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| **Radiocommunication Study Groups** |  |
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| Annex 4 to Working Party 5A Chairman’s Report | |
| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT  NEW REPORT ITU-R [LMS.ATG] | |
| Systems for public mobile communications with aircraft | |

# 1 Introduction

This report deals with the general principles, technical characteristics and operational features of terrestrial systems for public mobile communications with aircraft.

# 2 General operational considerations

2.1 The system should be fully compatible and capable of interfacing with the international public switched telephone network, public data network and simple in operation.

2.2 The system should have adequate bandwidth to meet the foreseeable demand for the services.

2.4 The Quality of Service should be comparable to that of the public switched network (voice and data).

2.5 The system should provide, in so far as possible, uninterrupted coverage throughout the designated service areas with the capability of coordinated operation across national borders.

2.6 The airborne equipment must be electromagnetically compatible with other aircraft systems in accordance with appropriate regulatory requirements and should have minimal impact on aircraft engineering, maintenance and operations.

2.7 The system must have no adverse influence on the safe operation of the aircraft.

# 3 System technical characteristics and operational features

*[Editorial Notes: We may need to change the titles of annexes as “Examples of systems for public mobile communications with aircraft in regions X, Y etc. to cover more countries. If it is strictly national systems, it may not be strictly appropriate for ITU.]*

3.1 System technical characteristics and operational features of the terrestrial system currently being deployed in Canada are given in Annex 1.

3.2 System technical characteristics and operational features of the terrestrial wireless broadband correspondence system with aircraft to be deployed in China are given in Annex 2.

3.3 Propagation and Doppler shift effects on a terrestrial air-to-ground system are given in Annex 3, which provides useful information for design of systems for public mobile communications with aircraft.

ANNEX 1

System for public communications with aircraft in Canada

In Canada, the band pair 849-851 MHz and 894-896 MHz is allocated to the aeronautical mobile service for public correspondence with aircraft[[1]](#footnote-1). Furthermore, the designation of this spectrum includes air-ground radiocommunication applications such as voice telephony, broadband Internet and data transmission.

The band plan, described below in Fig. 1, 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.



The technical rules for certification and systems deployment in the band in Canada are technology neutral. The maximum ERP limits for ground stations and airborne stations are as follows:

– Ground Station: 500 W ERP

– Airborne Station: 12 W ERP

The systems will be deployed using a cellular topology based on frequency reuse. The cell size and separation are dictated by the minimum and maximum flight altitudes of the serviced aircraft. Each ground station has an operating radius up to the radio horizon distance, which depends on the aircraft’s altitude – for example about 480 km for 13 700 metres.

Actual cell separations are influenced by additional issues such as ground station altitudes and antenna heights, fading margins, knowledge of aircraft locations, and topological considerations. These considerations together with traffic requirements represent some of the inputs required for the radio network planning of the air-ground network.

ANNEX 2

System for public communications with aircraft in China

# 1 Introduction

To meet the growing demand of the current and future airborne broadband communication, China has made significant effort on planning, developing, and deploying the Ground-to-Air (GTA) communication systems with aircraft. The system 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. The base stations deployed to cover the entire flight course and communicate with the airborne terminals to achieve broadband communication between the ground and airplanes. The prototype systems have been successfully tested in trial flights at the frequency range of 1.785-1.805 GHz. The system’s GTA (Ground-To-Air) broadband communication capability has been successfully tested in China.

# 2 Operational features

The system operational features are as follows:

– Automatically connecting to the terrestrial broadband wireless network to provide ground-to-air communications.

– Supporting the voice, trunked voice and broadband data communication services such as providing backhaul of the on-board WiFi, cellular pico-cells, and on-board wireline voice calls and internet access.

– Supporting the seamless communication roaming and handoff on the complete flight course.

# 3 System architecture

The basic system architecture is shown in Fig. 1:

The system functions are as follows:

– The system includes base stations (BTS) on the ground connected to PTSN, internet and airborne terminals with interfaces to other on-board devices such as wireline hubs, WiFi routers, pico-cells, among others.

– The radio access layer provides the radio access functions between the BTS and airborne terminals. The radio access layer performs basic radio access functions such random access, paging, voice communications, data communications and trunked voice functions.

– The core control layer provides the control functions, such as handoff, roaming, terminal and user authentication, voice call switching, and data routing. It is between the BTS and other core network equipment such as data switches and routers, soft switches, media gateways, AAA (Authentication, Authorization, and Accounting) servers, billing servers, and HLR (Home Location Register).

– This entire GTA communication network including all layers supports separation of different data flows and also provides adequate protection on the data.

Figure 1

System Architecture



ANNEX 3

*[Editorial Notes: This information is out-of-date and needs to be updated. We need to add more channel propagation models for frequencies higher than 800 MHz.]*

Propagation and Doppler effects in a terrestrial air-to-ground system

# 1 Air-to-ground propagation model

The basic air-to-ground propagation model consists of two paths between the transmitter and the receiver (see Fig. 1). One path is the direct line-of-sight (LOS) path and the other is one reflected from the Earth's surface. At the receiver, the direct and reflected signals add constructively and destructively, [Kirby, R.S et al, 1952], depending on the phase difference between the two signals which results from the ground reflection and the refractivity profile of the atmosphere. When the aircraft is within a few miles from the base station, the separation between fades is in the order of a second with linear dependence on frequency, [Painter, J.H. et al, 1973]. Higher fading rates can be encountered in very special cases due to reflections geometry.

The magnitude of each fade is affected by the ground characteristics in the reflection region, the incidence angle and the reflected angle. The ground conductivity is generally a function of frequency with the consequence that higher frequency causes larger reflection coefficient, [Report 238-4 (Geneva, 1982)].

The ground reflection is affected by the shape and the roughness of the reflection surface in the first Fresnel zone, which is, in the present case, the intersection between the first Fresnel ellipsoid for the reflected ray and the ground. The size of the first Fresnel zone is frequency dependent.

The ground distance between the base station and the reflection point is roughly equal to the aircraft ground distance scaled down by the ratio of the height of the base station antenna (h1) to the aircraft altitude (h2). As the aircraft moves, the reflection point moves at a much reduced velocity (by a factor approximately equal to hl/h2).

The distribution of power between the specula and diffuse components of the signal depends on the terrain roughness correlated with the transmitted frequency. Doubling the frequency corresponds to raising the scattering coefficient to the fourth power, decreasing the power of the specula reflection, and increasing the power of the diffuse component. Thus, the total received signal shows smaller fades caused by specular reflections but larger fluctuations due to the diffuse component when frequency is increased. The fading rate of the signal fluctuations due to the diffuse component is related to the coherence distance of the irregularities on the ground and to the velocity of the Fresnel zone on the ground and therefore is not affected by changes in the transmitted frequency.

The Earth’s atmosphere affects the propagation at UHF in mainly two ways: refraction and diffraction. The refraction, or ray bending, of UHF waves is due to gradients in the refractive index of the atmosphere. In what is called the standard atmosphere, the refractive index decreases linearly with altitude and as a result, the rays are bent downward over the spherical Earth. Using the approximation of 4/3 earth radius (CCIR Recommendation 528), the rays may be considered straight. A correction can be made to account for variations due to altitude and atmospheric refractive index, (Robertshaw, G.A., 1986).

The atmospheric variations in temperature, pressure and humidity affect the ray paths and consequently the phase of the signal. However, for the purpose of providing reliable air-to-ground communication, the exact location of the fades is less important than the fact that these fades exist. It is not critical to consider the exact profiles of the atmospheric refractive index and free space propagation can be assumed. The refractive effect of the Earth’s atmosphere is adequately taken into account using the effective earth radius method, [Robertshaw, G. A., 1986].

The diffraction effects of the atmosphere are due to scattering by turbulence in the troposphere and abnormal atmospheric conditions. At 850 MHz the scattered power is negligible compared to the received power. Thus, the scattering effects of the atmosphere can be neglected when there is a radio line-of-sight path which is determined by refractive effects.

The airborne antenna, attached at the bottom of the aircraft, acts as a half-wave dipole. The base station antenna is also assumed to be a half-wave dipole. The airborne antenna is located to minimize signals reflected from the aircraft surface.

The antenna directivities can cause small signal fluctuations as the aircraft moves because of the change in angles between the ray paths and the antennas. The airborne antenna is expected to be the principal contributor to this effect because the aircraft causes multiple reflections which modify the simple pattern of the ideal half-wave dipole antenna. The fluctuations of the received signal due to the antenna patterns are expected to be rather slow since the inertia of the plane limits its movements. Furthermore, the angles between the ray path and the antennas change slowly. The amplitude of these fluctuations depends on the antenna pattern. The largest fluctuations are expected when an aircraft engine (or other obstacles) shadows the paths between the airborne and base site antennas.

Figure 2 shows a received signal performance corresponding to the two paths model, as the aircraft moves away from the base station.

As frequency increases from 860 MHz to 1 600 MHz for example, the predominant effect is tree-space loss, with somewhat deeper fading due to larger ground conductivity and more specula reflection. Larger apparent terrain roughness, due to shorter wavelength offsets the larger fades due to larger scatter loss for the reflected signal. Near and beyond the radio-horizon the reflected signal becomes shadowed so that the model has to be modified to apply in these regions.

# 2 Effects of Doppler shift

Doppler shift has a considerable effect on the air-to-ground system design and complexity. Taking maximum aircraft speed to be 600 miles per hour, and operating frequency to be 850 MHz, then maximum Doppler shift is experienced by an aircraft flying on a base site radial at maximum aircraft speed, and is 760 Hz.

Conflicting Doppler shifts can cause interference both between two aircraft operating on a common base site, and between aircraft operating on adjacent base sites, where the Doppler shift is a large percentage of the channel bandwidth. If an aircraft flying toward the base site is operating on a channel, and an aircraft flying away from the base site is operating on the next higher channel, then the aircraft on the lower channel has up-Doppler at the base site, and the aircraft on the higher channel has down-Doppler at the base site. The received signals can overlap, causing interference at the base site. There is no equivalent interference effect on the uplink, since each aircraft experiences equal Doppler from all transmissions from a base station. Similarly, Doppler induced adjacent channel interference occurs at adjacent base sites.

There are ways to avoid these two forms of Doppler induced adjacent channel interference including using a guard band between adjacent channels greater than the maximum Doppler shift, or prohibiting adjacent channel assignments both within cells, and between adjacent cells.

Using either of these approaches leads to a serious decrease in bandwidth efficiency. A third approach precompensates for the Doppler shift at the aircraft transmitter. If the aircraft has an accurate measure of the received Doppler shift, it can apply the opposite shift (corrected for duplexing frequency offset) on the transmit. As a result of this precorrection, the signal received at the base site will be in the correct frequency band.

Doppler precompensation cannot compensate for adjacent site Doppler induced adjacent channel interference, however. Aircraft applying similar Doppler precorrections to compensate for co-site Doppler effects, will still have conflicting Dopplers at a mutually adjacent base site.

These three approaches apply with both single channel per carrier systems (SCPC) as well as multiple signals per carrier (e.g. Time Division Multiple Access) systems. With TDMA there are some additional considerations. In general, several aircraft with different Dopplers would be occupying time slots on a single carrier at a base site. If the guard band approach is taken, then it is necessary only to provide two guard bands around each TDMA carrier, so that the effects of the guard band are shared between the N voice channel time slots using that carrier. Making N large minimizes the effect of the guard bands. However, this approach imposes the burden of tracking up to N different Dopplers on the base site receiver with increased complexity as the tracking range increases due to higher frequencies. The Doppler precompensation approach can be used to eliminate the need for guard bands and mitigate the base site carrier recovery problem. The base site receiver will still have to deal with residual carrier offset between aircraft in different time slots.

REFERENCES

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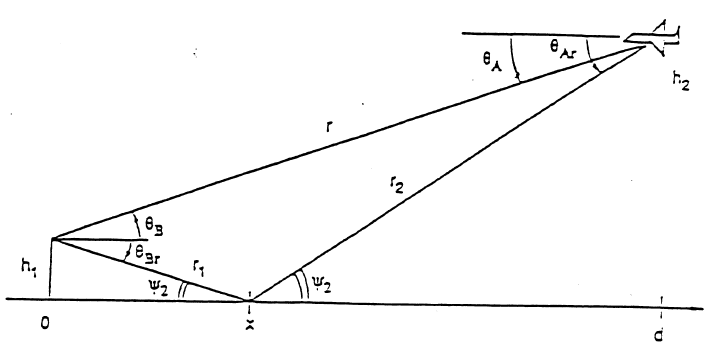
PAINTER, J.H., GUPTA, S.C. and WILSON, L.R [May，1973] - Multipath Modelling for Aeronautical Communications, IEEE Trans on Comm. PP 658-662.

ROBERTSHAW, G.A. [September, 1986] -Effective Earth Radius for Refraction of Radio Waves at Altitudes Above 1km, IEEE Trans. AP-34(9), pp. 1099-1105.

Two paths air-ground propagation model:

Figure 1

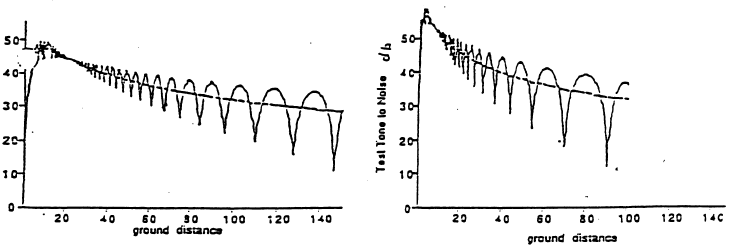
Geometry and notation for the air-to-around propagation model



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| hl=60 ft Medium dry ground | | hl=60 ft Medium dry ground |
| h2=30,000ftr.m.s.roughness=0.100 ft | h2=30,000ftr.m.s.roughness=0.100 ft |
| Freq=849.0 MHz half-wave dipole | Freq=849.0 MHz half-wave dipole |

Figure 2

Comparison between calculated received signal patterns for two different altitudes using   
half-wave dipole antennas at the base station



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1. Refer to <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09134.html> [↑](#footnote-ref-1)