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| **Radiocommunication Study Groups** |  |
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| Source: Document 5A/TEMP/368 | **Annex 11 toDocument 5A/976-E** |
| **16 November 2018** |
| **English only** |
| Annex 11 to Working Party 5A Chairman’s Report |
| Elements For a possible report on BroadbandAir To Ground Systems |
| **Frequency arrangements for broadband air-to-ground (A2G)communications links with passenger aircraft** |

*[Editor’s note: This report would need to clarify the main areas to be discussed. To progress the development of the report, the elements of this report should focus two aspects:*

1. *the technical and operational characteristics should be developed and further input is invited in this respect on a revision of Report ITU-R M.2282;*
2. *in parallel, a separate document may be considered to examine any frequency harmonised arrangements.]*

# 1 Scope

This report addresses the frequency arrangements associated with providing broadband wireless links (air-to-ground, A2G) to passenger aircraft throughout the world, to facilitate improved and seamless broadband access for use by both the travelling public and aircraft operators (including the crews). A general overview and the technical and operational characteristics of these systems are addressed in Report ITU-R M.2282.

# 2 Related Recommendations and Reports

Report [ITU-R M.2282](http://www.itu.int/pub/R-REP-M.2282) – *Systems for public mobile communications with aircraft*.

[There are various ITU-R Recommendations that detail the specification of both terrestrial and satellite IMT-Advanced technology. In particular, Recommendation ITU-R M.2012 contains the detailed specifications of the terrestrial radio interfaces of International Mobile Telecommunications-Advanced]

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3 Acronyms

A2G Air-to-Ground

DA2GC Direct-Air-to-Ground Communications

**Broadband Direct-Air-To-Ground-Communications (DA2GC) System**: digital two-way radio communications system in which base stations in the land mobile service communicate with base stations on aircraft.

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# 4 Introduction *[Editor’s note: Proposed to move to revision of ITU-R M.2282]*

[The global demand for ubiquitous wireless connectivity and take-up of so-called ‘smart-phones’ has grown very rapidly around the world, kicked off by the launch of the first Apple iPhone (generally credited with revolutionizing the cellular telephone market) back in June 2007. The range of smart‑phones, and their features and applications, has expanded at an incredible rate. And consumer adoption of the smart-phone[[1]](#footnote-1),[[2]](#footnote-2),[[3]](#footnote-3) has already reached over 50% in many countries (and around 80-90% in major developed countries) – with public expectations for ‘*anywhere – anytime*’ connectivity also escalating to the point where lack of coverage, poor building penetration and even just comparatively slower bit-rates are frequently seen as a serious shortfall in service quality.

While cellular telephone systems have evolved from analogue to digital technologies, and from relatively low-rate data to the mobile broadband speeds widely deployed today, deployment of network infrastructure (i.e. base-stations) has also expanded significantly - not just in outdoor locations across the landscape, but throughout public buildings, shopping malls, and within road/rail tunnels - to provide a *ubiquitous* user experience of wireless connectivity.

Business and consumer usage has expanded to encompass not only the traditional voice and text communications modes, but applications of the Internet, news and weather, comparative shopping, online fulfilment, social interactions, entertainment of all types, personal navigation, office/business applications, photography and recording of life’s minutiae of every description. The advertising and retail industries have extensively built on this ubiquity of service to promote and expand their business models; while service and transport industries are using it to dramatically improve customer service levels; and many other industries have harnessed the opportunities brought by the smart-phone in ways we could never have anticipated at the time of launching that first Apple iPhone. Today, most users rely so much on the convenience, connectivity and information aspects of their smart phone that lack of service often results in frustration, discomfort, anger, and even personal anxiety.

Building on the growing consumer demand, a variety of public transport services now also offer free or low cost wireless connectivity to passengers. For example, many buses and trains already offer in-vehicle Wi-Fi, with the vehicle backhaul connection to the Internet being provided via public cellular networks.

But while network operators are continuously expanding the coverage ubiquity of mobile broadband service on land, subject to capital availability and economic feasibility, the provision of equivalent services on passenger ships and aircraft is still lagging behind. Today, some of the larger cruise ships are planning or have commenced fitting distributed antennas and wireless broadband base-stations supported by satellite-based backhaul to land networks.

In contrast, despite the large number of commercial aircraft plying the skies, the connected passenger aircraft market has been slower to develop than expected, and remains rather limited - with only relatively few airlines fitting a small number of aircraft, and national operating authorizations settled in only relatively few countries. Moreover, indications are that services offered to date have fallen short of user and airline expectations – due to comparatively low data rates, frequent connection drop-outs, high user-tariffs, and excess equipment weight/aerodynamic drag impacts on efficient aircraft performance.]

## [3.1 General Air-to-Ground Scenario *[Editor’s Note: Proposed to move to revision of M.2282]*

To enable passengers to use their smart-phones within the cabin of a passenger airliner, at minimum power levels, a compact base-station or service access point is required to be fitted, along with a suitable distributed antenna running the length of the cabin. For convenient user terminal access, this base-station will rely on one of the frequency bands already identified for IMT by the ITU-R, and commonly provisioned in today’s smart-phones. An alternative option may be to simply provide a WiFi service within the cabin, via an on-board WiFi Access Point (AP), since most modern smart-phones can also connect to WiFi services.

Figure 1

General Air-to-Ground Scenario

*Terrestrial IMT network*

*Overflying passenger aircraft*

*Broadband air-to-ground link*

*On-board distributed antenna*

*Onboard microcell or AP*

On-board Wi-Fi access points are already being used to broadcast pre-recorded news and entertainment content to passengers on many aircraft, via their own personal tablets and smartphones. However, connections to the Internet need a broadband back-haul link to the global telecommunications network, enabling access to a wider range of applications, and to terrestrial voice and data services – to achieve equivalent seamless connectivity in the air as enjoyed by passengers on the ground going about their normal day-to-day lives, and prior to boarding the aircraft. This broadband back-haul functionality is the key focus of this document.]

# 5 Challenges of connecting aircraft to the world

The critical back-haul connection between passenger aircraft and the global telecommunications network can be implemented either via terrestrial systems (while over land) and/or via satellite systems.

However, a particular consideration is the requirement of many countries today that all telecommunications traffic originating or terminating within their national territory shall be accessible for national purposes. This requirement typically relies on a specific facility/node located within each country, to provide investigatory access, and is more readily met via direct air-to-ground communications (terrestrial) links within the country being over-flown, than by satellite links that often rely on a gateway earth station located in some other country. Nonetheless, the terrestrial versus satellite link backhaul options clearly remain complementary – and often seen as having distinct geographic roles, as shown in the following conceptual diagram:

Figure 2

Terrestrial and satellite roles in broadband links to passenger aircraft

*12nm territorial boundary*

As an aside, passenger aircraft registered in their country-of-origin (particularly the ‘flag’ carriers) are frequently considered part of the ‘national territory’ of their home country. As such, some countries may also require direct access to air-to-ground telecommunications for national purposes even when the aircraft is in-flight over international waters.

In particular, while satellite links are clearly needed for the long-haul trans-oceanic routes, they may be relatively costly and exhibit increased latency in the case of the short-haul and medium-haul routes supporting more frequent and larger numbers of passenger aircraft.

## 3.3 Operating environment [Editor’s Note: Consider what material should be retained.]

Today’s passenger airlines operate in a highly cost-competitive environment, and typically seek to maximize the efficient utilization of aircraft over both domestic and international routes. This means a strong focus on issues such as aircraft weight and fuel consumption; ground maintenance downtime and operational service availability; seat quantity and occupancy; and crew operating requirements - to note just a few. To minimize on-board equipment complexity and weight, and to avoid undue additional duties for flight crews, several matters are relevant:

• sufficient production/market scale for air-to-ground equipment/systems to encourage development efforts toward minimising both weight and cost; and

• harmonized regulatory frameworks applicable to passenger aircraft operating across national borders, particularly in relation to certification, operations and licensing; and

• harmonized frequency arrangements, to minimize systems technical design and operational complexity.

Achieving these objectives involves consideration of such issues as: adopting common technical standards covering technology, radiofrequency emission levels and antenna patterns; securing mutual recognition of technical authorizations/certifications; achieving agreement on common system operating procedures; recognition of legal/regulatory obligations while over-flying national territories; and various other matters.

The following sections offer a brief outline of these issues, along with suggested approaches aimed at harmonizing arrangements to the extent possible – and, to maximize equipment market scale, and minimize limitations on passenger airline operations.

# 4 Key operating issues

## 4.1 Altitude limits *[Editor’s Note: Consider what to retain and what to move to revision of M.2282]*

In the past, passenger use of entertainment systems and personal electronic devices (PEDs) on‑board commercial aircraft was generally restricted by aircraft operators to the ‘cruise’ portion of flight only – primarily so that passengers’ attention is not diverted from the flight safety briefing, and purportedly to protect the critical take-off and landing phases of flight (involving precision electronic navigational aids) from errant radiofrequency emissions and interference. This restriction has generally been implemented in the form of a ‘minimum altitude’ limit of 3000m AGL as a convenient threshold. Coincidentally, after take-off, aircraft typically achieve an altitude of 3000 m at some considerable distance from the point of departure – and generally beyond urban zones (even for most metro airports). This circumstance is potentially relevant to coverage planning for air-to-ground systems, since it infers that air-to-ground base-stations can generally be deployed in regional areas only:

Figure 3

Achieving 3000m altitude levels

3000 m

Recently, however, some airline operators have begun to consider the possibility of offering ‘gate-to-gate’ connectivity for passengers, enabling reliable connection continuity on loading ramps between terminal and aircraft, and as an incentive to attract greater airline patronage. This may dictate the need for base-stations located nearby airports.

## 6 Implications of common frequency arrangements

*[Editor’s note: proposed for deletion of “compliance with national technical regime”(subtitle changed to ‘benefits for cross-border operation” text, since Crossborder issues are always relevant but will vary from country to country based on agreements between those countries. This may be an operational needs to show that the system has to operate under the parameters for which it was granted by the national authority.]*

**Benefits for cross-border operations.** Where there are *differing* national regulatory and technical regimes between neighboring countries, aircraft need to track their position against national borders to trigger on-board system adjustments (power, mode, etc.), according to relevant national regulatory requirements - or even to deactivate air-to-ground systems over certain countries. While such adjustments might be undertaken by aircrew, as an additional duty, they are more usually implemented as an automatic function via a connection to the aircraft [ARINC] data bus that provides aircraft heading, altitude, air-speed and positional information (amongst other data). However, this requirement adds to complexity – since on-board passenger connectivity systems had to store relevant mapping and regulatory data to enable proper technical compliance as the aircraft passed over national borders. Clearly, differing national regulatory regimes lead to functional and processing complexity, and greater development and equipment costs. Notably, however, direct air-to-ground links located within relevant national borders can instead readily implement regulatory compliance via control channel signalling.

**Customer experience implications.** Any service variability due to differing national regulatory regimes is undesirable from the perspective of passenger usage experience – for example, variable connectivity (lower bit-rates), differing connection modality, and periodic session drop-outs throughout flights. As such, consensus on harmonised licencing and regulatory regimes applicable to broadband air-to-ground systems, particularly between neighboring countries, will contribute to a more beneficial passenger experience.

## 6.1 Routing of traffic when crossing borders

*[Editor’s note: Consider deletion/revision of this Section as topic is more relevant to national matters.]*

As noted above, many national administrations require that all telecommunications originating or terminating within their territorial boundary must be accessible for national purposes – often including not only session metadata (originating/terminating parties, time/date, duration, etc.), but also real-time traffic interception. This typically involves a requirement to route traffic via one or more ground interception centres located within the relevant country and designed to facilitate access under relevant legal authorisations and protections.

In addition, other regulatory obligations may differ between countries, and may impact the air-to-ground systems architecture and traffic routing procedures – such as:

• mandatory routing of emergency assistance calls (for example, calls to the special numbers 911, 112, 000, etc.) – requiring automatic connection of calls via shortest practical route to relevant public safety agencies (or call-handling centre) within the national territory;

• exclusive dealing prohibitions – in context of telecommunications, this generally requires that if services (e.g. roaming) are offered to one class of users, they must be equivalently offered to all other classes of users;

• third-line forcing prohibitions – in context of telecommunications, this disallows a refusal to provide services if the user does not firstly acquire some other service from the same supplier; and

• there may also be other regulatory requirements enacted in various countries that must be taken into account.

In general, existing terrestrial fixed/mobile network operators within respective countries will have already established the facilities, functional norms and operating protocols certified to meet such national regulatory obligations as a normal part of their national network operations.

# 7 Relevant technical aspects of harmonization

*[Editor’s note: Propose to move to revision of Report ITU-R M.2282, and replace with an introductory paragraph, such as: “Report ITU-R M.2282 outlines the key technical aspects of A2G systems, including the benefits of harmonized spectrum utilization.”]*

[The key technical aspects of air-to-ground systems discussed in this section relate to:

• ensuring effective inter-working and control signalling between airborne equipment mounted within/on passenger aircraft and corresponding terrestrial and/or satellite network infrastructure relevant to each country or area over which the aircraft is flying; and

• adopting common mechanical arrangements, that satisfy relevant airworthiness certification requirements, while minimizing weight and aerodynamic drag, and simplifying maintainability including rapid swap-in/swap-out of modules; and

• agreed common wireless technology characteristics (including emission levels, receiver performance, and antenna characteristics) and equipment functionality (such as Doppler compensation, and auto-configuration based on geographic position-detection); and

• harmonized spectrum utilization, including frequency bands and channel arrangements, to facilitate non-complex airline operations throughout the region, and simpler redeployment of passenger aircraft to alternative routes in response to varying passenger load demands/needs.]

## [7.1 Region-wide Systems Inter-working

To maximise seamless and transparent region-wide operations, establishing agreement on a harmonised air-to-ground technology platform is needed. The adoption of IMT-Advanced (LTE) technology for air-to-ground systems is already gaining broad international favour, and now appears to be the most popular and preferred choice for service operators and national administrations.

In addition, to simplify in-air operations and maximise passenger usage experience, establishing agreement on harmonised emission levels/power flux densities, out-of-band emissions, and minimum antenna elevation levels, is also necessary.

The antenna pattern and performance may be a particularly unique feature of air-to-ground links. In general, and to provide a reliable radiocommunications link with over-flying aircraft approaching/departing from all sky directions, both the airborne and ground antennas should exhibit an illumination pattern that varies with elevation-above-horizon:

• higher gain and linear (vertical) polarization for lower elevations between about 5-25⁰ above horizon; and

• lower gain and circular polarization for higher elevations between about 25-90⁰ above horizon.

Figure 4

Antenna Elevation Angle versus Polarization

*3000m agl*

*10000m agl*

*25⁰ ah*

*34 km*

*21 km*

*5⁰ ah*

*0 km*

*Linear pol*

*Circular pol*

Such an antenna pattern may also enable co-existence with other terrestrial services, such as coordinated sharing with fixed wireless systems utilizing highly directional antennas.

## 5.2 Mechanical and electrical aspects

Air-to-ground equipment modules developed for mounting in passenger aircraft should be sufficiently ruggedized and reliable, and include appropriate mounting/anchoring features to withstand the vibration and physical shock environment typically experienced by aircraft in flight. These mechanical aspects of the equipment are subject to formal ‘airworthiness certification’.

The equipment must also conform with standardized physical mounting methods, dimensions, and maximum weight, to enable simple and rapid fitting to a wide variety of aircraft. Further, power and electrical signalling cables must meet a range of mechanical, electrical and chemical (including smoke/fire aspects) requirements, and be terminated with standardized plugs for direct connection to other aircraft equipment. The equipment should also be designed for rapid swap-in/swap-out in the event of module failure, to minimize impact on aircraft operating schedules and ground-maintenance time.

Finally, to minimize adverse impact on aircraft fuel usage and operating costs, the air-to-ground equipment intended for mounting in/on an aircraft should be specifically designed to achieve minimum necessary size, weight and aerodynamic drag (for externally-mounted antennas).

## 5.3 Technology aspects

Several technology aspects should also be considered for possible harmonization, to ensure a uniform approach is adopted throughout the Region:

• Doppler (airspeed) compensation – while determining airspeed and consequent Doppler compensation necessary for proper receiver operation can be achieved by computational means and GPS data within the airborne equipment, an alternative and simpler approach is to take the airspeed indication directly from the aircraft avionics data bus, and apply it as a frequency scaling correction factor;

• Altitude detection – airlines may seek to continue the practice of prohibiting diversion of passenger attention to other activities, until the delivery of safety- related information is completed. This altitude information may also be automatically derived from the aircraft avionics data bus;

• Geo-position detection – this information may be required for purposes of implementing particular national regulatory requirements, by matching against aircraft position against geographic national border location information. While this can also be derived directly from GPS data, it is also available from the aircraft avionics data bus.]

## 5.4 Spectrum aspect

*[Editor’s note: This section will require further discussion and understanding. Questions were raised in the factual accuracy of text reflecting the usage of the bands (in particular 1 980-2 010/ 2 170-2 200 MHz) in countries, which require further discussion. In addition, input is invited to the next meeting for additional frequency bands.]*

To allow for cross-border roaming between countries, where bands assigned to local network operators may differ, modern smart-phones typically include multiple frequency bands. However, this means designing handsets to accommodate multiple filters, amplifiers and other radiofrequency components, along with sufficient intelligence to implement scanning and search algorithms, and to allow devices to ‘discover’ valid national networks that have established roaming agreements with the handset’s home network.

Not only do these multiple filters and radiofrequency components increase complexity, but the associated development effort is only cost-effective in the case of the very large sales volumes (tens of millions of units) associated with the global cellular handset market. Such scale is unlikely to apply to the on-board air-to-ground equipment destined for the global passenger aircraft market (estimated to be a few tens of thousands). Therefore, to be viable, it is critical to agree and harmonize on a single frequency band (possibly not more than two) for use by regional/global broadband air-to-ground applications.

The European region has already explored several frequency bands for this purpose, including the 1 900-1 920 MHz (TDD) band, the **1 980-2 010/2 170-2 200 MHz (FDD)** band, and the 5 855‑5 875 MHz band. The US market has also explored use of several bands including the 450 MHz band and the 800 MHz band. To enable seamless inter-regional flight operations, and unfettered day-to-day re-scheduling of aircraft to alternative routes, it seems appropriate that administrations consider harmonization of frequency arrangements with other regions.

The **1 980-2 010/2 170-2 200 MHz** is identified in the ITU-R Radio Regulations (RRs) for use by terrestrial and satellite IMT systems (on an equal basis, with no priority given to either service).

*[Editor’s note: Material is sought on additional frequency bands to the above paragraph on Frequency arrangements for broadband air-to-ground (A2G) communications.]*

There may also be other candidate bands that could be considered for harmonized air-to-ground systems in various countries.

# 6 Additional regulatory requirements

*[Editor's note: Consider deletion/revision of this Section text on legal intercept requirements as these are national matters.]*

## 6.1 Access for crime investigation

As noted earlier, many countries already require that all telecommunications traffic within their national territory can be made accessible for national crime investigation purposes. This is sometimes referred to as a ‘legal interception’ requirement, and is usually achieved via one or more terrestrial teletraffic routing nodes specifically established within each country for this purpose. Clearly, connection to these nodes is likely to be more easily achieved by terrestrial air-to-ground systems located within each country, while satellite air-to-ground systems could be used where aircraft are flying over international waters.

## 6.2 Recording of user terminal devices and traffic metadata

In some countries, aside from any interception requirement, regulatory provisions exist that require relevant metadata (such as: user terminal identity; origin/destination parties; time, date and duration of each call/session, as a minimum) to be recorded by a facility located within the borders of the relevant country for every call/session/transaction carried by a telecommunications network providing services within the national territory. Such requirements further infer that terrestrial air‑to-ground services may be more readily able to meet such requirements, while satellite air-to-ground systems are used where aircraft are flying over international waters.

[…..other matters to be determined/proposed….]

*[Editor’s Note: Consider moving text from Report ITU-R M.2282 to this document. For example, see the following possible excerpts.]*

**[System for public communications with aircraft in Canada and United States of America**

In Canada and the United States of America, the band plan, described below in Fig. 5, is based on two block pairs: 849-850.5/894-895.5 MHz and 850.5-851/895.5-896 MHz. The band 849‑851 MHz is limited to transmissions from ground stations and the use of the band 894‑896 MHz is limited to transmissions from airborne stations.

FIGURE 5

The band plan for aeronautical mobile service in Canada and the United States



The technical rules for certification and systems deployment in the band in the United States and Canada are technology neutral.]

# [4 System for general aviation air-to-ground radiotelephone within the United States of America

**4.1 General aviation air-to-ground radiotelephone service**

This service operates in the 454-459 MHz band and can provide a variety of telecommunication services to private aircraft such as small single engine planes and corporate jets. CFR47[[4]](#footnote-4) § 22.805 contains the channel allocations for the general aviation air-to-ground service. These channels have a bandwidth of 20 kHz and are designated by their centre frequencies in megahertz.

TABLE 1

Signalling channel pair for general aviation air-ground systems

|  |  |
| --- | --- |
| **Ground** | **Airborne mobile** |
| 454.675 | 459.675 |
| a) Channel 454.675 MHz is assigned to each and every ground station, to be used only for automatically alerting airborne mobile stations of incoming calls.b) All airborne mobile channels are assigned for use by each and every airborne mobile station. |

Communication channel pairs

|  |  |
| --- | --- |
| **Ground** | **Airborne mobile** |
| 454.700 | 459.700 |
| 454.725 | 459.725 |
| 454.750 | 459.750 |
| 454.775 | 459.775 |
| 454.800 | 459.800 |
| 454.825 | 459.825 |
| 454.850 | 459.850 |
| 454.875 | 459.875 |
| 454.900 | 459.900 |
| 454.925 | 459.925 |
| 454.950 | 459.950 |
| 454.975 | 459.975 |

The transmitting power of ground and airborne mobile transmitters operating in the general aviation air-ground radiotelephone service on the channels listed in CFR 47 § 22.805 must not exceed:

a) Ground station transmitters:the effective radiated power of ground stations must not exceed 100 Watts and must not be less than 50 Watts, except as provided in CFR 47 § 2.811.

b) Airborne mobile transmitters:the transmitter power output of airborne mobile transmitters must not exceed 25 Watts and must not be less than 4 Watts.

1. <http://www.worldatlas.com/articles/countries-by-smartphone-penetration.html>. [↑](#footnote-ref-1)
2. <https://newzoo.com/insights/rankings/top-50-countries-by-smartphone-penetration-and-users/>. [↑](#footnote-ref-2)
3. <https://en.wikipedia.org/wiki/List_of_countries_by_smartphone_penetration>. [↑](#footnote-ref-3)
4. Refer to: <http://www.gpo.gov/fdsys/pkg/CFR-2010-title47-vol2/pdf/CFR-2010-title47-vol2-part22-subpartG-subjectgroup-id140.pdf>. [↑](#footnote-ref-4)