of the final CEPT Report in response to the Mandate from the EC on the unpaired 2 GHz bands which should be delivered by November 2014, it is recommended to take care during the development and approval process for the ECC Decision(s) on Broadband DA2GC that the progress regarding one of the bands will not be hampered because of open questions regarding the other frequency range.

By summarising it has to be emphasised that a spectrum regulation for Broadband DA2GCS should not contain technical requirements which are not enforceable or which would unduly constrain the roll-out of such as system.

7.3 APPROPRIATE ECC REGULATION

Licensing:

The Broadband DA2GCS equipment under consideration is intended to provide non-safety related broadband communication services (e.g. internet and other type of services) to users on board aircraft using their own equipment or provided by the airline.

DA2G communications, by their very nature, cross national borders and, as such, are subject to international or regional in addition to national regulation.

Network investment and deployment costs as well as aircraft equipment costs are high for Broadband DA2GCS, especially when considering the first roll-out of DA2GCS. The implementation of such a system is only reasonable if a continuous and pan-European coverage is achieved, thus a CEPT wide harmonised radio spectrum designation and harmonised licensing conditions would be essential. In addition, a European harmonised authorisation framework is considered necessary to provide the regulatory certainty that network operators and airlines require to invest in a Broadband DA2GCS.

ECC Report 132 [21] includes reference terminologies as shown in Table 5 below in order to capture some fundamental differences between various regulatory options:

Table 5: Difference between regulatory options

<table>
<tr><th colspan="2">Individual authorisation
(Individual rights of use)</th><th colspan="2">General authorisation
(No individual rights of use)</th></tr>
<tr><th>Individual licence[12]
(1)</th><th colspan="2">Light-licensing
(2) (3)</th><th>Licence-exempt
(4)</th></tr>
<tr><td>Individual frequency planning / coordination
Traditional procedure for issuing licences</td><td>Individual frequency planning / coordination
Simplified procedure compared to traditional procedure for issuing licences
With limitations in the number of users</td><td>No individual frequency planning / coordination
Registration and/or notification
No limitations in the number of users nor need for coordination</td><td>No individual frequency planning / coordination
No registration nor notification</td></tr>
</table>

[12] Sometimes also referred to as “traditional licensing”

Spectrum coexistence amongst different Broadband DA2GC networks has not been studied within ECC. Licence-exemption for the ground stations seems to be problematic as some countries do not allow licence-exemption to be exclusive to a limited number of service providers.

Given the need for substantial financial investment, together with the requirement to protect other spectrum users, it is reasonable to envisage individual authorisation for the ground stations in Europe and that the aircraft stations are exempted from individual licensing. Free circulation and use is required for Aircraft Stations which are under the control of the Broadband DA2GC network and this could be achieved under the umbrella of an ECC Decision. In addition it is important that the chosen forms of regulation and licensing do not impose unreasonable restrictions on competition.

DA2GC aircraft stations operate under the control of the DA2GC ground station network and planes may operate in national airspace and also operate in international airspace.

Allocation:

ECC concluded that, by taking into account that a ground station (base station) for a Broadband DA2GC system has to be considered as a “land station” according to provision No. 1.69 of the ITU Radio Regulations RR), the allocation to mobile service (where the aeronautical mobile service is not excluded) would be appropriate for a Broadband DA2GCS. An allocation to the mobile service (with a primary status) is already available for the bands 1900-1920 MHz, 2010-2025 MHz and 5855-5875 MHz in the ITU-R Radio Regulations as well as in the ECA Table (ERC Report 25 [39]). In the future, a footnote in relation to the mobile service allocation in the ITU Radio Regulations Article 5 may be appropriate to ensure protection of DA2GC services.

Current authorisations and uses of the unpaired 2 GHz bands:

Currently, all or parts of the frequency band 1900-1920 MHz is licensed to mobile operators for the provision of electronic communications services in 36 CEPT countries, whereby the licences are mainly limited to UMTS/IMT-2000 TDD technology. On the other hand, the frequency band 2010-2025 MHz, or parts of it, is licensed to mobile operators in 13 CEPT countries for the provision of electronic communications services, mainly limited to UMTS/IMT-2000 TDD technology and in some cases in a technology neutral way. Existing licences in the unpaired 2 GHz bands have been awarded on an exclusive basis in some countries. In addition, some administrations use the band 2010-2025 MHz for short term licences, in particular for wireless cameras.

The mobile licenses (UMTS TDD) in force on the unpaired 2 GHz bands are not in use in Europe, noting also that the lack of interest of mobile operators for spectrum in the unpaired terrestrial 2 GHz band has been demonstrated during the auctions in some CEPT countries in 2011. The duration of those licenses vary from country to country, from 2014 - 2029 (or even unlimited duration, in United Kingdom).In addition it has to be mentioned that licences have already been surrendered in some countries.

Some of the licenses were awarded after spectrum auction processes and, as a result, considerable auction prices were achieved. In some countries, a license repeal process might be possible in case of continued non-implementation, whereas in other countries this will not be possible due to specific conditions and obligations which are part of the license (e.g. coverage obligations are interpreted in some cases as fulfilled when providing services via other spectrum where the same licensee has also a license and for which the network is implemented).

Other options for making the spectrum available for new usage need to be considered (e.g. liberalisation, transfer, interim licence conditions for new licensee until the end of the existing licence duration(s)).

Liberalisation frameworks would permit incumbent licensees in many of these countries to enable alternative service deployment, but the frameworks in some countries would or may maintain restrictions with regard to technology or use. A number of administrations may not be in a position to withdraw the existing licences and may seek agreements between the existing licence holder and possible new service operator(s). According to the results of a CEPT questionnaire on authorisation issues regarding the candidate bands for Broadband Direct-Air-to-Ground Communications (DA2GC) in 2013 [18], the prospects for change of use through liberalisation appear in general promising for the 2 GHz unpaired bands, whereby the precise liberalisation framework may need to be found by the individual administration. It may be helpful to describe more in detail the options for a precise liberalisation framework in accordance with the needs of the new foreseen spectrum usages (e.g. pan-European service coverage in case of Broadband DA2GC) and to set up a common European implementation schedule for future harmonised and efficient use of the 2 GHz unpaired bands.

Current authorisations and uses of the band 5855-5875 MHz:

Currently there is varied incumbent use in 15 countries in the 5.8 GHz range under individual authorisations, mainly FSS, FS (BFWA). In addition 3 countries indicated governmental use. In relation to ECC/REC/(08)01 [40] , some administrations may consider individual licensing for the road side ITS stations. The individual licences for FSS and FS applications are not related to a usage within the scope of the mobile service and therefore an amendment of these licences cannot be considered as an appropriate liberalisation measure. Implementation of Broadband DA2GC will require new licences subject to certain conditions and mitigation measures identified in the compatibility and sharing studies (see section 6.2).

Future spectrum designation and authorisation for Broadband DA2GC:

The development of (a) specific ECC Decision(s) on spectrum harmonisation for Broadband DA2GC systems is considered necessary because of the pan-European character of these systems. According to Article 12 of the ECC Rules of Procedures, Decisions should be the outcome of any decision making process on matters of significant harmonisation in the electronic communications regulatory field, within the context of the long term ECC strategy and policy.

An aircraft station operating in the territory of one country could cause interference to terrestrial systems operating in a neighbouring country. Consequently, ECC Decisions have to introduce emission thresholds for aircraft stations that apply to the territory of administrations which operate terrestrial systems in the same bands as those used by the aircraft-mounted DA2GCS stations. This constraint may be relaxed with the agreement of the administrations concerned, for example if the terrestrial system characteristics differ from those used in the calculation of the threshold or if the terrestrial systems are deployed only in parts of the country distant from the aircraft route.

The responses to the questionnaire [18] have shown that, for future Broadband DA2GC authorisations, the majority of the CEPT administrations consider individual authorisations for the GS (according to Nos. 1 or 2 in Table 5 above) as the most appropriate solution. The majority supported an individual licensing (1), whereas some supported a light-licensing procedure (2).

Individual or general authorisation for the AS (depending on national requirements) is considered as appropriate, taking into account that the Aircraft Stations (AS) will be operated under the control of the relevant DA2GC Ground Stations (GS), hence under the control of the network. The ECC regulation should also address the free circulation and use of the AS within CEPT.

This follows precedence cases for e.g. aircraft earth stations or ESOMPs as in ECC/DEC/(05)11 [31] or ECC/DEC/(13)01 [20]

7.4 RELEVANT EU REGULATION

The Directive 2002/21/EC [27] of the European Parliament and of the Council of 7 March 2002 on a common regulatory framework for electronic communications networks and services (Framework Directive), amended by Directive 2009/140/EC of the European Parliament and of the Council of 25 November 2009, aims at encouraging efficient use and ensuring effective management of radio frequencies and numbering resources, removing the remaining obstacles to the provision of the relevant networks and services, ensuring that there is no discrimination and encouraging the establishment and development of trans-European networks and the interoperability of pan-European services and this applies also to Broadband DA2GCS networks.

The three system proponents consider an EU harmonisation measure to be important for a European wide implementation of Broadband DA2GCS.

The European wide designation and timely implementation may also imply a European harmonised selection and authorisation of a Broadband DA2GCS[13]. For a successful launch of a Broadband DA2GC system, coordination of regulatory action by EU Member States would be highly advantageous. Differences in national selection procedures could create fragmentation of the internal market due to the divergent implementation of selection criteria, including the weighting of the criteria, or different timescales of the selection procedures. This would result in a patchwork of successful applicants selected in contradiction to the pan-European nature of Broadband DA2GC.

7.5 DEVELOPMENT OF A HARMONISED EUROPEAN STANDARD

ETSI should be invited to create (a) Harmonised European Standard(s) for Broadband DA2GC equipment to fulfil the requirements under article 3.2 of the R&TTE Directive [23][14]. Aircraft Stations (AS) will be operated under the control of the relevant DA2GC Ground Stations (GS), hence under the control of the network and should only transmit when so being enabled by the ground network. Specific procedures for this should be laid down in a Harmonised European Standard.

DA2GCS equipment should be in conformance with the respective Harmonised European Standard requirements. A proper split of the technical requirements between regulatory decisions on one side and standardisation on the other side would also provide flexibility with regard to future amendments. Some technical details may need amendment in the future and could be taken into a harmonised standard revision without the need to revise the regulations set out in the applicable ECC and EC Decisions.

[13] e.g. in a similar manner to the process used for identifying the pan-European operators for MSS 2 GHz
[14] to be replaced by the Radio Equipment Directive 2014/53/EU of 16 April 2014 [54]

ANNEX 1: SPECTRUM DEMAND

Performance figures for a LTE-based Broadband DA2GC system

The following tables give an overview on draft performance figures achievable with a LTE-based Broadband DA2GC system, mainly related to Release 8 features [12]. These performance figures were derived in extensive system level simulations for a multi-cell/multi-aircraft environment. The figures depend on the applied models as further described below (e.g. carrier frequency, inter-site distance, antenna characteristics and air traffic density per cell). Note that pure link level simulations cannot provide an accurate view on the expected performance of modern broadband wireless access technologies operated in interference-limited regimes.

Based on the statistical evaluation in [8] different air traffic density models were defined for deriving performance figures. These models also include altitude distributions for the aircraft resulting in a 3D modelling of the aircraft locations above a hexagonal cell grid on the Earth surface (see Figure 16), i.e. these values are varying during the capacity evaluation.

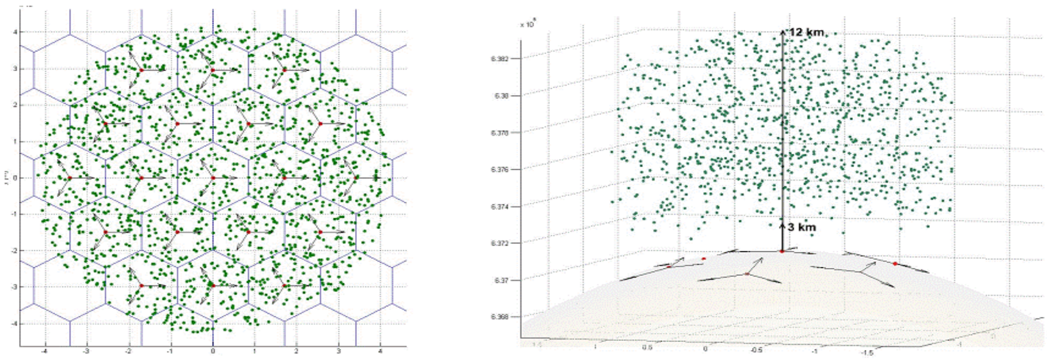


Figure 16: Exemplary set-up of hexagonal cell grid for system level simulation on the Earth surface (green dots: snapshot of 3D locations of involved aircraft)

Table 6: Spectral efficiency in bit/s/Hz for the forward link of a Broadband DA2GC system based on LTE Release 8 (FDD) for a carrier frequency of 2 GHz (at 5 GHz values are reduced by about 10–15%)

Forward link[15] Antenna configuration[16]	ISD of 120 km (3 sectors per cell, 3.1 aircraft/sector)	ISD of 170 km (3 sectors per cell, 6.3 aircraft/sector)
1x1 SISO V-pol.	1.2	1.1
4x1 MISO[17] V-pol.	1.8	1.8
2x2 MIMO VH-pol. x VHcirc.-pol.	2.1	2.1
2x2 MIMO X-pol. x VH-pol.	1.7	1.7

[15] Forward link: Ground-to-air link (equivalent to downlink in terrestrial mobile radio systems)
[16] SISO: Single Input Single Output; MISO: Multiple Inputs Single Output; MIMO: Multiple Inputs Multiple Outputs
[17] With beam forming

Table 7 Spectral efficiency in bit/s/Hz for the reverse link of a Broadband DA2GC system based on LTE Release 8 (FDD) for a carrier frequency of 2 GHz (at 5 GHz values are reduced by about 25–30% due to transmit power limitation at the aircraft)

Reverse link[18] Antenna configuration[19]	ISD of 120 km (3 sectors per cell, 3.1 aircraft/sector)	ISD of 170 km (3 sectors per cell, 6.3 aircraft/sector)
1x1 SISO V-pol.	0.9	0.9

The aircraft antenna characteristic was adapted to measured values of a real vertically polarised aircraft antenna with nearly omni-directional characteristic with respect to the horizontal plane and the elevation diagram according to Figure 17 (related to the cases in the tables denoted as SISO and MISO).

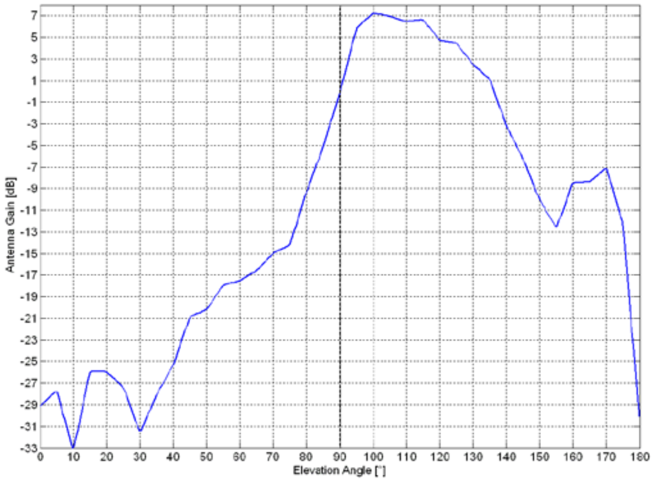


Figure 17: Antenna gain vs. elevation angle of aircraft antenna used in performance evaluation

Further improvements are feasible with more complex antenna constellations at the aircraft. A comparison with standard SISO configuration given in first line of Table 6**Error! Reference source not found.** shows an improvement of about 3 dB in SINR for application of two directional aircraft antennas with a 180° beam width. In principle this gain can be further increased by introduction of more beams with lower beam width, but as said before, there are technical and economical limitations for final realisation.

As already mentioned the ground stations of a Broadband DA2GC system will be equipped with sector antennas (typically 3 sectors per cell) as in usual terrestrial mobile radio networks. The main difference is in the vertical antenna characteristic as the antenna diagram will be up-tilted to achieve optimum coverage in the 3D air space.

To cope with increasing traffic demand it will be possible to install additional ground stations resulting in reduced ISD and/or to add additional sectors to existing ground stations (e.g. 6 sectors instead of 3) in traffic hot spots.

Estimated spectrum demand for a LTE-based Broadband DA2GC system

For the estimation of spectrum demand (related to 2020) the overall aggregate data rate by all passengers in a commercial aircraft during one flight is an important input parameter. The required data rates can be computed by applying certain simultaneity factors for service utilisation based on average session data rates.

[18] Reverse link: Air-to-ground link (equivalent to uplink in terrestrial mobile radio systems)
[19] SISO: Single Input Single Output; MISO: Multiple Inputs Single Output; MIMO: Multiple Inputs Multiple Outputs

The approach used here is based on a procedure described in [13], which is more related to best effort services in case of internet browsing and does not consider in detail the bursty data traffic nature of some applications. Therefore, based on instantaneously used service applications (e.g. several YouTube video sessions running in parallel) higher instant peak data rates may occur during a flight as those given by the evaluation. The communication system has to be able to handle such peaks to some extent.

For the data rate computation following assumptions was made for the penetration of the different available services in the aircraft, their statistics incl. data volume and session/call duration as well as for passenger and flight statistics:

- Average number of passengers per aircraft: 94 (corresponding to an average load factor of about 75%)
- Average flight duration: 1.5 h
- APC services:
  - Maximum onboard service usage time: 1 h (reduced time compared to flight duration caused by APC service restrictions during departure and landing)
  - GSMOBA voice services:
    - Service penetration: 10%
    - Call duration: 4 min (each user with only 1 call/flight)
    - Data rate: 12 kbit/s bi-directional
  - GSMOBA SMS services:
    - Not relevant for spectrum demand due to low data volume compared to user services
  - GSMOBA data services:
    - Service penetration: 6%
    - Session duration: 18 min
    - Date volume per session: 3 Mbyte
    - Download/upload ratio: 80% / 20%
  - Wi-Fi data services:
    - Service penetration: 15%
    - Session duration: 42 min
    - Date volume per session: 50 Mbyte
    - Download/upload ratio: 85% / 15%
- AAC services:
  - Maximum onboard service usage time: 1.5 h
    (in contrast to APC services the transmission of AAC services may also be permitted during departure and landing for exchange of operational parameters)
  - Data volume per flight: 30 Mbyte
  - Download/upload ratio: 60% / 40%

In general the assumptions made for the service penetration are conservative. In the future especially declining service prizes may result in higher utilisation factors and as a consequence of this in increased aggregate data rates.

The resulting data rates in downlink and uplink are computed based on the addition of the data rates of the different services using following formulas for a single service type:

- Average data rate:
  - Communication and interactive service types:
    - $R_{ba} = (N_a * T_s * R_{bi}) / T_f$
      - R_{ba}: average data rate per service
      - N_a: average number of active users during flight
      - T_s: session duration
      - R_{bi}: mean data rate per user
      - T_f: average flight duration
  - Event-driven applications:
    - $R_{ba} = (N_a * L * E) / T_f$
      - R_{ba}: average data rate per service
      - N_a: average number of active users during flight
      - L: average length of event or message

        - E: average number of events per user
        - T_f: average flight duration
- Maximum aggregate data rate:
    - $R_a = N * R_{bi}$
        - R_a: maximum aggregate data rate per service
        - N: maximum number of simultaneously active users during flight
        - R_{bi}: mean data rate per user

Incorporating the related values for call numbers/durations, data session volumes/durations and asymmetry for download/upload approximate values for the data rates required for a single aircraft are given as:

- Forward link data rate:
    - Average: about 1.40 Mbit/s
    - Maximum: about 2.26 Mbit/s
- Reverse link data rate:
    - Average: about 0.27 Mbit/s
    - Maximum: about 0.58 Mbit/s

Assuming a spectral efficiency of 2.1 bit/s/Hz for the forward link and 0.9 bit/s/Hz for the reverse link of the Broadband DA2GC system according to Table 6**Error! Reference source not found.** and **Error! Reference source not found.**, the following Table 8**Error! Reference source not found.** provides the number of aircraft which can be supported per sector in a multi-aircraft scenario based on the estimated required maximum data rate per aircraft (2.26 Mbit/s for the forward link and 0.58 Mbit/s for the reverse link).

Table 8: Number of aircraft supported in one sector according to assumptions made on spectrum efficiency and required data rates per aircraft (2 GHz carrier frequency assumed)

Link	Signal bandwidth 2 x 5 MHz FDD	Signal bandwidth 2 x 10 MHz FDD
Forward	4.6	9.3
Reverse	7.8	15.5

The aircraft numbers given in Table 6 and Table 7**Error! Reference source not found.** (3.1 and 6.7 aircraft/sector) refer to the assumption that in the year 2020 about 60% of the commercial aircraft are equipped by the LTE-based Broadband DA2GC solution. Business jets, which may further increase the values, are not taken into account.

For the forward link the estimated averaged data rate requirements might be fulfilled with a signal bandwidth of 5 MHz only with a ground station ISD of 120 km. However, to allow for a cost efficient initial rollout with larger ISD and to cope with instantaneous peak data rates as well as with increasing capacity demand a bandwidth of at least 10 MHz is deemed to be necessary (no bandwidth increment available for LTE between 5 and 10 MHz).

Due to underlying asymmetry in down-/upload data traffic a bandwidth of 5 MHz is barely sufficient for the reverse link, but a bandwidth of 10 MHz is preferable to cope with changes in traffic distribution and instantaneous service data rate peaks (e.g. for video or telemedicine).

ANNEX 2: CANDIDATE BANDS WHICH WERE CONSIDERED FOR BROADBAND DA2GC

Table 9: Category 1: Frequency bands for which compatibility/sharing studies have been carried out

Frequency band	Existing allocation in the RR suitable for Broadband DA2GC (MS or AMS) ?	Current level of harmonisation ?	Would the bandwidth required (2 x 10 MHz FDD or 20 MHz TDD) fit in the band ?	Proposed or future alternative usage under consideration (within CEPT) ?	Actual usage of the band - national level - within CEPT (- worldwide) for future sharing studies ?	Actual usage of adjacent bands - national level - within CEPT for future compatibility studies ?	
2400-2483.5 MHz (Note 1)	yes	high	yes	---	RLANs, SRDs/RFIDs, ISM	Aeronautical Telemetry, Amateur, Mobile applications, SAP/SAB (cordless cameras), MSS, ISM	
3400-3600 MHz (Note 2)	yes	high	yes	see amended version of ECC/DEC/(11)06 of 14 March 2014 [42]	BWA, FSS, FS links, RLS	RLS, FSS, BWA, FS links	
5855-5875 MHz (Note 3)	yes	medium	yes (air to ground)	AI 1.20 WRC-12	BFWA, ITS, SRDs, FSS (uplink), military systems (on a national level), ISM	RLS, TTT, BFWA, SRDs, ITS	

Note 1: After initial considerations it was decided not to study further this band (see section A.2.3 below)
Note 2: After initial considerations it was decided not to study further this band (see section A.2.4 below)
Note 3: See sections 6.2, 6.2.1 and 7

Table 10: Category 2: Frequency bands to be considered next or in case the studies for the category 1 bands will not show positive results

Frequency band	Existing allocation in the RR suitable for Broadband DA2GC (MS or AMS) ?	Current level of harmonisation ?	Would the bandwidth required (2 x 10 MHz FDD or 20 MHz TDD) fit in the band ?	Proposed or future alternative usage under consideration (within CEPT) ?	Actual usage of the band - national level - within CEPT (- worldwide) for future sharing studies ?	Actual usage of adjacent bands - national level - within CEPT for future compatibility studies ?	
2483.5-2500 MHz (Note 4)	yes	high	Yes (ground to air)	AI 1.18 WRC-12	MSS, ISM	RLANs, SRDs/RFIDs, ISM, ECS	
5150-5170 MHz (Note 4)	yes (1) (see also 5.446C)	high	yes		FSS (feeder links), RLANs, BBDR, AMS (Flight Test Telemetry)	MLS, AM(R)S, RLANs, FSS (feeder links) (2)	

(1) The current AMS allocation would need to be modified to allow Broadband DA2GC
(2) Compatibility studies with MLS, AM(R)S, RLANs and FSS have been completed

Note 4: It was not necessary to consider this band in detail.

Table 11: Category 3: Position on frequency bands which was open/undecided when the considerations were started

Frequency band	Existing allocation in the RR suitable for Broadband DA2GC (MS or AMS) ?	Current level of harmonisation ?	Would the bandwidth required (2 x 10 MHz FDD or 20 MHz TDD) fit in the band ?	Proposed or future alternative usage under consideration (within CEPT) ?	Actual usage of the band - national level - within CEPT (- worldwide) for future sharing studies ?	Actual usage of adjacent bands - national level - within CEPT for future compatibility studies ?	
1452-1492 MHz (Note 5)							
1900-1920 MHz / 2010-2025 MHz (Note 6)	yes	high	yes	ECS	UMTS (TDD)	DECT, UMTS (FDD), EESS, SRS, FS, SAP/SAB	
3600-3800 MHz (Note 7)	yes	high	yes	see amended version of ECC Decision (11)06 of 14 March 2014 [42]	BWA, FSS, FS links	BWA, FSS, FS links	
5905-5925 MHz	yes	high	yes (air to ground)	AI 1.20 WRC-12	FSS (uplink), military systems (on a national level)	FS links	

Note 5: It was not necessary to consider this band in detail (see section A.2.1 below)
Note 6: See sections 6.1 and 7
Note 7: After initial considerations it was decided not to study further this band (see section A.2.5 below)

Table 12: Category 4: Frequency bands with high regulatory obstacles for an introduction of Broadband DA2GC systems

Frequency band	Existing allocation in the RR suitable for Broadband DA2GC (MS or AMS) ?	Current level of harmonisation ?	Would the bandwidth required (2 x 10 MHz FDD or 20 MHz TDD) fit in the band ?	Proposed or future alternative usage under consideration (within CEPT) ?	Actual usage of the band - national level - within CEPT (- worldwide) for future sharing studies ?	Actual usage of adjacent bands - national level - within CEPT for future compatibility studies ?	
2300-2400 MHz (Note 8)	yes	low	yes		Aeronautical Telemetry, Amateur, Mobile applications, SAP/SAB (cordless cameras)	FS, MS, SRS	

Note 8: It was not necessary to consider this band in detail (see section A.2.2 below).

A.2.1 FREQUENCY BAND 1452-1492 MHz

The band 1452-1492 MHz had initially also been considered for Broadband DA2GC as one candidate application among others. However, one disadvantage for this band is given by the current allocation according to the ITU Radio Regulations and ERC Report 25 [39], which excludes the aeronautical mobile service. ECC had developed ECC Report 188 [41] on “Future Harmonised Use of 1452-1492 MHz in CEPT” which was finally approved in February 2013. The ECC/DEC/(13)03 [19] on “the harmonised use of the frequency band 1452-1492 MHz for Mobile/Fixed Communications Networks Supplemental Downlink (MFCN SDL)” was finally approved in November 2013, based on the results as described in ECC Report 202 [52]. In April 2014, the European Commission issued a Mandate to CEPT related to Wireless Broadband ECS in the band 1452-1492 MHz. Therefore compatibility or sharing studies related to Broadband DA2GC were not carried out for this band. Frequency band 2300-2400 MHz

The following aspects were discussed within CEPT:

- Due to the high number of diverging uses of the 2.3-2.4 GHz band within CEPT and that part of these use will continue in the long term, any activity on this band should be carried out under its responsibility, except the activity related to CEPT preparation to WRC-15 in this band, if any;
- Harmonisation work should be undertaken for the implementation of broadband MFCN;
- Incumbent use of the 2.3-2.4 GHz band should be ensured through appropriate regulatory framework. In that respect, using the LSA concept should be considered;
- In April 2014, the European Commission issued a Mandate to CEPT related to Wireless Broadband ECS in the band 2300-2400 MHz.

Taking into account the high number of diverging uses within CEPT and the intended harmonisation for broadband MFCN, the band 2300-2400 MHz is considered not suitable for Broadband DA2GC.

A.2.2 FREQUENCY BAND 2400-2483.5 MHz

Based on a consideration of the BDA2GC system described in ETSI TR 103 054 [1], by taking into account the aggregate effect, it is concluded that co-channel operation of a DA2GC forward link (ground-to-air) and outdoor RLAN devices in the band 2400-2483.5 MHz is not feasible. This would also be the case if only a few RLAN devices were operated on the same channel. It is concluded that co-channel operation of a DA2GC reverse link (air-to-ground) and outdoor RLAN devices in the band 2400-2483.5 MHz is not feasible because the RLAN devices would significantly be interfered (by considering an altitude for the AS of 3 000 m or 10 000 m).

Co-channel single entry compatibility studies between the DA2GC Aircraft Station as described in ETSI TR 101 599 [2] in 10 km altitude and RLANs on the ground in the band 2400-2483.5 MHz have shown that:

- RLANs equipped with sector antennas will be interfered by one DA2GC aircraft station in case the angle between the DA2GC aircraft station and the DA2GC ground station is 20 degree or less;
- RLANs equipped with omnidirectional antennas will be interfered by one DA2GC aircraft station in case the angle between the DA2GC aircraft station and the DA2GC ground station is below 5 degree;
- The same results for lower aircraft altitudes can be expected by taking into account the ATPC range of the transmitter.

Co-channel single entry compatibility studies between RLANs on the ground in the band 2400-2483.5 MHz and the DA2GC Aircraft Station as described in ETSI TR 101 599 [2] have shown that:

- At an aircraft altitude of 3 km interference can be observed on the aircraft station receiver from 5 to 90 degree elevation angle caused by one RLAN located in the mainbeam of the aircraft station;
- At an aircraft altitude of 10 km interference can be observed from 20 – 90 degree elevation angle caused by one omni-directional RLAN and from 22 to 58 degree elevation angle caused by one RLAN equipped with a 10 dBi sector antenna located in the mainbeam of the aircraft station;
- At aircraft altitudes above 14 km, no interference at the DA2GC AS is observed;
- The RLAN transmissions would severely reduce the throughput in the DA2GC system.

Additional improvements to mitigate interferences in this band could be considered in a next step. Furthermore it may be expected that a statistical approach using a Monte–Carlo simulation may lead to more favourable results of the studies. However, due to the high density of other applications in the band 2400-2483.5 MHz and due to the expected constraints resulting from their protection requirements, other frequency bands may be more favourable for the deployment of DA2GC.

Besides the aspects as described above, it was considered that a combination of the band 2400-2483.5 MHz with the band 5855-5875 MHz (forward link in one band, reverse link in the other band) would cause an additional burden and significantly increase the costs for the DA2GC operator because of the large separation of the bands.

A.2.3 FREQUENCY BAND 3400-3600 MHZ

The following aspects are relevant for an implementation of Broadband DA2GC within this band:

- The lower edge of the TDD band plan for MFCN (starting at 3400 MHz according to ECC Decision ECC/DEC/(11)06) [42] may be more suitable for TDD Broadband DA2GC systems than blocks in the higher portion of the band. However, it might also be necessary to carry out adjacent band compatibility studies with regard to the Radiolocation Service below 3400 MHz;
- Spectrum within the duplex gap of the FDD band plan for MFCN, 3490-3510 MHz, may also be considered for TDD Broadband DA2GC systems;
- The lower duplex band of the FDD band plan for MFCN (uplink for MFCN) would be suitable for the Reverse Link for FDD Broadband DA2GC systems (Aircraft Station to Ground Station), because this band is considered to be less used for FSS earth stations (space to Earth) within CEPT compared to spectrum above 3500 MHz.

Moreover, ECC had agreed to achieve harmonised frequency arrangements (ECC/DEC/(11)06) [42] for the 3.4-3.6 GHz and 3.6-3.8 GHz bands to support the development of MFCN with larger bandwidth in those bands in response to high broadband mobile requirements. The frequency arrangements in the 3.4-3.6 GHz band was subject to review which resulted in a preferred frequency arrangement based on TDD, see amended version of ECC Decision (11)06 [42] of 14 March 2014. A TDD arrangement has been defined for the 3.6-3.8 GHz band.

However, in the point of time when the band 3400-3600 MHz was studied, it was not clear whether a mixed duplex arrangement within CEPT (FDD in some countries, TDD in other countries) for MFCN in the band 3400-3600 MHz could be avoided in the future. If, at least in some countries, Broadband DA2GC had another duplex scheme than MFCN, this would lead to additional guard blocks in order to protect MFCN systems in adjacent blocks. In practice this would enlarge the required spectrum for Broadband DA2GC and de facto decrease the available spectrum for MFCN. The latter one would be in contradiction with the general aim of ECC/DEC/(11)06 [42].

Two options were considered as possible in principle for Broadband DA2GC, subject to additional analysis with regard to other services:

- 3410-3420 MHz (air-to-ground) paired with 3510-3520 MHz (ground-to-air)
  or
- 3400-3410 MHz (air-to-ground) paired with 3500-3510 MHz (ground-to-air).

The use of the sub-band 3 550-3 600 MHz for DA2GC forward link (ground-to-air) is considered less suitable due larger deployment of FSS earth stations making use of these frequencies.

The most spectrum efficient solution for DA2GC in the band 3400-3600 MHz would require a harmonised FDD frequency arrangement to include both Broadband DA2GC and MFCN. However, this would be in contradiction with ECC/DEC/(07)02 [43] and with the latest version of ECC/DEC/(11)06 [42].

Guard blocks would definitely be required for Broadband DA2GC systems as long as TDD is possible for MFCN within 3400-3600 MHz.

It has also to be taken into account that other compatibility scenarios with regard to the frequency band 3400-3600 MHz are still outstanding, e.g. the compatibility with radars below 3400 MHz.

Also other aspects, outside the compatibility considerations, were addressed during the discussion. The cross-border coordination looks very challenging.

ECC had also assessed the potential for interference from Broadband DA2GC aircraft and ground-station transmissions to FSS earth station receivers operating within the 3400-3600 MHz band in detail (and had drawn preliminary conclusions). There is likely to be a need for extensive physical separation (>450 km) to avoid the potential for harmful interference from Broadband DA2GC aircraft transmissions which are co-frequency with FSS earth station receivers.

Possible FDD Broadband DA2GC frequency arrangements within the 3400-3600 MHz band that minimise the potential for interference to FSS earth station receivers is a channel pairing of 3400-3410 MHz for aircraft transmissions and (within) 3490-3510 MHz for ground station transmission, or channel pairing of 3410-3420 MHz for aircraft transmissions with 3510-3520 MHz for ground-station transmissions. Possible TDD Broadband DA2GC operations below 3520 MHz would be helpful to minimise the potential for interference to the FSS.

Finally it was decided not to study further the band 3400-3600 MHz after initial compatibility considerations within ECC since it was not considered as a frequency band which could support the efficient use of spectrum for a pan-European Broadband DA2GC network.

ECC, during its meeting in November 2013, finally adopted CEPT Report 49 [44] on "*Technical conditions regarding spectrum harmonisation for terrestrial wireless systems in the 3400-3800 MHz frequency band*" and decided to identify the preferred frequency arrangement for the band 3400-3600 MHz based on TDD. ECC/DEC/(11)06 [42] was amended accordingly during the ECC meeting in March 2014. The relevant part of CEPT Report 49 [44] also includes the proposed BEM to be implemented in a future regulatory framework. This has been studied in ECC Report 203 [47] on "*Least Restrictive Technical Conditions (BEM) suitable for Mobile/Fixed Communications Networks (MFCN), including IMT, in the frequency bands 3400-3600 MHz and 3600-3800 MHz*".

A.2.4 FREQUENCY BAND 3600-3800 MHz

The compatibility issues are similar to those in the band 3400-3600 MHz (see section 4 above). Moreover, FSS deployment is denser in this band. Therefore, the band 3600-3800 MHz is generally considered as less suitable for Broadband DA2GC than the band 3400-3600 MHz.

A.2.5 FREQUENCY BANDS 1980-2010 MHz / 2170-2200 MHz

These bands are designated within CEPT for use by systems in the MSS (including those supplemented by a CGC) by ECC/DEC/(06)09 [45]. A corresponding Decision was developed and set into force by the European Commission (2007/98/EC) [46].

In the point of time when the list of candidate bands, as provided in this Annex, were under discussion it was questioned whether the frequency bands 1980-2010 MHz / 2170-2200 MHz could also be added to the list of candidate bands to be studied for Broadband DA2GC.

After some considerations, also with the MSS licensees, it was decided that the bands 1980-2010 MHz / 2170-2200 MHz should not be included in the list of candidate bands to be studied for Broadband DA2GC, but that this issue may further be discussed in the future.

ANNEX 3: DESCRIBING THE TRIALS AND PROVIDING INFORMATION FROM AIRLINES

Broadband DA2GC Trials

A.3.1 FIELD TRIALS WITH THE BROADBAND DA2GC SYSTEM BASED ON ETSI TR 103 054

A.3.1.1 First test flight in November 2011

Deutsche Telekom, Alcatel-Lucent and Airbus have successfully tested direct data communication - using LTE technology, a commercial 4G cellular mobile radio solution - between an aircraft and a radio network on the ground. When commercial, this solution will be able to provide in-flight mobile voice and broadband data communications services cost-effectively.

This world-wide first test flight took place in November 2011 over the German state of Saxony-Anhalt as part of a joint R&D project between Airbus, Alcatel-Lucent and Deutsche Telekom. Airbus provided an A320 test aircraft equipped with test equipment and Alcatel-Lucent was responsible for the overall technical solution. This included a DA2GC "onboard unit" (OBU) installed in the test aircraft to send and receive mobile data signals, for which Alcatel-Lucent developed special algorithms. On the ground, Alcatel-Lucent provided its end-to-end LTE solution including radio access network (RAN) and core network (ePC, evolved Packet Core). Deutsche Telekom prepared a ground network of two base stations positioned about 100 kilometres apart. The base stations, each equipped with 3 sector antennas, were connected to Alcatel-Lucent's LTE test centre in Stuttgart via Deutsche Telekom's broadband data transport network.

Trial set-up details

Two sites with an inter-site distance of about 100 km were equipped with LTE-based DA2GC GSs consisting of baseband unit (BBU) and remote radio head (RRH) and with antennas with three sectors (up-tilt), connected with an LTE evolved packet core (EPC) and measurement & data trace servers via a broadband data transport network.

An Airbus A320 aircraft was equipped with a DA2GC OBU with max. Tx power of 37 dBm and with two DA2GC antennas below the aircraft fuselage (2 Rx / 1 Tx).

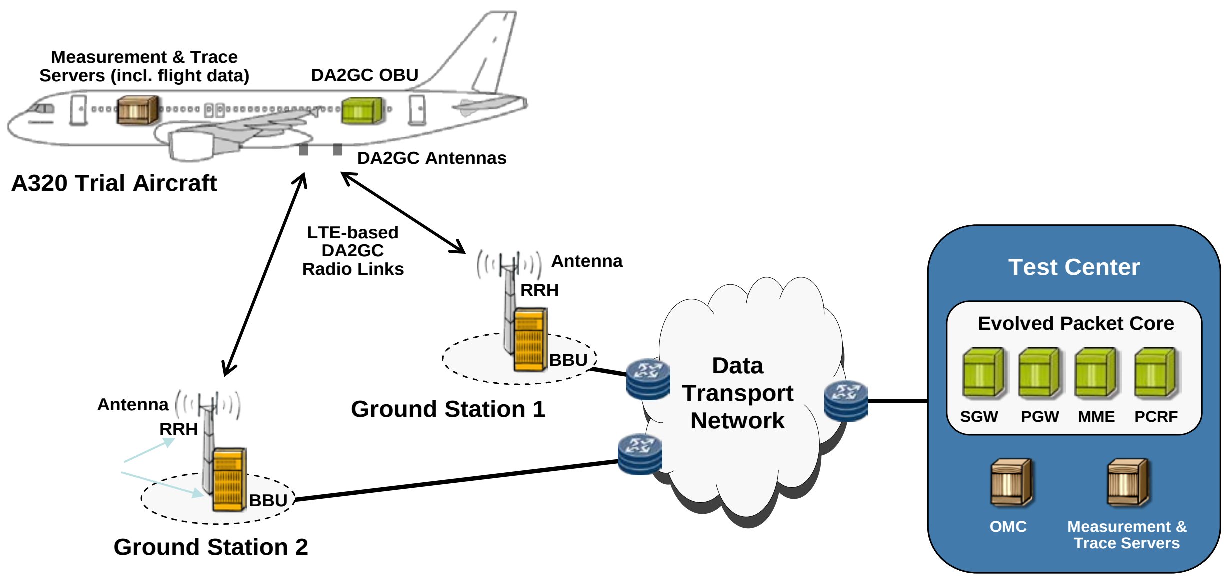


Figure 18: Trial flight set-up for the Broadband DA2GC system as described in ETSI TR 103 054

During the 3 hours lasting trial flight the aircraft flew with speeds between 500 and more than 800 km/h at different altitudes between 4000 m and 10000 m. The flight manoeuvres included phases with inter- and intra-site (sector) handovers as well as phases with large distances to the sites.

Trial results

The radio link between GS and AS was established at distances of more than 100 km from the sites to the aircraft flying at speeds of more than 800 km/h and altitudes up to 10000 m.

Peak data rates of up to 30 Mbit/s in the forward link (ground-to-air) and 17 Mbit/s in the reverse link (air-to-ground) were achieved.

In addition to high background data traffic a video conference was established between the teams in the aircraft and the test centre which allowed to follow the flight phases in real time and to demonstrate the low latency of the overall DA2GC system (round trip time < 50 milliseconds) compared to satellite-based systems.

It should be noted that the GS equipment used (except of antenna adjustment) was basically state of the art LTE-equipment for 2.6 GHz terrestrial cellular mobile deployment. Only the OBU was modified to allow the overall system to work in the aeronautical environment with large cell ranges and high aircraft speeds. The trial showed the very high performance and flexibility of the LTE-based technology even in this early release state. The Broadband DA2GC equipment will be further optimized in the next development stages.

A.3.1.2 Workshop and flights in October 2012

For the first time, DA2G was presented to representatives from eight major European airlines and National Regulatory Authorities. Some of the representatives witnessed the demo on the ground, whereas others took the chance to experience the demo in the air themselves. A Dornier 328 jet was fitted with two hand-sized antennas and equipped with a DA2GC OBU which was continuously monitored by technical experts.

Figure 19: Aircraft OBU (prototype) and aircraft antenna (hand sized)

Participants

Representatives of eight European Airlines
Two representatives of National Regulatory Authorities (NRA)

Agenda of workshop

Presentation and discussion of the DA2G system concept
Four trial flights and one demo flight with Dornier 328 jet equipped with DA2GC OBU
Seven representatives of airlines and one NRA representative participated in the demo flight on October 26th, 2012

DA2GC test region

Deutsche Telekom test sites with 3 antenna sectors each (100 km inter-site distance)
Sites connected to Alcatel-Lucent core network (ePC) in Stuttgart
2 x 10 MHz of currently unused terrestrial 2.6 GHz segment as temporary trial frequency

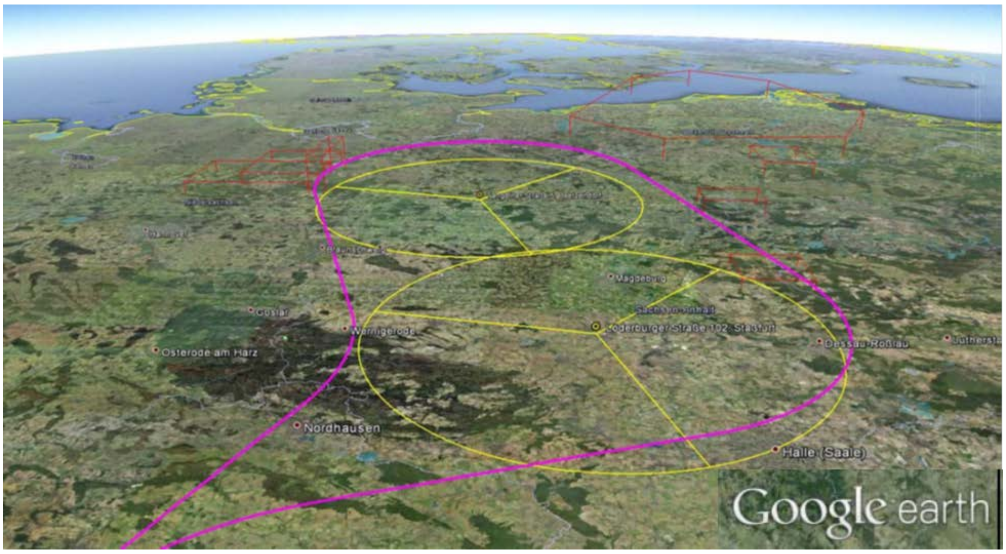


Figure 20: DA2GC test region with two ground station sites (sectorisation in yellow colour, flight track at altitude of about 7.5 km in magenta colour)

Applications tested during the flights

Surfing, downloading, e-mail transmission, use of Skype video and audio applications by Smartphones, Laptops and Tablet-PCs
Video conference maintained during the entire time the plane was in the range of the two DA2G base stations
Internet live TV
Small remotely controlled vehicle (buggy) equipped with a 3D-camera was operated. 3D live video transmitted to the plane via DA2GC and remote control signal from the plane re-transmitted via DA2GC to the buggy.

Facts about the demo flight event in October 2012

LTE-based DA2GC radio link:
Data rate reached peak levels of 26 MBit/s (downlink) and 17 MBit/s (uplink)
Latencies in average 50 – 60 ms (round trip time)
30 successful handovers between antenna cell sectors during flight
Maximum connectivity distance between aircraft and ground antenna @ 110 km (limitation by applied LTE parameter set)
Applications:
Three LTE bearers with different QoS established:
Video conference (3 Mbit/s downlink to aircraft, 2 Mbit/s uplink from aircraft)
Remote buggy control incl. 3D video signal (4 Mbit/s downlink, 1 Mbit/s uplink)
Internet access (best effort)
Successful internet access:
Use of passenger‘s own devices like laptops, smartphones
Access to internet applications like you tube and live TV football game
Login into corporate VPNs
Skype sessions between passengers and also to partners at ground location

Quotations from the flight participants which were impressed by the performance of DA2GC

“I turned the steering wheel in the aircraft and the buggy turned to that direction immediately. I did not perceive any delay!”
“Very easy logon to internet for Laptop as well as smartphone”
“HD video conference … great!”
„As a matter of fact: We had a very good experience!“
“If you can have DA2GC, that’s the way to go!“
“Real broadband, real time connection and working very well.”

“In terms of performance, I would say L-band has its place, Ku works, but DA2GC seems the way to go.”
“It was so easy to connect our corporate VPN!”
„I sent mails, I surfed, I downloaded a video, I sent a picture. So everything was very easy and fast.“
“Great to have a chat with my wife via Skype”

A.3.2 FIELD TRIALS WITH THE BROADBAND DA2GC SYSTEM BASED ON ETSI TR 101 599

The system based on ETSI TR 101 599 [2] has undergone a number of flight tests, initially in the United States and subsequently in Germany (in the 5.8GHz band). A description of the most recent trial flight, which took place in April 2013 in the Frankfurt area, is given below. For the purposes of this flight trial, the airborne equipment was temporarily installed inside a Lufthansa Flight Training jet aircraft. The aircraft used is shown in Figure 21. The power levels of the link were monitored by the German regulatory authority, the Federal Network Agenca (Bundesnetzagentur), who had issued a trial license to Lufthansa Systems AG.

Figure 21: Aircraft used during DA2GC Flight Trial

Key parameters for DA2GC equipment used in the flight trial

- Centre Frequency: 5865 MHz
- Channel Bandwidth: 20 MHz
- Operating Mode: TDD
- Modulation: OFDM
- Polarisation: Linear
- Maximum EIRP (Ground Station and Aircraft Station): +45dBm with ATPC
- Ground station antenna: Single 4-element phased array assembly with beamforming
- Maximum antenna gain (Ground Station): +20dBi, including beamforming gain
- Ground station beam: Single beam, steerable over ±45 deg in azimuth
- Operational elevation range (Ground Station): +5 to +90 deg
- Aircraft station antenna: 4 elements (2 x double patch) forming phased array with beamforming
- Maximum antenna gain (Aircraft Station): +10dBi, including beamforming gain
- Aircraft station beam: Single beam, steerable in azimuth and elevation

Physical antenna installations

Ground Station –

As noted above, the flight trial was conducted using a single 4-element (1st generation) antenna array at the Ground Station. This unit was mounted on the roof top of the Lufthansa Information Centre, in the vicinity of Frankfurt airport.

The Ground Station installation can be seen in Figure 22 below (where the DA2GC antenna array is the small rectangular shaped unit towards the centre of the picture).

Figure 22: DA2GC Ground Station mounted on roof top

Aircraft Station –

The aircraft station antenna assembly comprised two separate double patch antennas, which were mounted against the windows inside the aircraft cabin, as shown in Figure 23 below.

Figure 23: DA2GC Aircraft Station antenna mounting arrangement

Flight path details

The aircraft flew along a number of headings during the duration of the trial at standard flight levels used by commercial airliners and at varying distances from the Ground Station site near Frankfurt, as shown in Figure 24 below.

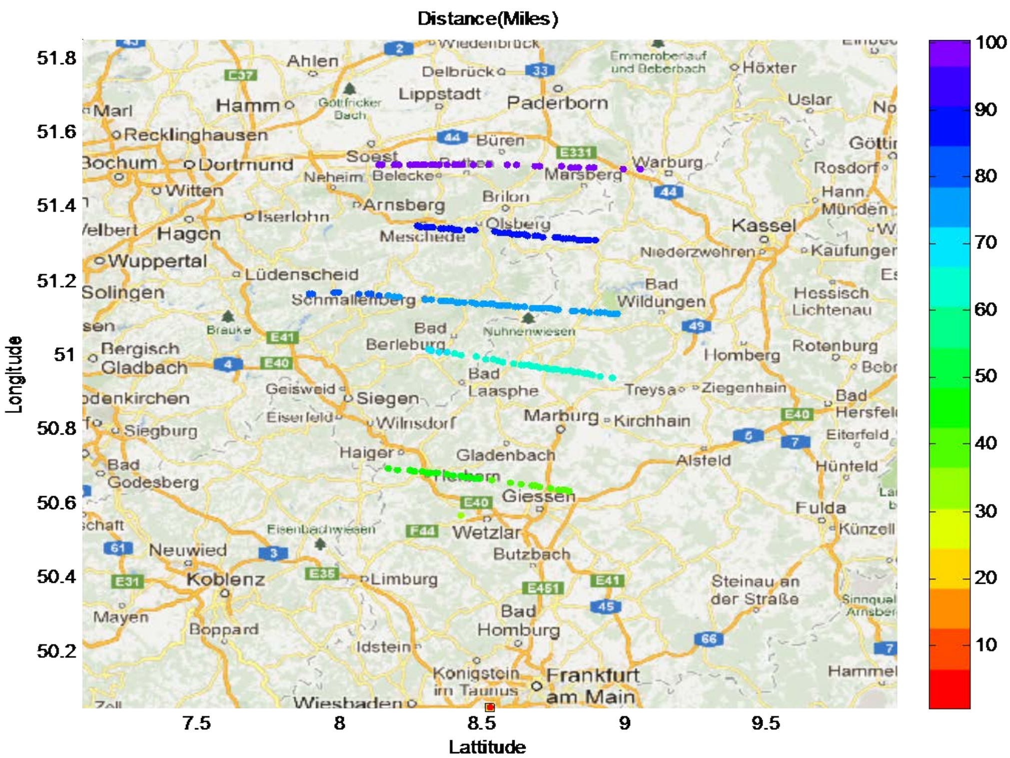


Figure 24: Trial flight paths

The air-to-ground link was established and the beamforming antennas enabled this to be maintained across a variety of ground paths with a distance range from 60km up to distances in excess of 100 km.

Despite the fact that relatively low gain antennas were used (compared to the 2nd generation equipment described in Section 5.2 of this Report and intended for eventual deployment) the beamforming enabled a usable data link to be maintained up to more than 100 km in range.

The achieved link performance was seriously compromised due to the use of simple patch antennas on board the aircraft, which had to be mounted internally in a less than optimum orientation, giving rise to additional losses and significant attenuation through the aircraft windows. Nevertheless, data rates of several Mb/sec were observed.

A.3.3 FIELD TRIALS WITH THE BROADBAND DA2GC SYSTEM BASED ON ETSI TR 103 108

A series of test flights at different frequencies were undertaken using UMTS TDD technology and two turbojet aircraft types.

Figure 25: Falcon Flight Test Aircraft

The aircraft antenna requirements were stringent. It was essential that no additional fixing/access holes were needed in the airframe. To achieve this objective it was, through a process of elimination, decided to modify the Marker Antenna. Two C-band antenna elements were fitted to the Marker Antenna such that the antenna:

- retained its marker functionality;
- had an identical form/fit factor.

The photograph below shows the certified antenna fitted to a commercial Boeing B737 aircraft.

Figure 26: Modified Marker Antenna

Ground Station

One set of flight trials used a commercial UMTS TDD base station configuration modified to operate in the 5 GHz band. The main equipment, which is capable of supporting both 5 MHz and 10 MHz channels, is shown below.

Figure 27: Ground Station Equipment

Aircraft Station

The 4 MCU avionics radio/server unit is shown below.

Figure 28: Avionics Equipment

A flight deck control unit was also included. It has a standard mechanical design that makes it compatible with most commercial aircraft. The unit supports the following functionality:

- System On/Off switch;
- Network On/Off switch (DA2GC link);
- Gate On/Off switch (Access Point);
- Indicator LEDs;
- Self-test function;
- USB port.

It is shown below with a memory device inserted in the USB port.

Figure 29: Flight Deck Control Unit

VHF trials were undertaken using aeronautical frequencies and UMTS FDD technology. They were conducted in the Azores to avoid interference to those frequencies used elsewhere in Europe.

2 GHz and 5 GHz trials used test frequencies and UMTS TDD technology. They were conducted in the UK. The 5 GHz trial included live video transmissions from the flight deck and cabin. Simultaneously an international voice call was made by one passenger while another browsed the internet and watched a streaming video from a ground server. Ranges in excess of 250 km were achieved which is operationally important to maintain coverage over, for example, the Mediterranean Sea.

These flights demonstrated a robust air to ground link in different spectrum bands, namely VHF (aeronautical communications), 2 GHz and 5 GHz.

A.3.4 INFORMATION FROM AIRLINES

European Airlines are following the CEPT activities on Broadband DA2GC. So far Lufthansa / Swiss / Austrian airlines, KLM / Air France, Air Berlin and British Airways have sent letters to CEPT showing their interest in a solution for Broadband DA2GC in Europe.

ANNEX 4: VARIOUS DA2GC SYSTEMS IN THE WORLD

Canada

Since the 1990s, the bands 849-851 MHz and 894-896 MHz have been used to provide Air-Ground Public Telephone Services such as two-way voice, fax and data on board aircraft. In 2008, Industry Canada published revised conditions to use this part of the spectrum to facilitate the provision of new enhanced Air-Ground Services such as broadband Internet access. The current band plan is based on two block pairs 849-851 MHz (uplink) and 894-896 MHz (downlink). The maximum e.r.p. limits for Ground Station is 500 W and 12 W for Airborne Station.

Each ground station is expected to cover 480 km for an aircraft at a height above ground around 13700 meters.

Two national individual licences are possible:

- one for 3 MHz (849-850.5 MHz / 894-895.5 MHz);
- one for 1 MHz (850.5-851 MHz / 895.5-896.5 MHz).

Spectrum licences auctioned by Industry Canada have 10-year licence terms.

United States of America

The service operates in the 849-851 MHz and 894-896 MHz frequencies, similar to that in Canada.
Commercial aviation air-ground systems may use any type of emission or technology that complies with the technical rules in Part 22, subpart G. In addition, FCC considers also introducing DA2G Communications in 14.0-14.5 GHz on a secondary status sharing with the FSS uplink. Air-ground mobile service would use between 150 and 250 ground stations to transmit to aircraft and receive from aircraft within the 14.0-14.5 GHz band. The ground stations would use four beams each, with an equivalent isotropically radiated power of about 39.5 dBW in 50 MHz, and would transmit in a predominantly northern direction to protect primary geostationary Fixed-Satellite Service (FSS) satellites.

Both in USA and in Canada, the technical rules for certification and systems deployment in the band are technology neutral.

In April 2014, AT&T announced plans to build an innovative broadband air-to-ground network in the continental United States, based on global 4G LTE standards using 2 x 5 MHz in the 2.3 GHz frequency range, to provide fast speeds and efficient utilisation of spectrum already owned by AT&T. The service is planned to be available as soon as late 2015.

China

The system in China is based on the SCDMA broadband wireless access standard in Recommendation ITU-R M.1801. The SCDMA wireless broadband access system contains base stations and terminals. A prototype system has been successfully tested in trial flights at the frequency range of 1.785-1.805 GHz.

The SCDMA radio interface supports a channel bandwidth of a multiple of 1 MHz up to 5 MHz. The system is based on TDD access scheme to separate the uplink and downlink.

Sub-channelisation and code spread, specially defined inside each 1 MHz bandwidth, provides frequency diversity and interference observation capability for radio resource assignment with bandwidth granularity of 8 kbit/s. The channelisation also allows coordinated dynamic channel allocations among cells to efficiently avoid mutual interference.

ASIA-PACIFIC TELECOMMUNITY

The APT has also started investigations into the DA2GCS subject and in August 2013, the APT Wireless Group adopted a questionnaire on the application of direct broadband radio communication systems between the air and the ground.

The motivations for APT to investigate the issue are indicated in the introduction of the questionnaire: the direct air-to-ground broadband radio communication system for the air passengers is developing because of low cost of capacity and short round-trip delays. This system requires constructing a network of base stations covering each flight route, while can better ensure communications bandwidth and lower communication costs. The application of this system is not only for high-speed internet service to the air passengers, but also for transmitting videos and pictures obtained by airplanes to grasp the damage in the case of disaster.

ANNEX 5: GENERAL REGULATORY ASPECTS

A.5.1 INTERNATIONAL TELECOMMUNICATION UNION (ITU)

The ITU instruments, at least those that are relevant to spectrum management, are the Constitution (CS), the Convention (CV) and, most important, the Radio Regulations (RR). These instruments are only binding the States and are therefore not directly applicable to individuals, operators or others, concerned by spectrum utilisation. Compliance with those instruments therefore presupposes that each State will take the measures required (legislation, regulations, clauses in licences and authorisations) to extend those obligations to other spectrum users (operators, administrations, individuals, etc.).

The principle underpinning most of the provisions of ITU Radio Regulations is set out in No. 4.3, which stipulates that any new assignment (i.e. any new authorisation to operate a radio station) must be made in such a way as to avoid causing harmful interference to services rendered by stations using frequencies assigned in accordance with the Table of Frequency Allocations and the other provisions of the Radio Regulations, the characteristics of which are recorded in the Master International Frequency Register (MIFR). In particular, a new assignment can only be recorded in the MIFR after completion of a procedure (for instance, Articles 9 and 11) aimed at ensuring that it will not cause harmful interference to assignments made in accordance with the RR and previously recorded systems.

Article 5 of the RR, Section IV (Table of Frequency Allocations) allocates frequency bands for the purpose of their use by one or more terrestrial or space radiocommunication services or the radio astronomy service under specified conditions. A radiocommunication service is defined as the transmission, emission and/or reception of radio waves for specific telecommunication purposes. Terrestrial services and space services can themselves be subdivided in several different types of services (fixed, mobile, broadcasting…). The list of the different services with corresponding definitions is given in Article 1 of the RR. Frequency bands are allocated to radiocommunication services on a primary or secondary basis. Stations of a secondary service shall not cause harmful interference to stations of primary services and cannot claim protection against harmful interference from stations of a primary service.

The RR as such provides an international framework for effective spectrum management that is primarily structured by the need for global harmonisation in various domains (satellite communication, maritime, civil aviation, scientific research…), coexistence capability between different types of radio communication networks and physical properties of frequency bands. It has major implications for the industry in terms of economies of scale and therefore for the design of radio products. As an international treaty, the RR is periodically revised by World Radiocommunication Conferences (WRCs) which are typically held every three or four years and allows addressing new development in the field of radiocommunications and technological change as appropriate.

In sum, the Radio Regulations applies to the relations between ITU Member states. It allows assignment to a station of any frequency providing that such a station does not cause harmful interference to, and does not claim protection from harmful interference caused by, a station operating in accordance with these regulations. As such, no provision of the Radio Regulations can affect the rights of the European Union to implement the desired harmonised technical conditions and to make available the spectrum for stations of any type, except for cases where there is a potential for interference with a country outside the EU (e.g. cross-border rights).

A.5.2 EU FRAMEWORK FOR THE DELIVERY OF ELECTRONIC COMMUNICATIONS NETWORKS AND SERVICES (ECN&S)

Within the EU there is a harmonised regulatory framework for rights of use in the context of Electronic Communications Networks and Services (ECN&S). The relevant texts are the “Framework” Directive [27] and the “Authorisation” Directive [28]. The following sections present the EU legal framework for radio frequencies authorisations as applicable to ECN&S.

The two directives mentioned above allow two kinds of authorisation status in relation to right of use of frequencies for ECN&S: general authorisations or individual rights of use (article 5 §1 of “Authorisation” Directive and article 9 §1 of the “Framework” Directive). The following gives a summary of to the two concepts as described in the “Authorisation” Directive.

Direct-Air-to-Ground Communication Systems clearly fall into this framework for the delivery of electronic Communications Networks and Services.

<u>General authorisations</u>

The “Authorisation” Directive sets the legal provisions for general authorisations. General authorisations allow any undertaking to provide electronic communications networks or services, whether by means of radio frequency spectrum or by wired means. Undertakings may be required to submit a notification but cannot be required to obtain an explicit decision before exercising the rights stemming from the general authorisation. For notification, member states shall not request more information than a declaration by a legal or natural person of the intention to commence the provision of ECN&S and minimal information needed to keep a list of providers of ECN&S (identification of provider, address, short description of the network or services, starting date for activity).

In the case of radio spectrum use, general authorisations are in practice limited to radio services that do not need to be coordinated to avoid harmful interference. General authorisation as opposed to individual rights of use cannot be transferred as, by definition, the spectrum can be accessed without the need to obtain an individual authorisation and therefore there is no exclusive right to be traded.

For “general authorisations”, only the compatibility studies conducted by CEPT will allow to determine a set of regulatory parameters to ensure protection of radio services. The harmonised implementation by national administrations is here critical to support effective enforcement policy. Key principles were provided in CEPT Reports 14 and 44 to support a strategy to improve the effectiveness and flexibility of spectrum availability for Short Range Devices (SRDs). It is questionable whether the availability of compatibility studies for DA2GC systems alone gives sufficient protection (e.g. so far there were no intra-DA2GC system compatibility studies performed or there is also the need to ensure compatibility between systems now and in the future) and there is no effective enforcement policy defined for this case. In general, it is questionable whether the SRD concept could apply in this case, which also is based on technology and application neutrality use of spectrum.

Especially the points that a general authorisation allows any undertaking to provide services, the non-existence of coordination to avoid harmful interference (e.g. what if there is more than one DA2GC system), the lack of exclusive rights (equivalent to additional risk/financing costs) and lack of possibility to transfer rights (which can be seen as an asset without any value of a potential DA2GC system operator) make the general authorisation option a questionable option for Direct-Air-to-Ground Communication Systems.

DA2GC system operators are expected to rely on the delivery of services with some QoS, in particular when it comes to coverage can only be provided through licenced spectrum where they have full control over the interference they face, and therefore have full understanding of the performance that will be delivered by their network equipment. Operators also need to have full visibility over their future access to spectrum in order to be in a position to develop investment plans. A concept of first come first served is not compatible with the delivery of services based on coverage characteristics. Overall, the exclusivity among DA2G licence at a given place, at a given time, for a predictable future, is a critical aspect of the DA2G concept in order to trigger infrastructure investment and deliver services with coverage QoS.

Individual rights of use

Taking into account the scarcity of radio frequencies in some frequency bands as well as the need to ensure efficient use of these frequencies individual rights of use /individual authorisations may be granted as opposed to general authorisations. Individual rights of use are often, depending on the context, called “licences” and both expressions can be used. For ECN&S, individual rights of use may be granted for four reasons, in order to:

- Avoid harmful interference;
- Ensure technical quality of service;
- Safeguard efficient use of spectrum;
- Fulfil other objectives of general interest as defined by Member States in conformity with Community law.

The “Authorisation” Directive defines a set of conditions that may be attached to individual rights of use (Annex B of the Directive).

Individual rights of use, which in many administrations take the form of licences granted to users, may be transferred as prescribed by Article 9b of the “Framework” Directive. The European Commission may adopt appropriate implementing measures to identify ECN&S bands for which individual rights to use radio frequencies may be transferred or leased (except for frequencies used for broadcasting). In other bands the choice is left to Member States to make provisions for undertakings to transfer or lease individual rights of use. When granting rights of use the Member States shall specify whether those rights can be transferred by the holder of the licence and under which conditions (in accordance with Article 9b).

An example in the context was in the timeframe 2007 to 2009 the conditions for implementing Mobile Satellite Service (MSS) networks in the 2 GHz range in Europe, which were set by a Commission Decisions. The DA2GC case has similarities to the MSS case as both applications are targeting at a pan-European market. Thus regulation principles for DA2GC might be derived from the MSS approach, but taking into account the experience made with regard to MSS. Contrary to MSS were the amount of spectrum (2 x 30 MHz) available allowed to accommodate two players, the situation regarding DA2GC is expected to be slightly different. Due to the fact that only 2 x 10 MHz of spectrum are expected to be designated to DA2GC, only one single network will be able to be deployed. However, DA2GC is going to compete with already existing satellite solution for connecting aircraft, which is exclusive today. Thus, the implementation of DA2GC creates competition in offering broadband communications services to air passengers.

The following steps towards authorisation DA2GC operation in Europe are recommended:

- Development of an ECC Decision designating a frequency band for DA2GC;
- Development of a Commission Decision on;
- the implementation of the ECC Decision within EU28;
- the authorisation/licensing conditions for DA2GC including an operator selection process;
- Execution of an operator selection process by the European Commission (e.g. by beauty contest);
- Authorisation/licensing of the successful DA2GC operator by NRAs (National Regulatory Authorities) according to conditions as described in the Commission Decision.

A.5.3 NATIONAL LEGISLATION

Article 18 of the Radio Regulations stipulates that “no transmitting station may be established or operated by a private person or by any enterprise without a licence issued in an appropriate form and in conformity with the provisions of these Regulations by or on behalf of the government of the country to which the station in question is subject”. The above term “licence” can be understood in its broad acceptance. This basically means that the use of spectrum must be explicitly permitted.

Understanding how the spectrum is effectively authorised requires actually clarifying the domain of use.

As underlined in ECC Report 132 [21], various terminologies are commonly used to qualify the type of authorisation that is delivered by NRAs: unlicensed, licence-exempt, licence free, general licence, general authorisation, light licensing, licensed, individual licence, individual authorisation…

In the following, the term "authorisation" shall be understood as the public legal act issued by NRAs for the purpose of delivering spectrum usage rights to private entities or citizens (i.e. "non-governmental" use of the spectrum), without prejudice to the form that such acts may take in different countries.

The following two terminologies should also be distinguished, consistently with ECC Report 132 [21]:

- Individual authorisation (Individual rights of use);
- General authorisation (No individual rights of use).

Individual rights of use are given for limited duration and do not constitute property act of the frequencies by the operator as they are part of the national domain.

Figure 30: National legislation from the radio spectrum to users summarises this overview of the baseline structure of national legislation on the use of spectrum in European countries:

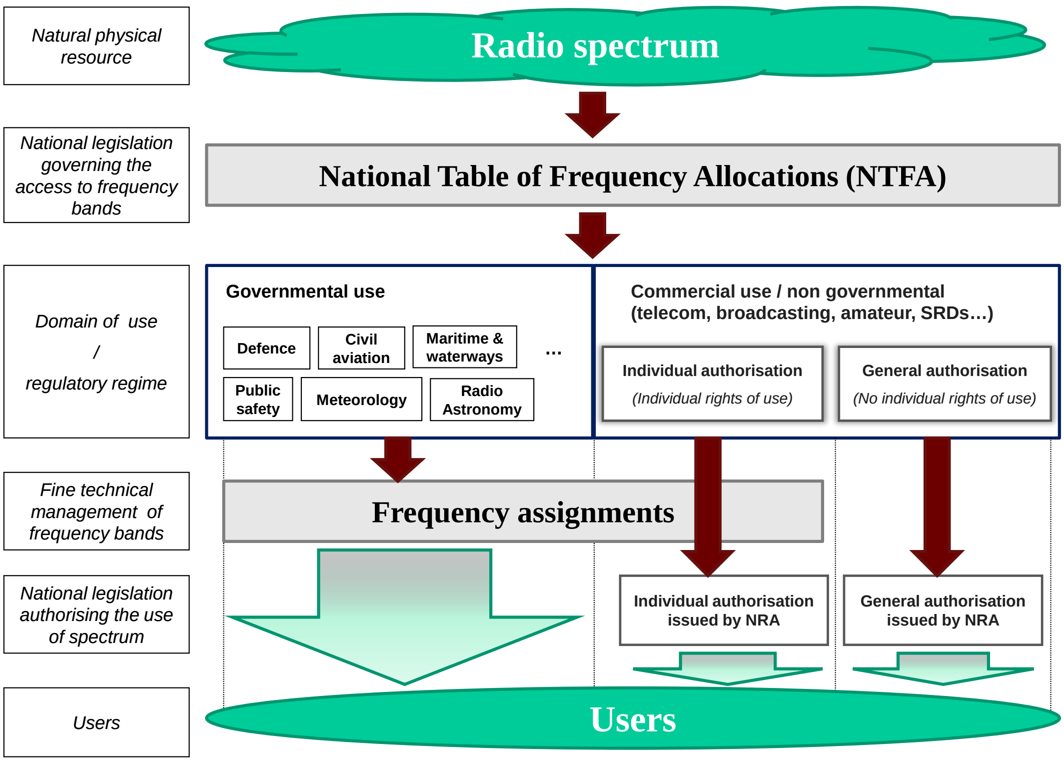


Figure 30: National legislation from the radio spectrum to users

The prime discrimination factor is whether the spectrum is used by governmental bodies, on the one hand, or for commercial purpose or by citizens (amateur, CB, SRDs…), on the other hand. DA2GC systems are clearly on the commercial purpose side and hence will ultimately require a licence award on national level.

National Tables of Frequency Allocations (NTFAs) and frequency assignments

National Tables of Frequency Allocations (NTFAs) primarily specify the radio services authorised by an individual administration in frequency bands and the entities which have access to them.

National frequency assignments, as derived from the ITU concept, allows the fine management of frequency bands in accordance with the rules set in NTFAs, particularly in bands shared by different type of users and also in respect of coexistence issues in adjacent bands. They may contain sensible data and their management require confidentiality procedures.

When registered at the BR IFIC, this information becomes publicly available; the purpose being primarily the granting of international rights for protection. Frequency assignments should be well distinguished from national authorisations delivered by NRAs.

A European DA2GC system should be included in the European Common Allocation Table by inclusion of ECC harmonisation measure (ECC Decision), the NTFAs of the individual administrations and also being registered at the BR IFIC.

ANNEX 6: REGULATORY PARAMETERS FOR BROADBAND DA2GC (GS AND AS), 2 GHz, FDD

Example:

System according to ETSI TR 103 054, frequency range: 1900-1910 MHz (FL) and 2010-2020 MHz (RL)

FL: 1900-1910 MHz, DA2GC carrier at 1905 MHz,

RL: 2010-2020 MHz, DA2GC carrier at 2015 MHz.

A.6.1 MAIN PARAMETERS FOR GROUND STATIONS

Table 13: Main parameters for ground stations

Parameter	DA2GC Ground Station (FDD)
Tx power	46 dBm
Antenna type	3 x 120° sector antennas (90° half power beam width)
Antenna gain (max.)	20 dBi
Antenna tilt	10° (up-tilt)
Channel bandwidth	10 MHz
Signal bandwidth (related to number of occupied resource blocks with bandwidth of 180 kHz)	9 MHz
Tx spectrum emission mask (SEM) / Spurious emissions	According to section A.6.1.1

A.6.1.1 Unwanted emission limits for Ground Stations

The spectrum emission limits for DA2GC Ground Stations are the same as for terrestrial LTE Base Stations. The corresponding values as defined in 3GPP TS 36.104 [49] are shown below:

Table 14: Unwanted emission Ground Stations

Frequency offset of measurement filter -3dB point, Δf	Frequency offset of measurement filter centre frequency, f_offset	Minimum requirement	Measurement bandwidth
0 MHz ≤ Δf < 5 MHz	0.05 MHz ≤ f_offset < 5.05 MHz	$-7dBm-\frac{7}{5}\cdot\left(\frac{f\_offset}{MHz}-0.05\right)dB$	100 kHz
5 MHz ≤ Δf < 10 MHz	5.05 MHz ≤ f_offset < 10.05 MHz	-14 dBm	100 kHz
10 MHz ≤ Δf < 25 MHz	10.5 MHz ≤ f_offset < 24.5 MHz	-15 dBm	1 MHz
25 MHz ≤ Δf	25.5 MHz ≤ f_offset	-30 dBm (Note 1)	1 MHz
Note 1: Spurious emissions valid for frequency offset larger than 250% of necessary bandwidth according to ERC/REC 74-01 [51].			

A.6.2 MAIN PARAMETERS FOR AIRCRAFT STATIONS

Table 15: DA2GC Aircraft Station (FDD) main parameters

Parameter	DA2GC Aircraft Station (FDD)
Tx power (max.)	40 dBm
Antenna gain (max.)	7 dBi
Minimum operational height above ground	3 000 m
Channel bandwidth	10 MHz
Signal bandwidth (related to number of occupied resource blocks with bandwidth of 180 kHz)	9 MHz
Tx spectrum emission mask (SEM) / Spurious emissions	According to section A.6.2.1

A.6.2.1 Unwanted emission limits for Aircraft Stations for channel bandwidth of 10 MHz

For the aircraft station the “General LTE UE spectrum emission limits” as defined in 3GPP TS 36.101 [50] apply. The corresponding values are shown below:

Table 16: Unwanted emission limits for Aircraft Stations

Spectrum emission limits (dBm)		
Δf_{OOB} (MHz)	Δf_{OOB} (MHz)	Δf_{OOB} (MHz)
± 0-1	-18	30 kHz
± 1-2.5	-10	1 MHz
± 2.5-2.8	-10	1 MHz
± 2.8-5	-10	1 MHz
± 5-6	-13	1 MHz
± 6-10	-13	1 MHz
± 10-15	-25	1 MHz
± 15-20		1 MHz
± 20-25		1 MHz

A.6.3 FURTHER REQUIREMENTS

Table 17: Ground Station (GS) further requirements

Ground Station
Coordination with MFCN base stations (with carrier frequency at 1922.5 MHz) required, if no additional mitigation measures are applied.
Coordination with SRS earth stations (E-s) required for protecting the DA2GC GS reception.
Coordination with FS and TRR stations required (separation distances up to about 20 km) for protecting the DA2GC GS reception.

ANNEX 7: REGULATORY PARAMETERS FOR BROADBAND DA2GC (GS AND AS), 5.8 GHz, TDD

Example: System according to ETSI TR 101 599, frequency band: 5855-5875 MHz

A.7.1 E.I.R.P. AND PFD MASKS

A.7.1.1 E.i.r.p. mask for Ground Station (GS):

The limits on e.i.r.p. levels for the Ground Station are shown in Figure 31 below:

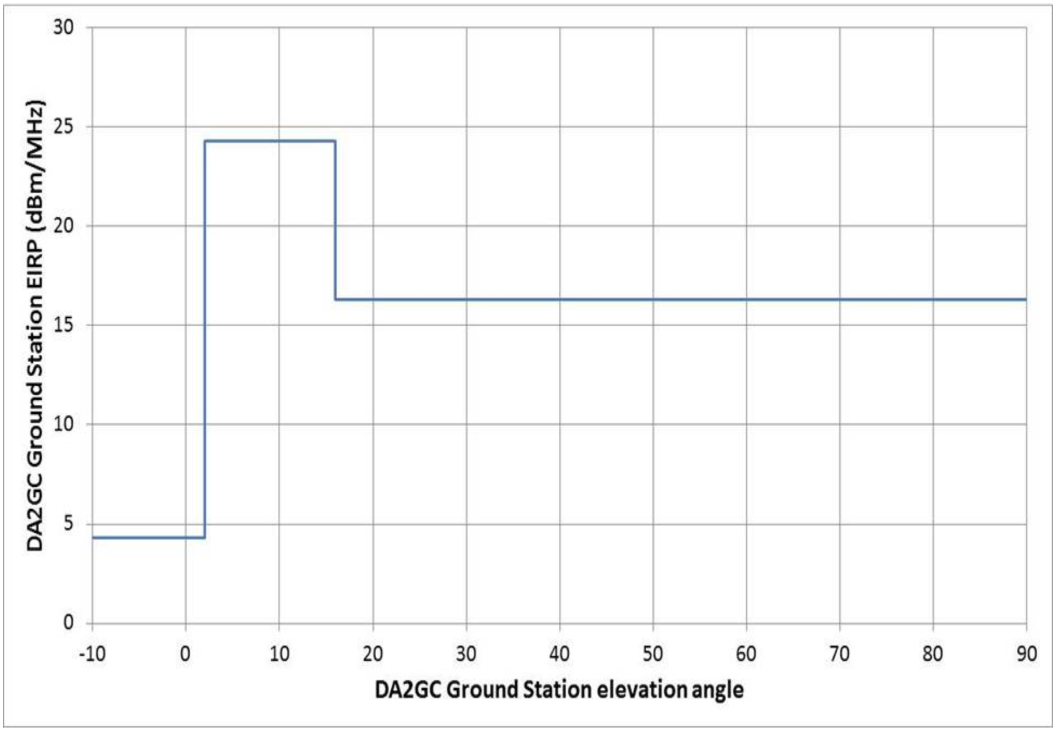


Figure 31: e.i.r.p. mask for the Ground Station according to ETSI TR 101 599

The exact values for the three elevation angle ranges shown in Figure 31 are defined in Table 18 below:

Table 18: Ground Station e.i.r.p. mask definition

Elevation Angle	Average e.i.r.p. level (dBm/MHz)
< 2°	4.3
2° to 16°	24.3
>16°	16.3

This average e.i.r.p. mask represents the sum of the powers generated by all beams of the DA2GC Ground Station in any given azimuth direction.

Any measurement of the average power for enforcement purposes will need to be performed over a significantly long duration to ensure that a true average is obtained.

Peak e.i.r.p. levels can exceed the average values in Table 18 for small percentages of time.

A.7.1.2 Peak e.i.r.p. mask for Aircraft Station (AS):

Table 19: Possible simplified aircraft station e.i.r.p. mask

Elevation at ground (degrees)	Aircraft e.i.r.p. (dBm/MHz)	Note
0 to 5 degrees	29.5-C	
5 to 27 degrees	29.5-C to 27.0-C	Straight line interpolation
27 to 28 degrees	27.0-C to 19.5-C	Straight line interpolation
28 to 90 degrees	19.5-C to 13.0-C	Straight line interpolation C = 20*log(10 000/h with h (>=3 000 m) = height above ground of the aircraft in metres

Figure 32 shows the mask for an AS in 10 km height above ground for example

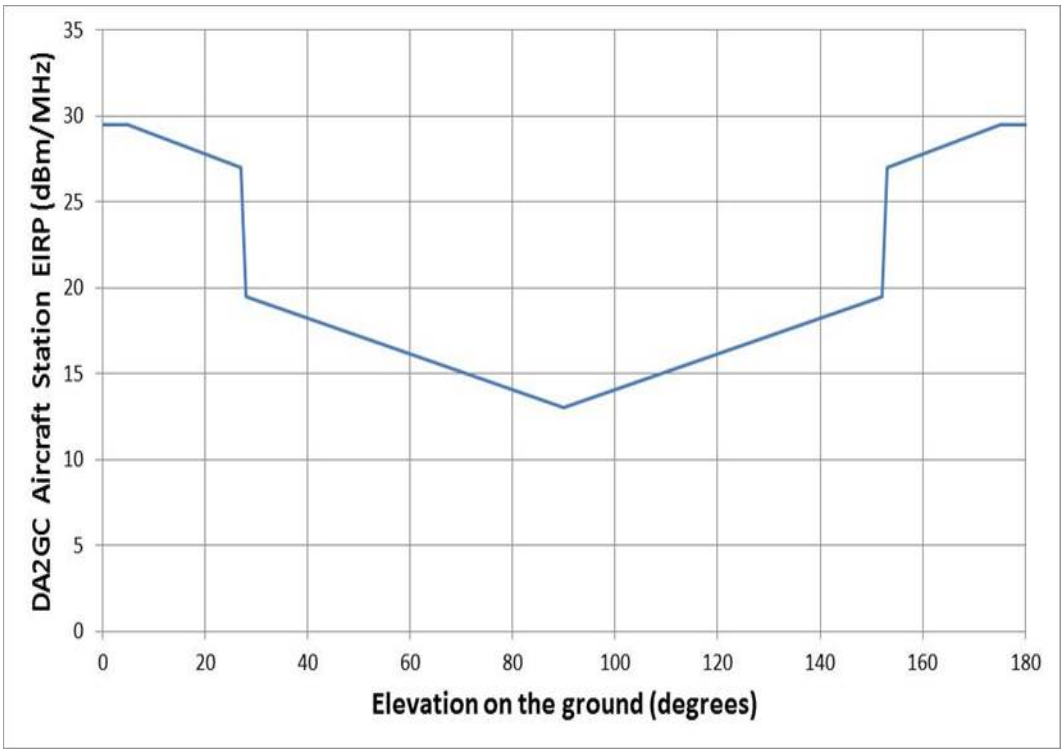


Figure 32: AS e.i.r.p. mask for an aircraft height above ground of 10 km (example)

A.7.2 FURTHER REQUIREMENTS

Table 20: Ground Station (GS) further requirements

Ground Station (GS)
Coordination with BFWA stations
Coordination with ITS RSU
Minimum elevation angle for the beam between GS and AS: 5 degrees for all azimuths
The radiated power must not exceed -38 -10log (20/BW) dBm/MHz below 5850 MHz and -8 dBm/MHz above 5875 MHz to protect other radio applications. BW = transmitter bandwidth (MHz).

Table 21: Aircraft Station (AS) further requirements

Aircraft Station (AS)
DAA to protect BFWA
The radiated power must not exceed -38 -10log (20/BW) dBm/MHz below 5850 MHz and -8 dBm/MHz above 5875 MHz to protect other radio applications. BW = transmitter bandwidth (MHz).
Minimum operational height above ground: 3 000 m

ANNEX 8: REGULATORY PARAMETERS FOR BROADBAND DA2GC (GS AND AS), 2 GHZ, TDD

Example: System according to ETSI TR 101 599, frequency band: 1900-1920 MHz

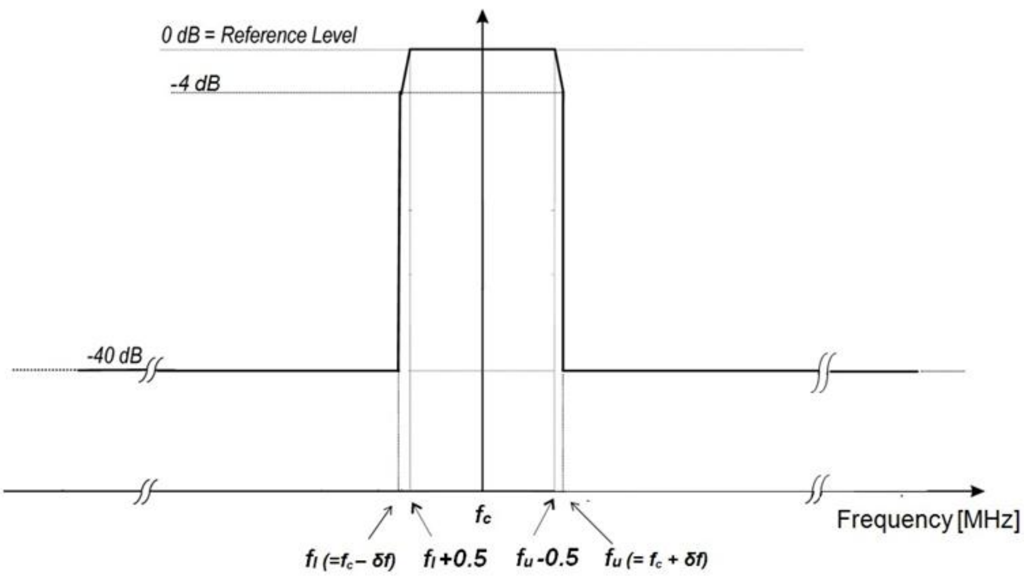
A.8.1 AIRCRAFT STATION

Table 22: DA2GC AS Transmitter characteristics

Parameter	Value
Max e.i.r.p.	32 dBm/MHz
Minimum operational height above ground	3 000 metres

NOTE 1: The e.i.r.p. level in Table 22 represents the maximum operational level at all times for a single beam and in all pointing directions.

The out-of-band aircraft station emissions when operating in the 1900 -1920 MHz band should fall within the limits given in Figure 33 when operating under highest output power conditions.



NOTE 1: 0 dB Reference Level represents the maximum spectral power density of the transmitted signal
NOTE 2: F_c depends on choice of precise centre frequency within the candidate unpaired 2GHz bands
NOTE 3: δf depends on choice of channel bandwidth, and ranges from 2.5 MHz to 10 MHz

Figure 33: Aircraft station emission mask

NOTE 2: The maximum spectral power density referred to in Note 1 of Figure 33 is equivalent to +15dBm/MHz into the aircraft antenna in the case of a 20 MHz channel.

NOTE 3: The -40dB relative level applies below 1900 MHz and above 1920 MHz, regardless of the choice of centre frequency and bandwidth.

A.8.2 GROUND STATION

Table 23: DA2GC GS Transmitter characteristics

Parameter	Value
Max e.i.r.p.	32 dBm/MHz

NOTE 4: The e.i.r.p. level in Figure 21 represents the maximum operational level at all times for a single beam, in the direction of the aircraft.

In addition:
The Ground Station radiated power must not exceed the following values outside the DA2GC designated band (≤ 20 MHz):

Table 24: Radiated power outside the DA2GC designated band

Elevation Angle	Maximum e.i.r.p. level (dBm/MHz)
< 2°	-40.0
2° to 16°	-20.0
>16°	-28.0

Other requirements

Table 25: Ground Station – Other requirements

Ground Station
Coordination with MFCN base stations (with carrier frequency at 1922.5 MHz) required

ANNEX 9: REGULATORY PARAMETERS FOR BROADBAND DA2GC (GS AND AS), 2 GHz OR 5.8 GHz, TDD

Example: System according to ETSI TR 103 108, frequency bands: 1900-1920 MHz and 5855-5875 MHz

A.9.1 BROADBAND DA2GC TRANSMITTER CHARACTERISTICS

Table 26: DA2GC transmitter characteristics

Parameter	Value
Channel bandwidth	5 MHz or 10 MHz
Transmitter maximum output power for GS	38 dBm (10 MHz channel) 35 dBm (5 MHz channel)
Transmitter maximum output power for AS	36 dBm (10 MHz channel) 33 dBm (5 MHz channel)
Transmitter maximum e.i.r.p. (GS – Sector Antenna)	41 dBm/MHz
Transmitter maximum e.i.r.p. (GS – Directional Antenna)	50 dBm/MHz
Transmitter maximum e.i.r.p. for AS	29 dBm/MHz

Note:

The directional antenna will only be used where maximum range is required. This will be mainly over sea. To protect any systems located near the coast, the main beam shall not illuminate any landfall within 4 km. The directional antenna may be used in remote areas, such as desert regions, subject to agreement by the regulatory administration(s).

A.9.2 SPECTRUM EMISSION MASK

The spectrum emission mask taken from ETSI TR 103 108 [3] is given below for 10 MHz (5 MHz) channels:

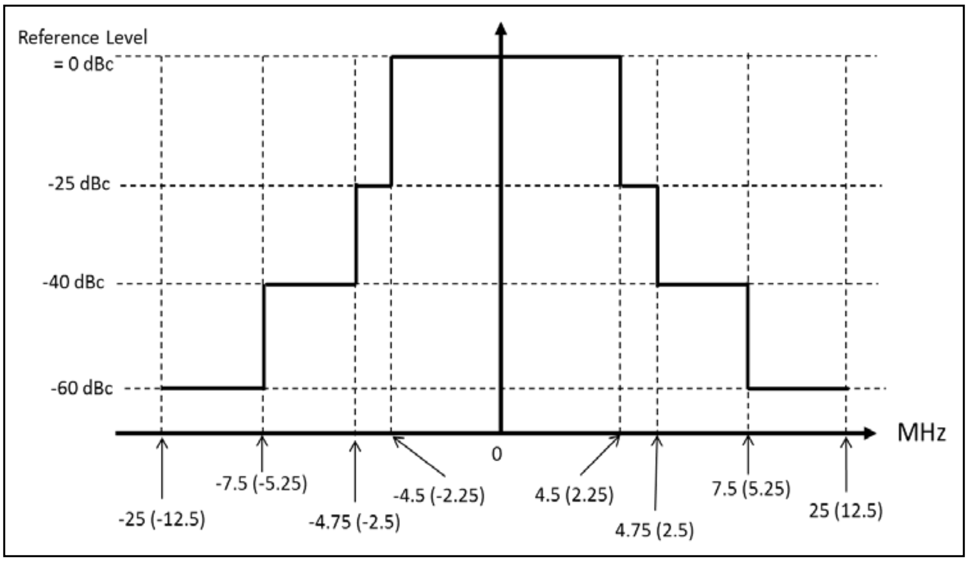


Figure 34: Spectral Emission Mask for both GS and AS

Note 1: 0 dBc Reference Level is the spectral density relative to the maximum spectral power density of the transmitted signal. For example:
i) for a Ground Station with a directional antenna, using a 10 MHz bandwidth, the Reference level (0 dBc) would be 60 dBm/(10 MHz) = 50 dBm/MHz,
ii) for an Aircraft Station using a 5 MHz bandwidth, the Reference level (0 dBc) would be 39dBm/(5 MHz) = 32 dBm/MHz

Note 2: On the Frequency Offset axis, the figures apply to a 10 MHz bandwidth system, whereas the figures in parentheses apply to a 5 MHz bandwidth system.

A.9.3 E.I.R.P. MASKS

A.9.3.1 Peak e.i.r.p. mask (for sector antennas) for Ground Station (GS)

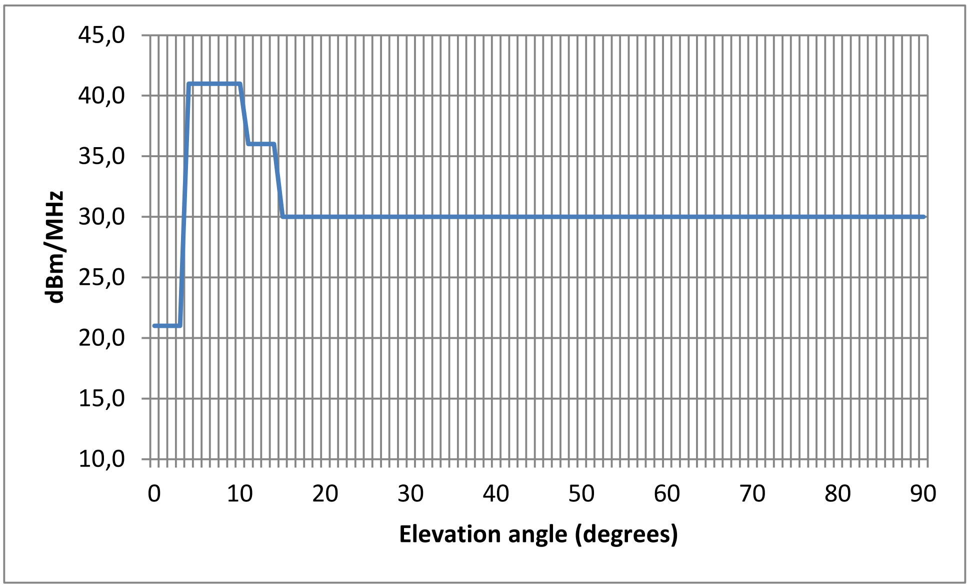


Figure 35: Peak e.i.r.p. mask (for sector antennas) for Ground Station (GS)

The exact values for the three elevation angle ranges shown in Figure 35 are defined in the following Table 27

Table 27: Exact values for the three elevation angle ranges shown in Figure 35

Elevation Angle	Peak e.i.r.p. level (dBm/MHz)
ϴ < 4°	21
4°≤ ϴ ≤ 10	41
11°≤ ϴ ≤ 14°	36
ϴ > 14°	30

A.9.3.2 Peak e.i.r.p. mask for Aircraft Station (AS)

The elevation angle in the following figure denotes angles below the fuselage where 0 degrees is the horizontal.

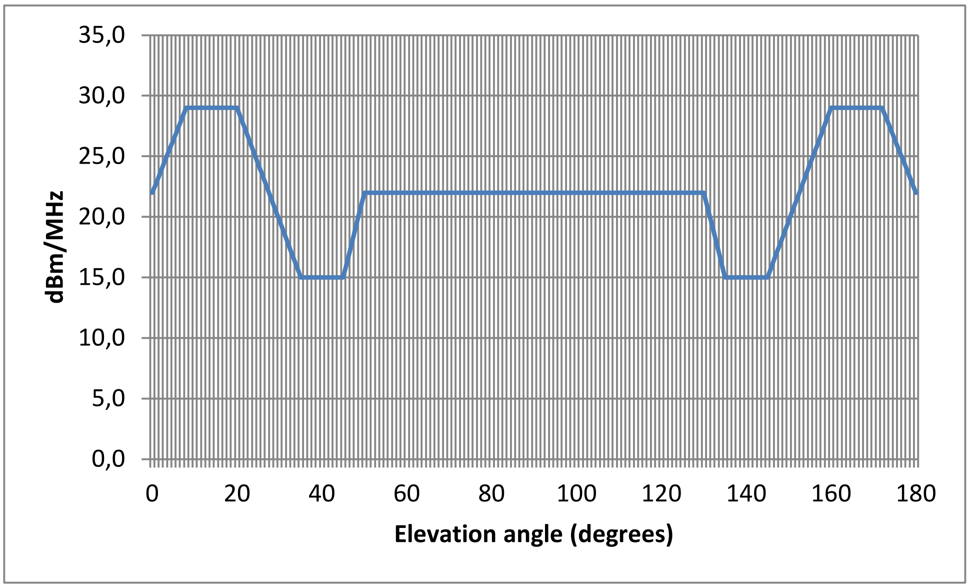


Figure 36: Peak e.i.r.p. mask for Aircraft Station (AS)

Table 28: Peak e.i.r.p. mask (values) for Aircraft Station (AS)

Elevation at ground (degrees)	Aircraft e.i.r.p. (dBm/MHz)	Note
0 to 8	22 to 29	Straight line interpolation
8 to 20	29	
20 to 35	29 to 15	Straight line interpolation
35 to 45	15	
45 to 50	15 to 22	Straight line interpolation
50 to 90	22	

A.9.3.3 Aircraft Station Mitigation Attenuation

The AS introduces additional transmitter attenuation according to its height above ground as follows:

Table 29: AS transmitter attenuation

Height above ground (metres)	Attenuation (dB)
3 000 to 4 999	8
5 000 to 5 999	6
6 000 to 6 999	4
7 000 and above	0

A.9.4 FURTHER REQUIREMENTS

Table 30: Ground Station (BS) further requirements

Ground Station (GS) operating in the 5855-5875 MHz band
Coordination with BFWA stations
Coordination with ITS RSU
The radiated power must not exceed -38 -10log (20/BW) dBm/MHz below 5850 MHz to protect other radio applications. BW = transmitter bandwidth (MHz)

Table 31: Coordination with MFCN

Ground Station (GS) operating in the 1900-1920 MHz band
Coordination with MFCN Base Stations (with carrier frequency at 1922.5 MHz) required.

Table 32: Aircraft Station (AS) further requirements

Aircraft Station (AS) operating in the 5855-5875 MHz band
Additional reduction in maximum e.i.r.p. by 4 dB for aircraft height above ground up to 7 km, in airspace above those regions where co-channel BFWA is used and is to be afforded protection.
The radiated power must not exceed -38 -10log (20/BW) dBm/MHz below 5850 MHz to protect other radio applications. BW = transmitter bandwidth (MHz).
Minimum operational height above ground: 3 000 m

Table 33: Aircraft Station (AS) operational height

Aircraft Station (AS) operating in the 1900-1920 MHz band
Minimum operational height above ground: 3 000 m

ANNEX 10: LIST OF REFERENCE

[1] ETSI TR 103 054 V1.1.1 (2010-07), System Reference Document on Broadband Direct-Air-to-Ground Communications operating in part of the frequency range from 790 MHz to 5150 MHz; FM48(10)003
[2] ETSI TR 101 599 V1.1.3 (2012-09), System Reference Document on Broadband Direct-Air-to-Ground Communications System employing beamforming antennas, operating in the 2.4 GHz and 5.8 GHz bands; FM48(12)036
[3] ETSI TR 103 108 V1.1.1 (2013-07), System Reference Document on Broadband Direct-Air-to-Ground Communications System operating in the 5.855 GHz to 5.875 GHz band using 3G technology; FM48(13)037
[4] Airbus: Global market forecast 2010 – 2029; December 2010.
[5] Boeing: Current market outlook 2010 – 2029; July 2010.
[6] Eurocontrol: Long-term forecast flight movements 2010 – 2030; December 2010.
[7] Eurocontrol: Trends in air traffic Volume 6 – Business aviation in Europe 2009; April 2010.
[8] TriaGnoSys: Passenger aircraft traffic estimation for European terrestrial cellular system; February 2010.
[9] Cisco Visual Networking Index: Global mobile data traffic forecast update 2010 – 2015; February 2011.
[10] 4G Americas: Sustaining the mobile miracle - a 4G Americas blueprint for securing mobile broadband spectrum in this decade; March 2011.
[11] IMDC: The perfect storm – Airline connectivity and operations; January 2010.
[12] 3GPP TS 36.300: Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (Release 8); March 2010.
[13] EU-IST-Project WirelessCabin: Deliverable D5 – Market survey and recommendations; August 2003.
[14] ECC Report 209 on Compatibility/sharing studies related to Broadband Direct-Air-to-Ground Communications (DA2GC) in the frequency bands 1900-1920 MHz / 2010-2025 MHz and services/applications in the adjacent bands
[15] ECC Report 220 on compatibility and sharing studies of DA2GC, PMSE video links, SRD and DECT in the 2 GHz unpaired bands
[16] ECC Report 210 on Compatibility/sharing studies related to Broadband Direct-Air-to-Ground Communications (DA2GC) in the frequency bands 5855-5875 MHz, 2400-2483.5 MHz and 3400-3600 MHz
[17] Outline of the response from CEPT to the European Commission in response to the Mandate “To undertake studies on the harmonised technical conditions for the 1900-1920 MHz and 2010-2025 MHz frequency bands (“Unpaired terrestrial 2 GHz bands”) in the EU”
[18] FM(13)132rev1: Summary of the Responses to the Questionnaire on DA2GC systems
[19] ECC Decision (13)03: ECC Decision of 8 November 2013 on the harmonised use of the frequency band 1452-1492 MHz for Mobile/Fixed Communications Networks Supplemental Downlink (MFCN SDL)
[20] ECC Decision (13)01: ECC Decision of 8 March 2013 on the use, free circulation, and exemption from individual licensing of earth stations on mobile platforms (ESOMPs) in the frequency bands available for use by uncoordinated FSS earth stations within the ranges 17.3-20.2 GHz and 27.5-30.0 GHz.
[21] ECC Report 132: Light Licensing, Licence-Exempt and Commons
[22] 676/2002/EC - Radio Spectrum Decision of the European Parliament and the Council of 7 March 2002 on a regulatory framework for radio spectrum policy in the European Community
[23] R&TTE Directive: Directive 1999/5/EC of the European Parliament and of the Council of 9 March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity
[24] Mandate to CEPT to undertake studies on the harmonised technical conditions for the 1900-1920 MHz and 2010-2025 MHz frequency bands in the EU
[25] RSPG opinion on review of spectrum use
[26] RSCOM12-05: Results of the public consultation concerning the unpaired bands 1900-1920 MHz and 2010-2025 MHz
[27] Framework Directive: Directive 2002/21/EC of the European Parliament and of the Council of 7 March 2002 on a common regulatory framework for electronic communications networks and services
[28] Authorisation Directive: 2002/20/EC of the European Parliament and the Council of 7 March 2002 on the authorisation of electronic communications networks and services
[29] Responses to the questionnaire on the implementation of BFWA in the frequency band 5725-5875 MHz according to ECC Recommendation (06)04 (document FM(12)090rev5)

[30] Mandate to CEPT to study and identify harmonised compatibility and sharing conditions for Wireless Access Systems including Radio Local Area Networks in the bands 5350-5470 MHz and 5725-5925 MHz ('WAS/RLAN extension bands') for the provision of wireless broadband services (document RSCOM13-32rev3 of 2 September 2013)

[31] ECC Decision (05)11 on the free circulation and use of Aircraft Earth Stations (AES) in the frequency bands 14.0-14.5 GHz (Earth-to-space), 10.7-11.7 GHz (space-to-Earth) and 12.5-12.75 GHz (space-to-Earth)

[32] ECC Report 016 Refarming and secondary trading in a changing radiocommunications world

[33] ECC Report 169 Description of practices relative to trading of spectrum rights of use

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

[35] ECC Decision (04)08 on the harmonised use of the 5 GHz frequency bands for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs)

[36] EN 302 571 Intelligent Transport Systems (ITS);Radiocommunications equipment operating in the 5 855 MHz to 5 925 MHz frequency band

[37] ECC Report 101 Compatibility studies in the band 5855-5925 MHz between Intelligent Transport Systems (ITS) and other systems

[38] ECC Recommendation (06)04 Use of the band 5725-5875 MHz for Broadband Fixed Wireless Access (BFWA)

[39] ERC Report 25 The European table of frequency allocations and applications in the frequency range 9 kHz to 3000 GHz

[40] ECC Recommendation (08)01 Use of the band 5855-5875 MHz for Intelligent Transport Systems

[41] ECC Report 188 Future Harmonised Use of the 1452-1492 MHz in CEPT

[42] ECC Decision (11)06 on harmonised frequency arrangements for mobile/fixed communications networks (MFCN) operating in the bands 3400-3600 MHz and 3600-3800 MHz

[43] ECC Decision (07)02 on availability of frequency bands between 3400-3800 MHz for the harmonised implementation of Broadband Wireless Access systems (BWA)

[44] CEPT Report 49 from CEPT to the European Commission in response to the Mandate "Technical conditions regarding spectrum harmonisation for terrestrial wireless systems in the 3400-3800 MHz frequency band"

[45] ECC Decision (06)09 on the designation of the bands 1980-2010 MHz and 2170-2200 MHz for use by systems in the Mobile-Satellite Service including those supplemented by a Complementary Ground Component (CGC)

[46] EC Decision 2007/98/EC on the harmonised use of radio spectrum in the 2 GHz frequency bands for the implementation of systems providing mobile satellite services

[47] ECC Report 203 Least Restrictive Technical Conditions suitable for Mobile/Fixed Communication Networks (MFCN), including IMT, in the frequency bands 3400-3600 MHz and 3600-3800 MHz

[48] Decision No 243/2012/EU of the European Parliament and of the Council of 14 March 2012 establishing a multiannual radio spectrum policy programme

[49] 3GPP TS 36.104: Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception

[50] 3GPP TS 36.101: Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception

[51] ERC Recommendation 74-01 on unwanted emissions in the spurious domain

[52] ECC Report 202 on Out-of-Band emission limits for Mobile/Fixed Communication Networks (MFCN) Supplemental Downlink (SDL) operating in the 1452-1492 MHz band

[53] ECC Report 184 on the Use of Earth Stations on Mobile Platforms Operating with GSO Satellite Networks in the Frequency Range17.3-20.2 GHz and 27.5-30.0 GHz

[54] Directive 2014/53/EU of 16 April 2014 of the European Parliament and of the Council on the harmonisation of laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC

[55] 3GPP TS 36.300: Evolved Universal Terrestrial Radio Access (E-UTRA) and Evolved Universal Terrestrial Radio Access Network (E-UTRAN); Overall description; Stage 2 (also in ETSI TS 136 300)