Radiocommunication Study Groups

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GENERAL ASPECTS

IAFI[1]

FURTHER UPDATES TO THE WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R M.[IMT.A2G]

Systems for non-safety air-ground communications (excluding UAS) using terrestrial IMT and other land mobile technologies

1 Introduction

46th meeting of Working Party (WP) 5D initiated work on the development of a new Report ITU-R M.[IMT.A2G] titled "*Systems for non-safety air-ground communications (excluding UAS) using terrestrial IMT and other land mobile technologies*". During 48th meeting of WP 5D, significant progress was achieved towards development of the working document towards this preliminary draft new report. A liaison statement to WP 5A was also developed for getting clarity on following:

– Material (including in particular existing work on air-ground communication topic) related to the general principles, technical characteristics and operational features of terrestrial systems for non-safety air-ground communication using land mobile technologies.

– Relevant examples of National uses of non-IMT/land mobile technologies that could be incorporated as the annexes in this new Report.

2 Proposal

IAFI proposes further edits in the draft working document towards further improvement of the working document towards a preliminary draft new Report ITU R M.[IMT.A2G] on Systems for non-safety air-ground communications (excluding UAS) using terrestrials IMT and other land mobile technologies. The edits are highlighted in turquoise colour.

Attachment: 1

[1] IAFI is a sector Member of ITU-R. For more details, please see https://iafi.in.

ATTACHMENT

Annex 3.3 to Working Party 5D Chair's Report

WORKING DOCUMENT TOWARDS A PRELIMINARY
DRAFT NEW REPORT ITU-R M.[IMT.ATG]

Systems for non-safety air-ground communications (excluding UAS) using terrestrial IMT and other land mobile technologies

(YYYY)

TABLE OF CONTENTS

Scope

This Report deals with the general principles, technical characteristics and operational features of terrestrial systems for non-safety communications with aircraft (excluding UAS), using IMT and land mobile technology based air-ground applications. The connectivity between OBU and user equipment of on-board passengers (e.g. smart phones, laptops, tablets, etc.) is not in the scope of this Report.

[Regarding IMT technology based ATG application, this report addresses non-safety communications between Terrestrial IMT base stations and an On Board IMT unit (OBI) mounted in an aircraft (excluding UAS). Studies of relevant usages, technical and operational aspects and capabilities supported by IMT are addressed.]

Otherwise, examples of national implementation on ATG also are included in the annex.

[Note: The implementation of this Report is subject to compliance with the provisions of the Radio Regulations.]

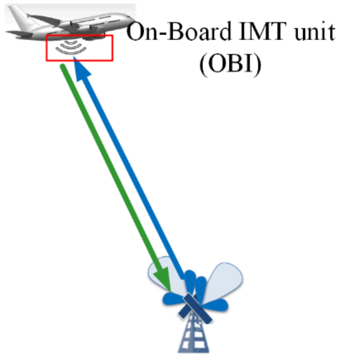
[Note: Discussion on whether relevant regulatory information may be included in the report is not finalized, and further discussion is needed. However, no new regulation will be developed in this report.]

1 Introduction

IMT Air-to-Ground (ATG)enables non-safety public communication (e.g. broadband connectivity) to on board passengers by establishing uplink and downlink communications between terrestrial IMT base stations and an On-Board ATG IMT Unit (OBI) installed on the aircraft (excluding UAS), The OBI includes an external antenna, typically mounted at the bottom of the aircraft(excluding UAS) to connect with the terrestrial base station(s), as shown in Figure 1.

FIGURE 1

IMT ATG scenario



[Editor's note: The specific type of terrestrial IMT base station should be further discussed in WP 5D #48 meeting.]

Further the OBI, acts as customer premises equipment (CPE) which enable on board passengers' user equipment such as smart phone, laptops and tablets to access the broadband communications. The connectivity between OBI and user equipment of on-board passengers (e.g. smart phones, laptops, tablets, etc.) is not in the scope of this Report.

[Editor's note: The report skeleton and below text proposals from inputs have not been discussed in 47th ITU-R WP 5D meeting]

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Air-to-ground (ATG) network refers to in-flight connectivity technique, using ground-based cell that send signals up to an aircraft's antenna(s) of onboard ATG terminal. As a plane travels into different sections of airspace, the onboard ATG terminal automatically connects to the cell with strongest received signal power, just as a mobile phone does on the ground. In this network, a direct radio link will be established between Base Station (BS) on the ground and Customer Premises Equipment (CPE like antenna, modem, Wi-Fi router, etc.)mounted on the aircraft.

Air-to-ground (ATG) communications play an increasingly important role in modern aviation, particularly with the growing demand for in-flight connectivity. Passengers expect reliable internet access while flying, which has driven innovation in ATG communication technologies. One significant advancement in this field is the use of IMT-advanced and IMT-2020 technologies, especially under the framework of the International Mobile Telecommunications Air-to-Ground (IMT ATG) systems. These developments represent a fundamental shift from traditional satellite-based communications to more efficient, high-speed connections that provide significant benefits in terms of both performance and cost.

This article explores the role of IMT-advanced and IMT-2020 in ATG communications, focusing on how IMT ATG enables in-flight connectivity by establishing communication links between terrestrial IMT base stations (BS) and on-board ATG units mounted on aircraft. It also highlights the emerging standards, such as those set forth in 3GPP TR 38.876 V18.2.0, and discusses key trends in the aviation industry.

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2 Relevant ITU-R Recommendations and Reports

3 Acronyms

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Recommendation ITU-R M.2150

Question ITU-R 262/5

Report ITU-R M.2282

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[4 Role of IMT in air-to-ground communications]

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The role of IMT-advanced in air-to-ground communications

The introduction of IMT-advanced technology into ATG communications has been a game-changer in the aviation industry. Compared to older 2G and 3G networks, IMT-advanced offers significantly faster download and upload speeds, making it more suitable for delivering high-quality in-flight broadband services. IMT-advanced networks rely on LTE (Long-Term Evolution) technology, which enables the transmission of high-speed data over large distances. In the context of air-to-ground communications, LTE-based systems are used to maintain continuous connectivity between an aircraft and terrestrial base stations. This is particularly challenging due to the high speeds at which airplanes travel, as well as the altitude at which they operate. Several countries, including the United States and parts of Europe, have already deployed IMT-advanced-based ATG networks for commercial flights. For example, one company's ATG network in the United States relies on an IMT-advanced LTE system that delivers in-flight Wi-Fi to millions of passengers each year. However, while IMT-advanced has been instrumental in advancing in-flight connectivity, it is increasingly being complemented—and in some cases replaced—by IMT-2020 technology.

The advent of IMT-2020 for air-to-ground communications

IMT-2020 technology represents the next major step in air-to-ground communications, offering even greater speed, lower latency, and the ability to connect more devices simultaneously. Unlike IMT-advanced, which is primarily designed for consumer data, IMT-2020 is optimized for a broader range of applications, including machine-to-machine communication, real-time data processing, and the Internet of Things (IoT). The IMT ATG system, when integrated with IMT-2020, allows for higher data rates, improved spectral efficiency, and better coverage for aircraft flying at high altitudes. This is achieved through advanced features such as beamforming and massive MIMO (Multiple Input, Multiple Output), which enable IMT-2020 networks to transmit signals more efficiently and over longer distances than IMT-advanced networks. In addition to improving passenger connectivity, IMT-2020 also opens up new possibilities for operational efficiency in aviation. Aircraft equipped with IMT-2020-enabled ATG systems can transmit real-time data about their performance to ground stations, allowing airlines to optimize flight paths, monitor engine health, and enhance safety.

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[5D/176:

4 Overview of airborne user equipment and devices]

5 Usage and deployment scenarios

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4.XX Consideration of regulatory aspects

The use of non-safety communications between base stations on ground and airborne user equipment supported by the terrestrial component of IMT should not contradict the Radio Regulations.

Since this communication link involves user equipment on-board airborne vehicles such communication falls into definition related to aeronautical mobile service. In particular:

1.32 *aeronautical mobile service:* A *mobile service* between *aeronautical stations* and *aircraft stations*, or between *aircraft stations*, in which *survival craft stations* may participate; *emergency position-indicating radiobeacon stations* may also participate in this service on designated distress and emergency frequencies.

1.81 *aeronautical station:* A *land station* in the *aeronautical mobile service*.

In certain instances, an aeronautical station may be located, for example, on board ship or on a platform at sea.

1.83 *aircraft station:* A *mobile station* in the *aeronautical mobile service*, other than a *survival craft station*, located on board an aircraft.

Based on that the basic regulatory scenario of the use of such links should be related to IMT systems deployed in the bands allocated to aeronautical mobile service. It should be noted that not all the bands identified for IMT have allocation to aeronautical mobile service. Therefore before the deployment of non-safety communications between base stations on ground and airborne user equipment the relevant compatibility studies should be performed to allow such use in some IMT bands. Situation in the IMT bands already allocated to AMS may be more favourable comparing to other bands.

Otherwise such use should follow provision **4.4** of the Radio regulations:

4.4 Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations.

To follow the principle "shall not cause harmful interference to, and shall not claim protection from harmful interference" may lead to limitation of deployment of such links within national territories at the appropriate distances from border of other countries unless agreement between the concerned administrations,

[Editor's note: it should be discussed to which extent this Report should address the compatibility and regulatory aspects noting that these issues have a great impact on the practical deployment of non-safety communications between base stations on ground and airborne user equipment supported by the terrestrial component of IMT]

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6 Technical and operational characteristics

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6.1 System architecture

6.2 Deployment and system characteristics

[Editor's note: This section includes the deployment and system parameters of terrestrial base stations, and the related parameters of UE served by base stations.]

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[7 Industry and scandalization activities on IMT ATG]

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The IMT ATG system is being standardized by the 3rd Generation Partnership Project (3GPP), a global initiative that develops telecommunications standards. The most recent technical report, 3GPP TR 38.876 V18.2.0, outlines the key specifications for ATG systems, including the use of IMT-2020 technology in this context. According to the report, the OBI (or ATG UE) is designed to function as customer premises equipment, which establishes and maintains the communication link between the aircraft and the terrestrial IMT base station. One of the primary challenges addressed by the 3GPP standards is the need to maintain a stable connection despite the high speeds and altitudes at which aircraft operate. To overcome this, IMT-2020 ATG systems make use of advanced techniques such as carrier aggregation, which allows multiple frequency bands to be used simultaneously, and seamless handover, which ensures that the connection remains uninterrupted as the aircraft moves between coverage areas.

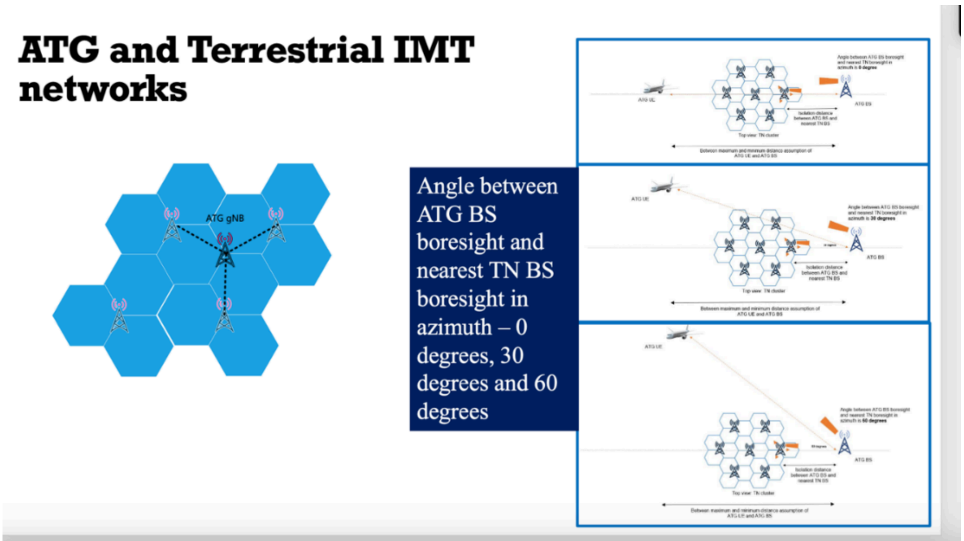
From various trials and commercial operation [https://inflight.telekom.net/ean/] of adapted LTE ATG solutions, the following characteristics are considered by the 3GPP for ATG network deployment scenarios.

a) Extremely large inter-site distance (ISD) and large coverage range: In order to control the network deployment cost and considering the limited number of flights, large ISD is preferred, e.g., about 100 km to 200 km. At the same time, when the plane is above the sea, the distance between the plane and the nearest base station could be more than

200 km and even up to 300 km. Therefore, ATG network should be able to provide up to 300 km cell coverage range.

b) Utilizing non-disjoint frequency for deploying both ATG and terrestrial networks, i.e. same operating band but ATG network and TN use adjacent carriers: Operators are interested to adopt the same frequency for deploying both ATG and terrestrial networks to save frequency resource cost, while interference between ATG and terrestrial networks becomes non-negligible and should be addressed.

c) Much powerful on-board ATG terminal capacity: On-board ATG terminal can be much powerful than normal terrestrial UE, e.g., with higher EIRP via much larger transmission power and/or much larger on-board antenna gain.



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[7 Challenges and future prospects]

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Despite the significant progress made in the development of IMT-advanced and IMT-2020 ATG systems, several challenges remain. One of the primary concerns is the availability of spectrum for ATG communications. As more devices and services compete for access to radio frequencies, ensuring that there is sufficient bandwidth for high-speed in-flight connectivity will be crucial. Another challenge is the cost of deploying ATG infrastructure. Installing base stations capable of communicating with aircraft at high altitudes requires significant investment, particularly in rural or remote areas where existing infrastructure may be lacking. Looking to the future, the continued development of IMT-2020 and beyond-IMT-2020 technologies promises to further enhance the capabilities of air-to-ground communication systems. With the potential for faster data rates, lower latency, and greater network reliability, these technologies will play a key role in meeting the growing demand for in-flight connectivity in the coming decades.

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8 Examples of National implementation on ATG

Technical characteristics and operational features of the systems for ATG in some countries in Region 1 are given in Annex 1.

Technical characteristics and operational features of the systems for ATG in some countries in Region 3 are given in Annex 2.

Note: The Annexes are provided by individual administrations for information purposes only.

9 Summary

Annex 1

Systems for public communications with aircraft in some countries in Region 1

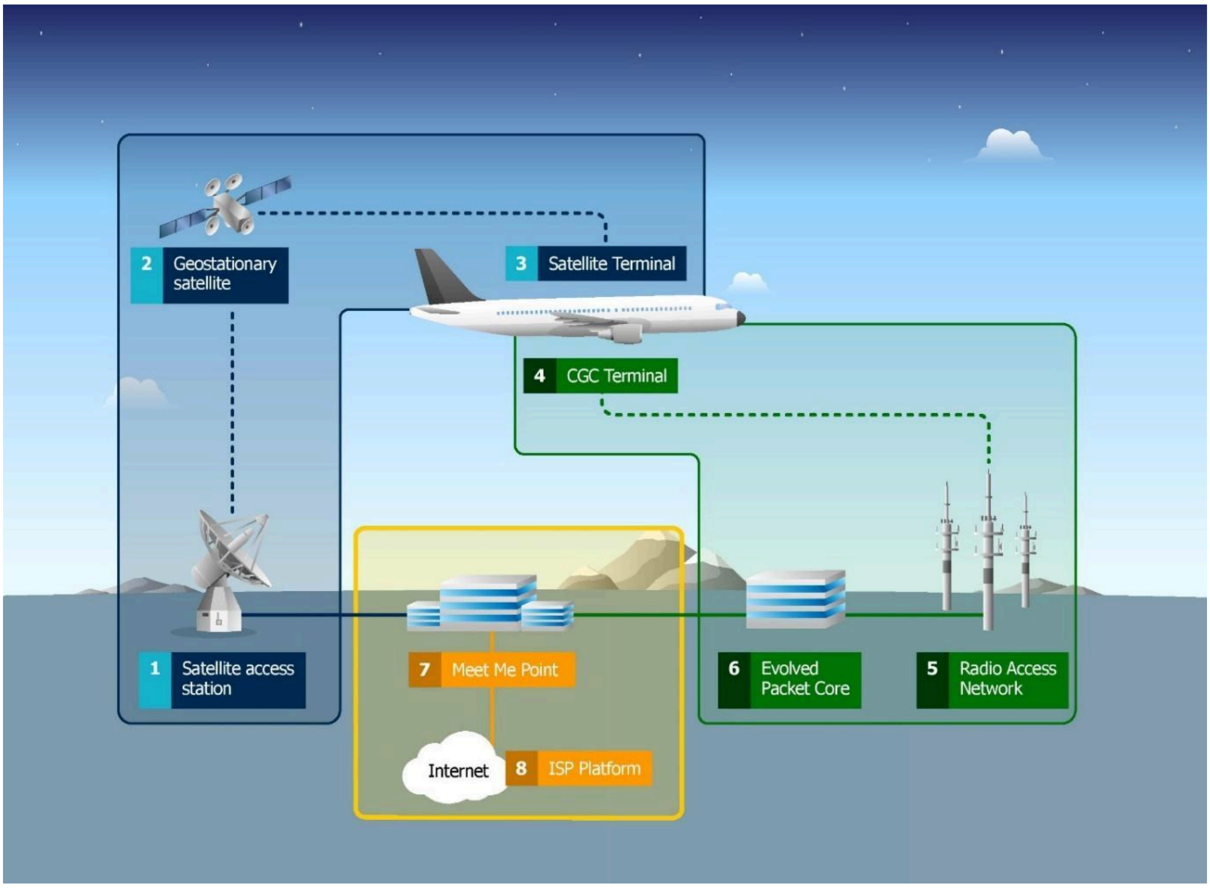
1 Broadband air-to-ground (ATG) systems within the European Conference of Postal and Telecommunications (CEPT)

1.1 European Aviation Network

The European Aviation Network (EAN) provides aerial broadband coverage across all 27 EU states and Switzerland, United Kingdom and Norway. As shown in Fig. A1-1 below, EAN is a hybrid system, with an MSS path and a broadband ATG terrestrial path configured for every aircraft. For the latter, a total of 300 Base Stations (BSs) have been deployed across the European continent.

FIGURE A1-1

European Aviation Network



NOTE – This Report only addresses the link between Base station on the ground and OBU/CGC terminal. The other portions of the figure are not relevant to this Report.

1.2 ATG of the EAN system architecture

The broadband ATG system is a complementary ground component of EAN and is based on 3GPP LTE Rel. 10+ specifications. In particular, synchronization algorithms of the OBU were modified compared to terrestrial mobile radio usage in order to cope with the high Doppler frequency shift caused by aircraft speed, and the Tx power was increased to enable very large cell sizes. In addition, the Ground Station (GS) antenna adjustment was matched to cover typical aircraft altitudes between 3 and 12 kilometres by adaptation of vertical diagrams including antenna up-tilt.

The major building blocks of the ATG radio link of the EAN system architecture are:

– broadband ATG network infrastructure on-board aircraft, e.g., OBU, interface to on-board network(s), external antenna, cabling;

– terrestrial radio access network for broadband ATG, consisting of BS that are configured with special ATG radio heads and antennas to establish high-performance radio links to aircraft. These GSs are deployed on elevated sites with clear line of sight to the horizon and are furnished with broadband backhaul links.

The other major building blocks of the ATG of the EAN system architecture are listed below, but are out scope of the report:

– service access network infrastructure on-board the aircraft, e.g., Wi-Fi coverage and Mobile Communications on board Aircraft (MCA), both already standardized and certified for on-board implementation;

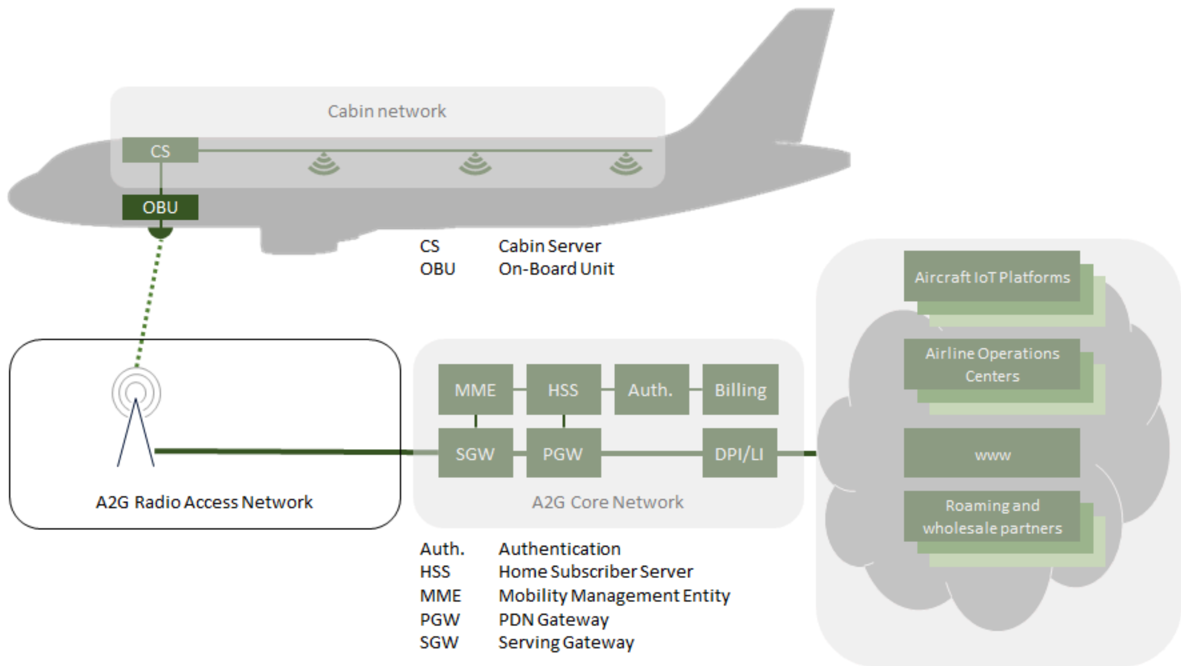
– dedicated mobile core network for session, mobility, subscriber and security management providing IP connectivity to external packet data networks (e.g., intranet, Internet, IP Multimedia Subsystem (IMS));

– central network components required for O&M, billing, etc. in the ATG network;

– various IP-based service delivery platforms, e.g., for passenger services or for airline or aircraft repair/manufacturer internal applications.

FIGURE A1-2

System architecture for the broadband ATG of the EAN system



NOTE – This Report only addresses the link between Base station on the ground and OBU/CGC terminal. The other portions of Fig. A1-2 are not relevant to this Report.

1.3 ATG of EAN spectrum aspects

EAN has been licenced by European countries under their national regulations to provide public communications with commercial aircraft operated within the European airspace. The authorisations are based on ECC Decision (06)09 — titled "On the designation of the frequency bands 1 980-2 010 MHz and 2 170-2 200 MHz for use by systems in the Mobile-Satellite Service including those supplemented by a Complementary Ground Component (CGC)" — as well as other applicable EC regulations. Under these authorisations, air-ground communications may make use of the frequency bands: 1 980-2 010 MHz / 2 170-2 200 MHz. Currently, paired spectrum of 2 × 15 MHz is licenced for EAN in 1 980-1 995 MHz for air-to-ground links and 2 170-2 185 MHz for ground-to-air links.

1.4 User experience

EAN is in live commercial operations since 2018. The system reset the benchmark for connectivity in the skies with regards to capacity, latency, per-aircraft throughput, network densification flexibility, aircraft retrofit time, aircraft retrofit cost, and cost per bit.

Key properties of the ATG of the EAN system include:

– the radio link between the BS and the OBU in the aircraft is established at distances of up to 150 kilometres from the sites to the aircraft, with aircraft flying at speeds up to 1 200 km/h and altitudes up to 12 000 metres;
– peak data rates of up to 100 Mbit/s in the forward link (ground-to-air) and 30 Mbit/s in the reverse link (air-to-ground), as well as round-trip times of less than 50 milliseconds are consistently being achieved;
– cell ranges are designed in consideration of local air traffic densities, spanning from 30 kilometres around the major aviation hubs to 150 kilometres in sparsely flown areas;
– the traffic mix is dominated by streaming applications and messaging applications; thus the user behaviour resembles that of terrestrial services.

2 Broadband Air-to-Ground (ATG) systems within Saudi Arabia

2.1 Introduction

A broadband air-to-ground (ATG) system constitutes an application for various types of telecommunication services, such as Internet access and mobile multimedia services, during flights. It aims to provide access to broadband communication services during domestic and regional flights. With 200 million air passengers annually, the Middle East is one of the largest aviation markets and home to some of the largest airlines worldwide.

The main application field is Air Passenger Communications (APC). In addition, a broadband ATG system can also support Airline Administrative Communications services (AAC) and thus improve aircraft operation. Safety-relevant communications such as Air Traffic Control (ATC) and related services are not intended to be covered.

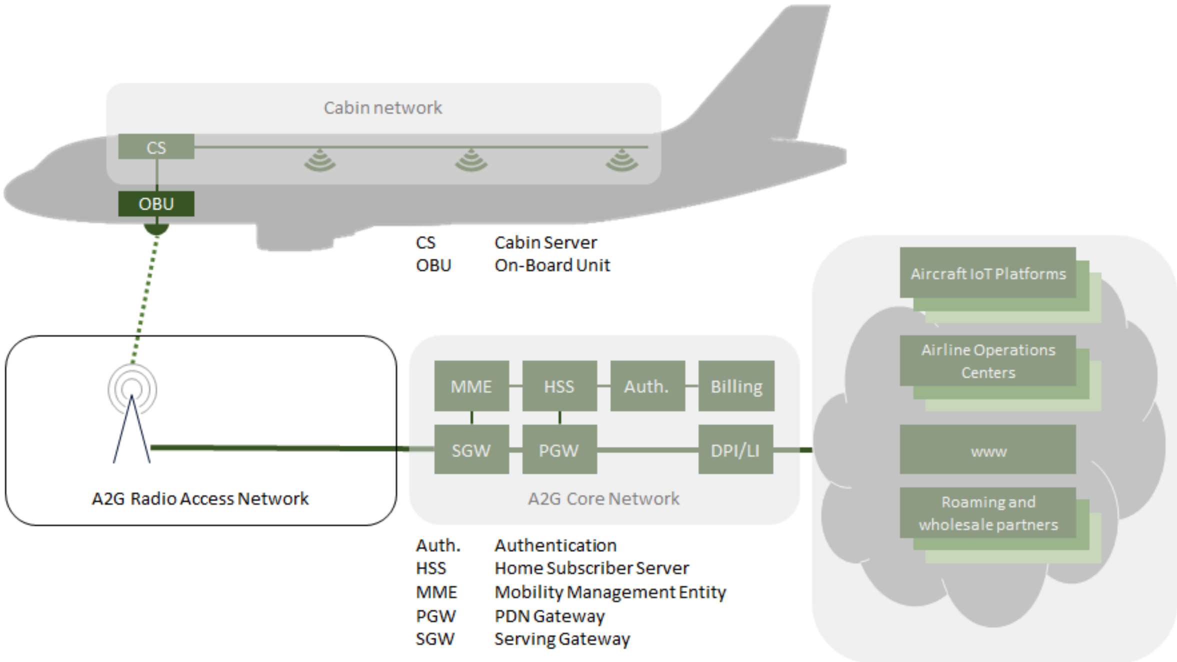
2.2 ATG system architecture

The ATG system is based on 3GPP LTE Rel. 10+ specifications. In particular, synchronization algorithms of the OBU are modified compared to terrestrial mobile radio usage in order to cope with the high Doppler frequency shift caused by aircraft speed, and the Tx power is increased to enable very large cell sizes. In addition, the GS antenna adjustment is matched to cover typical aircraft altitudes between 3 and 12 kilometres by adaptation of vertical diagrams including antenna up-tilt.

The major building blocks of the ATG system within Saudi Arabia are the same as and shown in Fig. A1-3.

FIGURE A1-3

System architecture for the broadband ATG system



2.3 Spectrum aspects in Saudi Arabia

In April 2021, the Communications, Space and Technology Commission (CST) of Saudi Arabia has launched its Spectrum Outlook for Commercial and Innovative Use 2021-2023[2]. The spectrum outlook details Saudi Arabia's path to becoming a world leader in radiocommunication and wireless technologies by attracting investments, meeting current data and connectivity demands, and proactively anticipating future needs. Correspondingly in this outlook, CST aims to leverage innovation in spectrum management by expanding its range of resources and services, while ensuring the digital ecosystem is ready to unlock its full potential. Drafting this outlook followed a transparent and collaborative process that involved public consultation and engagement with more than 65 wireless technology organizations from different 20 countries. The broad aim of this Spectrum Outlook is to adopt a range of measures to provide transparency and predictability for all spectrum users in the Kingdom, providing spectrum users certainty over the amount of spectrum available in different bands. One of these measures referred to the release of the bands 1 980-2 010 MHz and 2 170-2 200 MHz in a technology-neutral auction in 2021, which acknowledges industry interest to deploy a ATG system in these bands.

2.4 ATG trial network and test flights in Saudi Arabia

In 2018, Saudi Arabia was the first country in the Middle East to deploy a ATG system for trial purposes. A total of 10 ATG BSs and a dedicated ATG core network were deployed to cover the air routes between Riyadh and Jeddah, which is the busiest city pair with regards to domestic air travel.

[2] Spectrum Outlook for Commercial and Innovative Use 2021-2023, CST (2021).

The system architecture of the ATG trial system was a subset of the system architecture described above, including the same bands 1 980-1 995 MHz and 2 170-2 185 MHz for FDD operation. A test aircraft was equipped with Wi-Fi access network infrastructure and ATG network infrastructure (OBU) and flown for 10,000 kilometres on different routes between Riyadh and Jeddah during a structured flight test campaign.

Key results of the trial included:

– downlink (ground-to-aircraft) throughput above 90 Mbit/s and uplink (aircraft-to-ground) throughput above 30 Mbit/s;

– round trip time (RTT) of less than 50 milliseconds;

– various high-bandwidth-low-latency applications demonstrated, e.g., video conferencing, OTT video, social networking, and enterprise applications with VPN;

– live high-definition video conference between the test aircraft and an exhibitor's booth at the GITEX 2018 exhibition in Dubai;

– maximum distance between BS and aircraft 120 kilometres.

In 2022, a first regular commercial aircraft of an airline (Airbus A321) was equipped with a ATG system and received certification by the General Authority of Commercial Aviation. Flight test results were consistent with the results of the trial in 2018. The aircraft was not dedicated to a test campaign but flew on its regular route schedule and automatically connected to the network whenever reaching the coverage area. The results were publicly shared at the "Connecting the World from the Skies" event, that was organized by ITU and CST.

2.5 Spectrum award for ATG in Saudi Arabia

In November 2022, Saudi Arabia conducted an auction for the band 1 980-1 995 MHz and 2 170-2 185 MHz to provide air-to-ground (ATG) services across the kingdom's airspace.

These ATG services are scheduled to be commercially launched and made available on aircraft by the second quarter of 2025.

Annex 2

Systems for ATG in some countries in Region 3

1 Air-to-ground communication system based IMT-2020 in China

1.1 Introduction

On 6 January 2020, the focus of the 2020 National Civil Aviation Work Conference clearly required "to strengthen smart civil aviation research and accelerate the promotion and application of new technologies". The development of ATG service needs the cooperation of basic service resources such as wireless spectrum, BS address and transmission network. In order to effectively save spectrum resources, make full use of wireless network resources of operators, and reuse existing frequencies with ground mobile communication service, the appropriated choice is to carry out ATG ground-air communication service.

Meanwhile, according to the 2017 Statistical Bulletin on the Development of the Civil Aviation Industry issued by the Civil Aviation Administration of China in May 2018, the passenger traffic volume of the whole industry in 2017 was 551.56 million, an increase of 13.0% over the previous year, and the passenger traffic volume of domestic routes was 496.11 million, an increase of 13.7% over the previous year. It is estimated that the number of domestic air passengers will exceed 1.2 billion in 2025, as shown in Table A2-1.

TABLE A2-1

Forecast of civil aviation broadband communication in China

Year	2020	2021	2022	2023	2024	2025
Number of Civil aircraft	4 039	4 524	5 067	5 675	6 356	7 118
Passenger（Million）	69.312	77.630	86.645	97.379	109.064	122.152

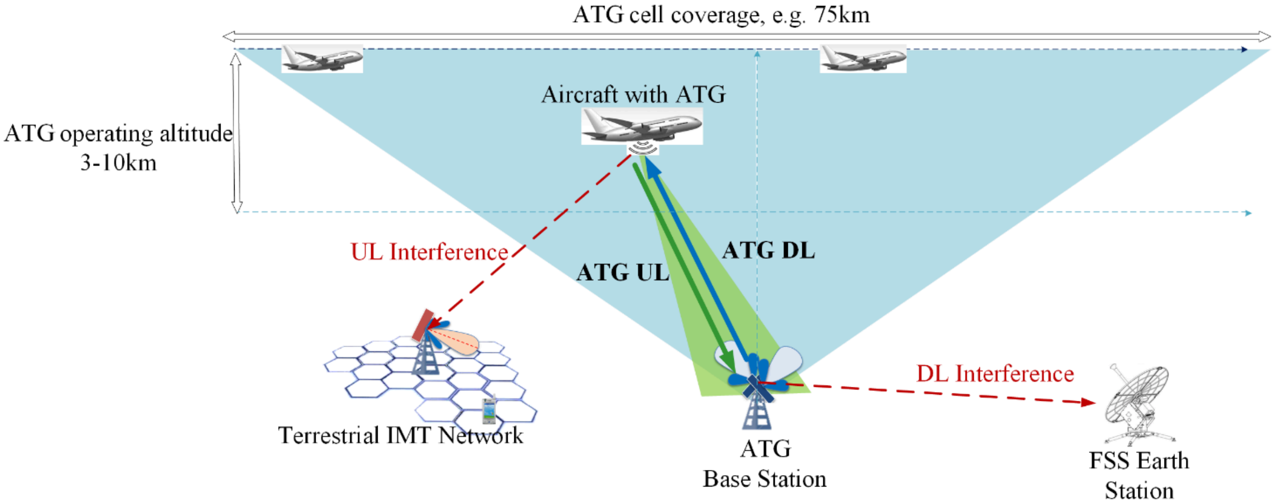
1.2 Spectrum aspect in China

The candidate frequency bands currently planned for ATG system are 1.9 GHz for ATG Uplink; 3.5 GHz for ATG Downlink in China.

ATG network architecture and interference scenarios are shown in Figure A2-1. In ATG network, ATG ground BSs are deployed to provide connectivity for aircraft. As seen in Figure A2-1, downlink (DL) of ATG system is defined as a communication link from base station on the ground to OBU of the aircraft. Moreover, regarding aircraft aspects, it can be seen as mobile terminals in ATG network, mainly operates approximately up to 10 km in the altitude level. Possible interference scenario between ATG DL and fixed-satellite service (space-to-Earth) can be considered; while other interference scenarios is for further study.

FIGURE A2-1

An example of ATG network architecture and interference scenarios



Therefore, China is researching that frequency range 1.9 GHz, or portions thereof, could be developed for ATG UL; while frequency range 3.5 GHz, or portions thereof, could be applied to ATG DL. It is notable that 3.5 GHz is necessary to improve its spectrum efficiency, thus expending ATG area is an excellent attempt to enhance frequency utilization of 3.5 GHz.

1.3 Operational and technical aspects in China

Operators in China are planning to develop ATG network for future commercial operation. Take China Telecommunications Corporation (China Telecom) for example. Since 2014, China Telecom has cooperated with China Eastern Airlines, China Southern Airlines, Xiamen Airlines, Hainan Airlines and Air China to provide aviation Internet services for China Airlines flights worldwide. Additionally, regarding China Mobile Communications Corporation, it will sign aviation airborne communication framework cooperation agreements with Air China, China Eastern Airlines, China Southern Airlines, Xiamen Airlines and other enterprises to create a new upgrade experience of Internet plus civil aviation.

The 3.5 GHz band ground-to-air transmission of the ATG BS is realized by a 3.5 GHz band active antenna processing unit (AAU). The 3.5 GHz frequency band is only used for one-way ground-to-air transmission, not for air-to-ground reception. See Table A2-2 for the 3.5 GHz band index of the ATG BS.

TABLE A2-2

Example on ATG BS system parameter

Parameters	Values
Frequency band	3.5 GHz
System bandwidth	100 MHz
Resource block (RB)	273
Subcarrier spacing (SCS)	30 kHz
Antenna uptilt	15°
Number of antenna ports	64
Type of polarization	dual-polarization
TRP	200 W
Antenna element gain	10 dBi

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