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Annex 33 to Joint Task Group 4-5-6-7 Chairman's Report

PRELIMINARY DRAFT NEW
REPORT ITU-R M.[AERO-IMT.SHARING.C-BAND]

Sharing and compatibility studies between aeronautical mobile[/ground mobile] applications and potential IMT systems in the 4 400-4 990 MHz band

1 Introduction

This Report provides sharing and compatibility studies between aeronautical mobile/ground mobile applications and potential IMT systems in the 4 400-4 990 MHz band.

2 Related ITU-R Recommendations and Reports

Recommendation ITU-R M.1459:	"Protection criteria for telemetry systems in the aeronautical mobile service and mitigation techniques to facilitate sharing with geostationary broadcasting-satellite and mobile-satellite services in the frequency bands 1 452-1 525 MHz and 2 310-2 360 MHz"
Report ITU-R M.2118:	"Compatibility between proposed systems in the aeronautical mobile service and the existing fixed-satellite service in the 5 091-5 250 MHz band".
Report ITU-R M.2119:	"Sharing between aeronautical mobile telemetry systems for flight testing and other systems operating in the 4 400-4 940 and 5 925-6 700 MHz bands"
Report ITU-R M.2292:	"Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses"

3 Allocation information

Table 1 lists the allocations contained in Article **5** of the Radio Regulations (RR) (Edition of 2012) together with the associated footnotes for the mobile service in the frequency range 4 400-4 990 MHz.

TABLE 1

Frequency allocations in the 4 400-4 990 MHz

Allocation to services		
Region 1	**Region 2**	**Region 3**
4 400-4 500	FIXED MOBILE 5.440A	
4 500-4 800	FIXED FIXED-SATELLITE (space-to-Earth) 5.441 MOBILE 5.440A	
4 800-4 990	FIXED MOBILE 5.440A 5.442 Radio astronomy 5.149 5.339 5.443	

5.440A In Region 2 (except Brazil, Cuba, French overseas departments and communities, Guatemala, Paraguay, Uruguay and Venezuela), and in Australia, the band 4 400-4 940 MHz may be used for aeronautical mobile telemetry for flight testing by aircraft stations (see No. 1.83). Such use shall be in accordance with Resolution 416 (WRC**-07) and shall not cause harmful interference to,** nor claim protection from, the fixed-satellite and fixed services. Any such use does not preclude the use of this band by other mobile service applications or by other services to which this band is allocated on a co-primary basis and does not establish priority in the Radio Regulations. (WRC-07)

5.442 In the bands 4 825-4 835 MHz and 4 950-4 990 MHz, the allocation to the mobile service is restricted to the mobile, except aeronautical mobile, service. In Region 2 (except Brazil, Cuba, Guatemala, Paraguay, Uruguay and Venezuela), and in Australia, the band 4 825-4 835 MHz is also allocated to the aeronautical mobile service, limited to aeronautical mobile telemetry for flight testing by aircraft stations. Such use shall be in accordance with Resolution **416 (WRC-07)** and shall not cause harmful interference to the fixed service. (WRC-07)

4 Technical characteristics used in technical studies

4.1 System characteristics of aeronautical mobile applications

The system characteristics of aeronautical mobile applications evaluated in the document are summarized in Table 2.

TABLE 2

System characteristics of aeronautical mobile applications in each technical study

(a) Study #1 (Annex 1): based on AMT

Parameter	Value
Aircraft antenna pattern	Omni-directional
Peak aircraft antenna gain (dBi)	3
Average aircraft antenna gain (dBi)	–4.8
Maximum aircraft e.i.r.p. density (dB(W/MHz))	–2.2
Average aircraft e.i.r.p. density (dB(W/MHz))	–10.0
Peak aircraft antenna input power density (dB(W/MHz))	–5.2
Ground receiver antenna aperture (m)	2 to 5
Ground receiver antenna pattern	Rec. ITU-R F.1245
Ground receiver antenna height (m)	30
Ground antenna elevation angles (degrees)	0-20
Nominal permissible long-term interference at receiver antenna output (dBW/MHz to be exceeded for no more than 20% of the time)	–145.5
Nominal permissible short-term interference at receiver antenna output (dBW/MHz to be exceeded for no more than 0.4% of the time)	–142.5

(b) Study #2 (Annex 2): based on Unmanned Aircraft Vehicle

Parameter	Value
Bandwidth (MHz)	1
Thermal noise (dBm)	–110
Antenna height (m)	0 to 10000
Antenna type and gain	Omnidirectional 3dBi
Protection criterion	I/N=–6dB

(c) Study #3 (Annex 3): based on AMS and AMT

Station Type	AMS Airborne	AMS Ground	Mobile Ground	Mobile Transportable	AMT Ground
Bandwidth (MHz)	10	10	18.5	2.46	10
Modulation	OQPSK	OQPSK	BPSK	OQPSK	Digital
Antenna gain (dBi)	7.2	3	4	24	40
Antenna pattern	Omni-directional	Omni-directional	Omni-directional	Rec. ITU-R F.1245, 0° elevation, 360° azimuth	Rec. ITU-R F.1245, 0° elevation, 360° azimuth
Antenna height above ground (m)	2,400 19,000	10	2	10	30
Noise figure (dB)	4.5	4	3	4	T_{system}=250 K
Interference threshold I/N (dB)	-6	-6	-6	-6	-4

4.2 IMT system characteristics

The IMT system characteristics used in the technical studies contained in the document are based on Report ITU-R M.2292 “Characteristics of terrestrial IMT-Advanced systems for frequency sharing/interference analyses”. Details of the technical characteristics employed in the respective studies are contained in the corresponding Annexes.

5 Interference scenarios considered in each technical study

Table 3 summarizes interference scenarios considered in each technical study

TABLE 3

Interference scenarios considered in each technical study

<table>
<tr><th colspan="2">Interference</th><th rowspan="2">Study #1 (Annex 1)</th><th rowspan="2">Study #2 (Annex 2)</th><th rowspan="2">Study #3 (Annex 3)</th></tr>
<tr><th>From</th><th>To</th></tr>
<tr><td>IMT station</td><td>Ground station</td><td>YES
• IMT macro cell base station and IMT outdoor user equipment
• Adjacent-channel interference (single-entry)</td><td>–</td><td>YES
• IMT macro cell base station and user equipment
• Co-channel interference (single-entry and aggregate)</td></tr>
<tr><td>IMT station</td><td>Airborne station</td><td>–</td><td>YES
• IMT macro cell base station
• Co-channel interference (single-entry)</td><td>YES
• IMT macro cell base station
• Co-channel interference (single-entry and aggregate)</td></tr>
<tr><td>Ground station</td><td>IMT station</td><td>–</td><td>–</td><td>–</td></tr>
<tr><td>Airborne station</td><td>IMT station</td><td>–</td><td>–</td><td>–</td></tr>
</table>

6 Summary of results in each technical study

Table 4 shows summary of results in each technical study in terms of required separation distances to achieve co-existence between aeronautical mobile applications and potential IMT systems.

TABLE 4

Summary of results in each technical study in terms of required separation distance

Study #1	With regard to the IMT (using 61 dBm e.i.r.p., already including feeder loss) interfering into AMT ground station receiver using the assumed operating parameters, such as antenna gain, for this Study in the band 4 400-4 500 MHz and 4 800-4 990 MHz the following observations may be reached: • For adjacent channel interference, with 43.6 dB frequency off-set factor, the separation distance is 4.7 kilometres (for 4 800-4 990 MHz) to 5.2 kilometres (for 4 400-4 500 MHz) for long-term interference between a single IMT macro cell base station and AMT ground receiver based on Recommendation ITU-R P.452-15 (p = 20%) with no terrain; • For adjacent channel interference, with 43.6 dB frequency off-set factor, the separation distance is 3.3 kilometres (for 4 800-4 990 MHz) to 3.7 kilometres (for 4 400-4 500 MHz) for short-term interference between IMT macro cell base station and AMT ground receiver based on Recommendation ITU-R P.452-15 model (p = 0.4%) with no terrain; • For adjacent channel interference, with 43.6 dB frequency off-set factor, the separation distance is 40 to 60 metres for long-term interference and short-term interference between IMT outdoor user equipment and AMT ground receiver based on Recommendation ITU-R P.452-15 model (p = 20% and p = 0.4%) with no terrain;
Study #2	• For separation distances between IMT base station and airborne receiver close to 400 km based on a free-space propagation model, it is shown that IMT base stations e.i.r.p. levels are restricted to 38.8 dBm/MHz for one single interferer.
Study #3	• Under co-channel interference conditions, and using the assumed operating parameters, such as aircraft operating altitude, for this Study in the case of protecting airborne station receivers from IMT base station interference, the required single entry separation distances vary between 162 km for an aircraft at 2 400 m altitude to 509 km at 19 000 m altitude. Aggregate interference analyses indicate that base station operations may be precluded within a distance of 446 km from the aircraft encompassing an area of about 623 318 km^2 when the aircraft is at 2 400 m altitude. For an aircraft at 19 000 m altitude, the corresponding distance and area are greater than 706 km and 1.5 million km^2, respectively. • Under co-channel interference conditions, separation distances between about 300 to 500 km may be required to satisfy the aggregate I/N protection requirement of ground based stations in the mobile service from IMT base stations without consideration of terrain. The area within which aggregate interference from IMT user equipments exceeds the mobile service receiver interference threshold will be smaller than the corresponding exclusion area identified for a base station.

7 Conclusions

This Report provides sharing and compatibility studies between aeronautical mobile / ground mobile applications and potential IMT systems in the 4 400-4 990 MHz band. The results of studies would be summarized as follows:

– For co-channel interference, one sharing study show large separation distances are required to protect certain types of aeronautical mobile service stations. In the case of protecting airborne station receivers from a single IMT base station interference, the separation distances vary between ranges from 162-509 km for aircraft altitude at 2.4 km and 19 km respectively. In the case of protecting airborne station receivers from IMT base station aggregated interference, the separation distances range from 446-706 km for aircraft altitudes at 2.4 km and 19 km respectively. In this case, the corresponding protection zones encompass an area of about 623 318 km^2 and

1.5 million km^2, respectively. Based on this analysis, co-channel sharing between aeronautical mobile applications and IMT systems in the 4 400-4 990 MHz is not practical in the geographic areas located within the exclusion zones required up to 706 km.

– Also for co-channel interference, another sharing study shows large separation distances are required to protect certain types of aeronautical mobile service stations. For separation distances between IMT base station and airborne receiver close to 400 km based on a free-space propagation model, it is shown that IMT base stations e.i.r.p. levels need to be restricted to 38.8 dBm/MHz for one single IMT base station interferer to protect airborne receiver.

– For adjacent channel interference, one study shows the separation distance required to protect one of three mobile ground receivers (i.e., AMT ground receiver) is approximately 5 km, with assuming a 43.6 dB frequency off-set factor. [The adjacent channel study assumes that incumbent systems for aeronautical/ground mobile applications do not use the entire 4 400-4 990 MHz band and there could be free spectrum available to implement potential IMT system using the adjacent channel solution in this band. If systems in incumbent services, the fixed and mobile services, currently use the entire band, the use of adjacent channel solution would result in loss of spectrum for these services, which may impact operations and future planning for the incumbent services.]

Annexes: 3

ANNEX 1

STUDY #1

Adjacent band compatibility studies between potential IMT system and aeronautical mobile telemetry ground system in the frequency bands 4 400-4 500 MHz and 4 800-4 990 MHz

1 Introduction

1.1 Scope and objective

Fixed service and mobile service are the primary allocation in the frequency bands 4 400-4 500 and 4 800-4 990 MHz, and point-to-point fixed wireless system is the major application service in the frequency bands. However, according to footnote **5.440A** in Radio Regulation (Edition of 2012) , the frequency band 4 400-4 940 MHz may be used for aeronautical mobile telemetry for flight testing by aircraft stations in Region 2 (except Brazil, Cuba, French overseas departments and communities, Guatemala, Paraguay, Uruguay and Venezuela), and in Australia. This document provides the detailed studies of adjacent band compatibility between IMT system and AMT ground system in the frequency bands 4 400-4 500 MHz and 4 800-4 990 MHz.

1.2 Glossary of terms

ITU International Telecommunication Union

IMT International Mobile Telecommunications

AMT Aeronautical mobile telemetry

e.i.r.p. Equivalent isotropically radiated power

2 Characteristics and parameters

2.1 IMT parameters

IMT base station and user equipment parameters for macro suburban deployment are shown in the following table based on Report ITU-R M.2292.

TABLE 1

Deployment-related parameters for frequency bands between 3 and 6 GHz for IMT suburban deployment

Base station characteristics	
Cell radius / Deployment density	0.3-2 km (typical figure to be used in sharing studies 0.6 km)
Antenna height	25 m
Sectorization	3-sectors
Downtilt	6 degrees
Frequency reuse[1]	1
Antenna pattern	Recommendation ITU-R F.1336, *recommends 3.1*
Antenna polarization	Linear / +- 45 degrees
Below rooftop base station antenna deployment	0%
Feeder loss	3 dB
Maximum base station output power (20 MHz)	46 dBm
Maximum base station antenna gain	18 dBi
Maximum base station output power (e.i.r.p.)	61 dBm
Average base station activity	50 %
Average base station power/sector (to be used in sharing studies)	58 dBm

User equipment characteristics	
Maximum user equipment output power	23 dBm
Average user equipment output power	–9 dBm
Typical antenna gain for user equipment	–4 dBi
Antenna height	1.5 m

[1] If the IMT network consists of three cell layers – macro cells, small outdoor cells and small indoor cells – they will not all use the same carrier. Two layers may use the same carrier, although separate carriers in the same or different bands are also possible.

2.2 AMT ground systems parameters

The table below provides the key AMT parameters to be used for these studies[2].

TABLE 2

Representative AMT characteristics for use in compatibility studies

AMT ground system parameters		
Parameter	**Symbol**	**Value**
Aircraft antenna pattern	–	Omni-directional
Peak aircraft antenna gain (dBi)	G_{tmax}	3
Average aircraft antenna gain (dBi)	G_{tave}	–4.8
Maximum aircraft e.i.r.p. density (dB(W/MHz))	–	–2.2
Average aircraft e.i.r.p. density (dB(W/MHz))	–	–10.0
Peak aircraft antenna input power density (dB(W/MHz))	P_t	–5.2
Ground receiver antenna aperture (m)	–	2 to 5
Peak ground receiver antenna gain (dBi)		0
Ground receiver antenna pattern	–	Rec. ITU-R F.1245
Ground receiver antenna height (m)		30
Ground antenna elevation angles (degrees)		0-20
Nominal permissible long-term interference at receiver antenna output (dBW/MHz to be exceeded for no more than 20% of the time)		–145.5
Nominal permissible short-term interference at receiver antenna output (dBW/MHz to be exceeded for no more than 0.4% of the time)		–142.5

3 Methodologies and propagation models used to assess compatibility

3.1 Possible types of interference to the AMT ground system

Possible types of interference from IMT system have been identified to impact AMT ground system:

a) Unwanted emissions from IMT in adjacent channels

Adjacent channel interference from unwanted emissions generated by IMT system to AMT ground system is studied.

b) Co-frequency emissions

Co-channel interference case between IMT system and AMT ground system is not evaluated because it can be avoided by using different frequency bands between the two systems in the same geographical area.

2 From Report ITU-R M.2119: Sharing between aeronautical mobile telemetry systems for flight testing* and other systems operating in the 4 400-4 940 and 5 925-6 700 MHz band.

3.2 AMT interference criteria

The following methodology is adopted in Report ITU-R M.2119.

Nominal permissible long-term interference at AMT ground receiver antenna output is -145.5 dBW/MHz. This means permissible interference is to be exceeded for no more than 20% of the time.

Nominal permissible short-term interference at AMT ground receiver antenna output is -142.5 dBW/MHz. This means permissible interference is to be exceeded for no more than 0.4% of the time.

3.3 Methodologies

Assuming one base station macro cell or user equipment deployment interfere AMT ground receiver, the received interference power level at the AMT ground receiver is calculated according to the equation:

$$I_r = P_{IMT} + G_{IMT} + G_{AMT}(\theta) - L(f,d) - S - F$$

I_{IMT} [3]: the received interference power level in 1 MHz bandwidth at the AMT ground receiver (dBm);

P_{IMT}: transmission power per MHz bandwidth of IMT system (dBm);

G_{IMT}: antenna gain of IMT system (dB);

$G_{AMT}(\theta)$: reception antenna gain of AMT ground system (dB);

$L(f,d)$: the path loss (dB);

S: shadowing loss (dB) with standard deviation of 10 dB in log-normally distribution. In determined study, it is set to 0 dB;

F: frequency offset factor dependant on the frequency offset between IMT macro base station/user equipment and AMT ground receiver. In determined study, it is set to 43.6 dB or 33 dB, which is IMT macro base station or user equipment transmission power suppression at the first adjacent frequency based on the table below.

[3] Consider the interference aggregation from multiple IMT small cell deployments.

TABLE 3

Macro base station operating band unwanted emission limits for 5, 10, 15 and 20 MHz channel bandwidth

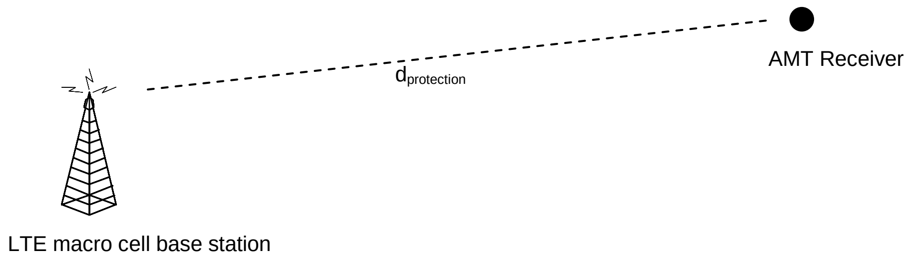
Frequency offset of measurement filter -3 dB point, Δf	Frequency offset of measurement filter centre frequency, f_offset	Minimum requirement	Measurement bandwidth
0 MHz ≤ Δf < 5 MHz	0.05 MHz ≤ f_offset < 5.05 MHz	$-7dBm - \frac{7}{5} \cdot \left(\frac{f\_offset}{MHz} - 0.05 \right) dB$	100 kHz
5 MHz ≤ Δf < min(10 MHz, Δf_{max})	5.05 MHz ≤ f_offset < min(10.05 MHz, f_offset_{max})	–14 dBm	100 kHz
10 MHz ≤ Δf ≤ Δf_{max}	10.5 MHz ≤ f_offset < f_offset_{max}	–15 dBm (Note 5)	1 MHz

3.4 IMT system scenario topology

IMT macro cell base station at the suburban scenario is deployed near the AMT ground receiver.

FIGURE 1

IMT macro cell scenario topology



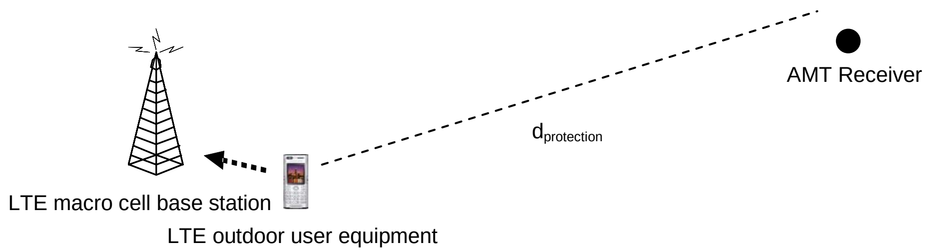
Where:

$d_{protection}$ Separation distance: the distance between the AMT ground receiver and IMT macro cell base station.

IMT outdoor user equipment is deployed near the AMT ground receiver.

FIGURE 2

IMT User Terminal scenario topology



Where:

$d_{protection}$ Separation distance: the distance between the AMT ground receiver and IMT user equipment.

3.5 Propagation models

3.5.1 Propagation model A - Recommendation ITU-R P.452-15

The propagation model is from Recommendation ITU-R P.452-15.

Basic transmission loss is from Recommendation ITU-R P.452-15 as follows:

$$L_{bfsg} = 92.5 + 20 \log f + 20 \log d + L_{d50} \qquad \text{dB}$$

where:

f: frequency (GHz);

d: path length (km);

L_{d50}: the median diffraction loss (dB):

$$L_{d50} = L_{m50} + \left(1 - e^{-\frac{L_{m50}}{6}}\right)\left(L_{t50} + L_{r50} + 10 + 0.04d\right) \qquad \text{for } \nu_{m50} > -0.78$$

$$= 0 \qquad \text{otherwise}$$

where:

L_{m50}: the median knife-edge diffraction loss for the main edge (dB);

L_{t50}: the median knife-edge diffraction loss for the transmitter-side secondary edge (dB);

L_{r50}: the median knife-edge diffraction loss for the receiver-side secondary edge (dB);

ν_{m50}: the diffraction parameter of the main edge (dB).

Recommendation ITU-R P.452-15 requires the terrain information as input for diffraction loss. The proposal below uses the typical terrain information contained in the Table 4 of Recommendation ITU-R P.452-15 and the method of applying height-gain correction in the Figure 3 of Recommendation ITU-R P.452-15.

TABLE 4

Nominal clutter heights and distances

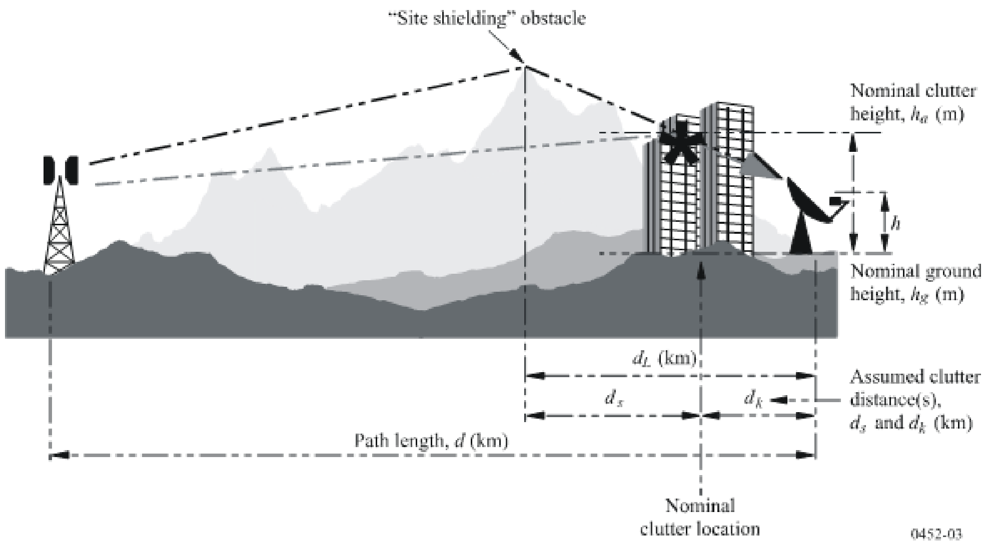
Clutter (ground-cover) category	Nominal height h_a (m)	Nominal distance d_k (km)
High crop fields Park land Irregularly spaced sparse trees Orchard (regularly spaced) Sparse houses	4	0.1
Village centre	5	0.07
Deciduous trees (irregularly spaced) Deciduous trees (regularly spaced) Mixed tree forest	15	0.05
Coniferous trees (irregularly spaced) Coniferous trees (regularly spaced)	20	0.05
Tropical rain forest	20	0.03
Suburban	9	0.025
Dense suburban	12	0.02
Urban	20	0.02
Dense urban	25	0.02
High-rise urban	35	0.02
Industrial zone	20	0.05

h_a: Nominal clutter height (m) above local ground level.

d_k: Distance (km) from nominal clutter point to the antenna.

FIGURE 3

Method of applying height-gain correction



For transmitter and receiver side, the terrain info is according to the above table. The concrete value is based on which scenario the node is located. It’s assumed that the path includes transmit terrain, receive terrain and dense suburban terrain in the middle path; the 20 m high terrain that characterizes the coniferous trees is chosen as default for the dense urban middle path.

3.5.2 Propagation model B – Free space

The propagation model B is free space model.

Basic transmission loss is as follows:

$$PL = 92.5 + 20 \log f + 20 \log d \qquad \text{dB}$$

where:

f : frequency (GHz)

d : path length (km)

4 Studies and results of compatibility

Protection distance between IMT macro cell base station and AMT ground receiver in adjacent channels based on determined study is shown as following table.

TABLE 5

Protection distance between IMT macro cell base station and AMT ground receiver in adjacent channels based on Propagation model A

Frequency (MHz)	Frequency offset factor (dB)	Interference criteria	Min. separation distance (m)
4 400-4 500	43.6	Long-term interference	5 213
	43.6	Short-term interference	3 696
4 800-4 990	43.6	Long-term interference	4 736
	43.6	Short-term interference	3 358

TABLE 6

Protection distance between IMT macro cell base station and AMT ground receiver in adjacent channels based on Propagation model B

Frequency (MHz)	Frequency offset factor (dB)	Interference Criteria	Min. separation distance (m)
4 400-4 500	43.6	long-term interference	5 262
	43.6	short-term interference	3 725
4 800-4 990	43.6	long-term interference	4 779
	43.6	short-term interference	3 383

Protection distance between IMT outdoor user equipment and AMT ground receiver in adjacent channels based on determined study is shown as following table.

TABLE 7

Protection distance between IMT outdoor user equipment and AMT ground receiver in adjacent channels based on Propagation model A

Frequency (MHz)	Frequency offset factor (dB)	Interference criteria	Min. separation distance (m)
4 400-4 500	33	Long-term interference	60
	33	Short-term interference	40
4 800-4 990	33	Long-term interference	60
	33	Short-term interference	40

TABLE 8

Protection distance between IMT outdoor user equipment and AMT ground receiver in adjacent channels based on Propagation model B

Frequency (MHz)	Frequency offset factor (dB)	Interference Criteria	Min. separation distance (m)
4 400-4 500	33	long-term interference	224
	33	short-term interference	159
4 800-4 990	33	long-term interference	204
	33	short-term interference	144

5 Summary

With regard to the IMT (using 61 dBm e.i.r.p., already including feeder loss) interfering into AMT ground station receiver (using a maximum 0 dBi AMT ground station antenna gain (back-lobe) by assuming for the purposes of this Study that the AMT antennas only point away from the IMT interferer, e.g., the AMT ground station points to the sky while the IMT station is on the ground in the band 4 400-4 500 MHz and 4 800-4 990 MHz the following observations may be reached:

– For adjacent channel interference, with 43.6 dB frequency off-set factor, the separation distance is 4.7 kilometres (for 4 800-4 990 MHz) to 5.2 kilometres (for 4 400-4 500 MHz) for long-term interference between a single IMT macro cell base station and AMT ground receiver based on Recommendation ITU-R P.452-15 (p = 20%) with no terrain;

– For adjacent channel interference, with 43.6 dB frequency off-set factor, the separation distance is 3.3 kilometres (for 4 800-4 990 MHz) to 3.7 kilometres (for 4 400-4 500 MHz) for short-term interference between IMT macro cell base station and AMT ground receiver based on Recommendation ITU-R P.452-15 model (p = 0.4%) with no terrain;

– For adjacent channel interference, with 43.6 dB frequency off-set factor, the separation distance is 40 to 60 metres for long-term interference and short-term interference between IMT outdoor user equipment and AMT ground receiver based on Recommendation ITU-R P.452-15 model (p = 20% and p = 0.4%) with no terrain;

– Co-channel interference case was not analysed in this study.

ANNEX 2

STUDY #2

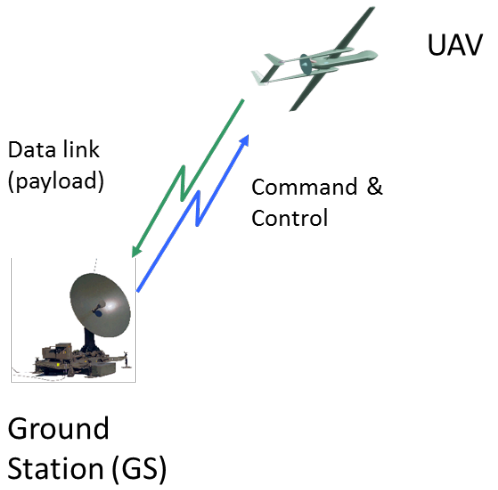
Sharing study between aeronautical mobile applications and IMT systems in the bands 4 400-4 990 MHz

1 Introduction

The 4 400-4 990 MHz band is commonly used for aeronautical applications especially for Unmanned Aircraft Systems (UAS), in particular for unmanned aerial vehicles which are dedicated to sophisticated array of missions due to their small size and decreased radar, acoustical, and infrared signatures. There are diverse types of missions: ground mapping, life rescue, life search and communication relay over all the national territory and above the sea.

This application consists in a bidirectional data radio link between a fixed or nomad ground station (GS) and an Unmanned Aircraft Vehicle (UAV). Depending on the UAS type, the data links and the Command and Control (C&C) links between the UAV can be separated or multiplexed in a single line of sight channel.

Each equipment is a transceiver, e.g. with telecommand (when GS transmits to on-board UAV) and telemetry (when UAV transmits to GS) purposes, as described in the figure below.



It has to be noted that the nature of the application influences the typical required bandwidth: larger bandwidth would be expected for applications that perform full-motion video with camera.

Automated aircraft can be designed by categories of altitudes. It is then considered that the following types of UAV would fly at different altitudes (medium altitude: from 3 to 6 kilometres, high altitude: from 6 to 12 kilometres).

2 Technical characteristics and parameters

a) IMT Systems

IMT base station parameters for macro suburban deployment are shown in the following table based on Report ITU-R M.2292.

TABLE 1

Deployment-related parameters for bands between 3 and 6 GHz for IMT suburban deployment

Base station characteristics	
Feeder loss	3 dB
Maximum base station output power (20 MHz)	46 dBm
Maximum base station antenna gain	18 dBi

b) Aeronautical systems

The UAS which characteristics are detailed below is a representative example of a system for governmental purposes in France using the 4.4-5 GHz band. Due to the lack of information in ITU-R Recommendations on aeronautical mobile systems operating within 4 400-4 900 MHz band, it is proposed to consider I/N=–6dB as a protection criterion for the sharing studies.

Unmanned Aircraft Vehicle	
Bandwidth (MHz)	1
Thermal noise (dBm)	–110
Antenna height (m)	0 to 10000
Antenna type and gain	Omnidirectional 3dBi
Protection criterion	I/N=–6dB

3 Methodologies and propagation models

A minimum coupling loss approach is used, modelling only a single interferer-victim pair (as to be base station-to-airborne receiver), taking into account that the UAV antenna is omnidirectional.

According to the nature of the airborne aeronautical receiver, the propagation model separating the radar receiver from the IMT base stations within the urban area is assumed free space loss (FSL) for distances lower than the horizon distance.

For one base station macro cell interfering co-channel with airborne aeronautical receiver, we derive
the required isolation to ensure the protection of the radar receiver:

$$\text{Isolation(dB)} \geq \text{e.i.r.p. (dBm/MHz)} + G_R\text{-I/N-Noise(dBm/MHz)}$$

where

$$\text{Isolation} = \text{PathLoss}\ (d_{separation}).$$

G_R is the antenna gain of the receiver. In co-channel sharing, restricted in-band level for base station could be required to ensure the protection of the airborne receiver:

$$\textit{InBand Emission level}_{\ (dBm/MHz)} = \text{e.i.r.p.} + \min(0, (\text{Isolation(dB)} - (\text{e.i.r.p.} + G_R\text{-I/N-Noise}))).$$

4 Results

We derive for different distance the required in-band emission level which would ensure the protection of the airborne receiver from one single base station. Some observations can be made, emphasizing this studied case as not a worst case:

– the best case (for sharing case) corresponds to the large separation distance (more than 400 km), where 38.8 dBm/MHz e.i.r.p. level for IMT base station is required. This "best case" for one single base station corresponds to a maximum e.i.r.p. 9 dB lower than the assumption for a macrocell station in Report ITU-R M.2292, leading to a strong reduction of the coverage performance for macrocells (rural, urban)[4].

– In addition, if this band was be restricted to small cells deployment and high capacity deployment, the interference assessment would require higher networks density assumptions and strong aggregation effect which is not taken into account in this calculation aggregation assumptions and/or with lower separation distance.

Distance(IMT base station Tx,Airborne Rx) (km)	412	132	60	29.7	20.2	15.6	13.1	11.6
Required in-band emission level (dBm/MHz) (IMT e.i.r.p.)	38.8	28.9	22.1	16.0	12.6	10.4	8.9	7.8

5 Summary

This document analyses the sharing studies between IMT macro base station systems and airborne systems within 4 400-4 900 MHz band.

For separation distances (between IMT base station and airborne receiver) close to 400 kilometres, it is shown that IMT base stations emission levels are restricted to 38.8 dBm/MHz for one single interferer. Such constraint strongly impacts cell radius reduction[5] , making the deployment of the IMT macrocells within any (urban, suburban, rural) area in the same frequency band unfeasible from a cross-border prospective. The aggregate interference would lead to much more severe interference. For other radio environments (micro, pico and hotspots) IMT mobile networks would be subject to similar constraints, given that the aggregation factor increases with the density of the network.

[4] Roughly half of the cell radius.

[5] At most one tenth of the cell radius.

ANNEX 3

STUDY #3

Technical assessment of potential interference between IMT systems and the mobile service in the 4 400-4 990 MHz band

1 Introduction

This analysis assesses the potential impact of introducing IMT systems on current mobile systems operating in the 4 400-4 990 MHz band. Analyses are provided to identify the minimum required separation distance required to protect a receiver in the mobile service from a single IMT base station or user equipment under worst-case assumptions, as well as aggregate analyses to identify the area around a mobile station where the aggregate interference from multiple IMT base stations may exceed the protection criteria.

2 System parameters

Parameters of IMT base stations and user equipment are taken from Table D of Report ITU-R M.2292 “Characteristics of Terrestrial IMT-Advanced Systems for Frequency Sharing/Interference Analyses”.

With the exception of Recommendation ITU-R M.1459, which has been applied successfully to the protection of aeronautical mobile telemetry (AMT) systems in the 1.5 GHz, 2.3 GHz, and 4-6 GHz bands, there are no ITU-R recommendations that provide mobile system parameters to be used for sharing studies involving mobile systems operating in the 4 400-4 990 MHz band. However, parameters for certain systems for the aeronautical mobile service (AMS), in the 14.5 15.35 GHz band appear to be representative of mobile systems operating in the 4 400-4 990 MHz band. An earlier study in Report ITU-R M.2119 with respect to the potential sharing of an AMT system operating in the 4 400-4 990 MHz bands also provides sample ground station parameters for a type of system addressed in this study. A second report, Report ITU-R M.2118, also includes relevant descriptions of AMT system parameters and AMT system operation. Report ITU-R M.2119 notes that the elevation from the ground station to the aircraft was below 20º for 98% of the time and below 5º for 85% of the time.

Table 1 provides the parameters of the different types of mobile service stations assumed for the purposes of this study.

TABLE 1

Mobile system parameters

Station Type	AMS Airborne	AMS Ground	Mobile Ground	Mobile Transportable	AMT Ground
Bandwidth (MHz)	10	10	18.5	2.46	10
Modulation	OQPSK	OQPSK	BPSK	OQPSK	Digital
Antenna gain (dBi)	7.2	3	4	24	40
Antenna pattern	Omni-directional	Omni-directional	Omni-directional	Rec. ITU-R F.1245, 0° elevation, 360° azimuth	Rec. ITU-R F.1245 0° elevation, 360° azimuth
Antenna height above ground (m)	2,400 19,000	10	2	10	30
Noise figure (dB)	4.5	4	3	4	T_{system}=250 K
Interference threshold I/N (dB)	-6	-6	-6	-6	-4
Propagation model	P.528 p=1%	P.452 p=1%	P.452 p=1%	P.452 p=1%	P.452 p=20%

3 Single entry interference analyses

Single entry analyses were performed to determine the separation distance required to protect the mobile service receivers listed in Table 1 from IMT base station interference operating on the same frequency. It is assumed that base stations are operating at a maximum IMT base station e.i.r.p. of 61 dBm in the direction of the mobile system and the Recommendation ITU-R F.1336 antenna pattern is assumed for the base station with a base station antenna height of 25 meters. As indicated in Table 5, the Recommendations ITU-R P.528 or ITU-R P.452 propagation model is used to calculate path loss at 4 695 MHz without consideration of terrain.

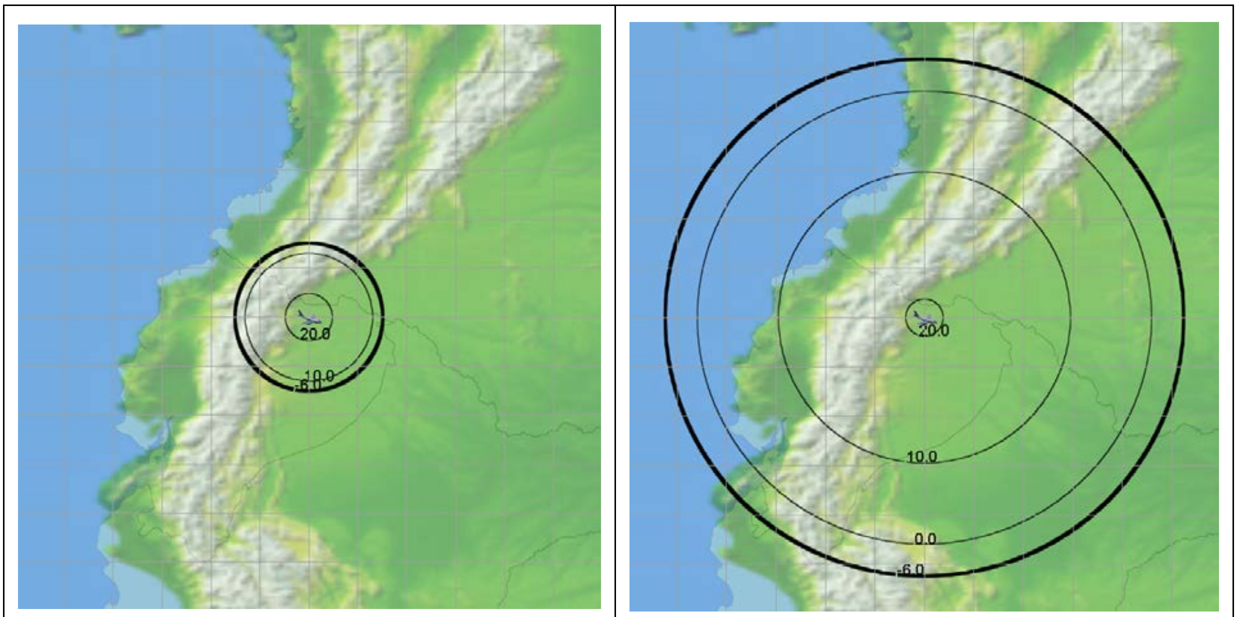
The I/N contours for mobile and AMS/AMT ground terminals are circular because:

- an omnidirectional pattern is assumed for mobile stations with low gain antennas;
- high gain antennas at AMS/AMT ground stations are assumed to point at any azimuth (0 – 360º) at a minimum elevation angle of 0º (or even negative, depending on how the AMT antenna is sited on local terrain); or
- high gain antennas at mobile ground stations (transportable stations) are assumed to point at any azimuth (0 – 360º) at an elevation angle of 0º.

For the case of interference from an IMT base station into an airborne receiver, I/N contours are presented in Figure 1 for the two aircraft heights listed in Table 1 assuming the maximum base station power and a base station antenna pattern based on Recommendation ITU-R F.1336.

FIGURE 1

I/N Contours for IMT base station Interference into an airborne receiver



I/N Contours for Aircraft Height = 2.4 km	I/N Contours for Aircraft Height = 19 km

Single entry I/N contours for interference from a single IMT base station and from a single user equipment operating at their maximum power levels were computed for all of the other cases listed in Table 1. Table 2 summarizes the required separation distances for these single entry interference cases

TABLE 2

Required single entry separation distances for IMT Interference into mobile systems

Mobile Station	AMS Airborne (2.4 km)	AMS Airborne (19 km)	AMS Ground	Mobile Ground	Mobile Transportable	AMT Ground
IMT base station interference	170 km	535 km	231 km	218 km	353 km	136 km
IMT User equipment interference	36 km	29 km	7 km	8 km	147 km	20 km

4 Aggregate interference analyses

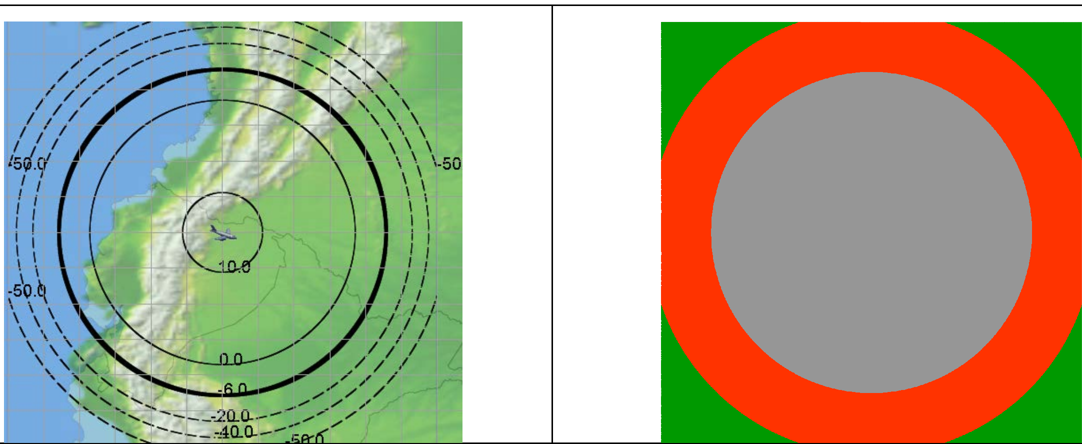
An aggregate analysis of IMT base station interference into an airborne receiver at 2 400 metre altitude was performed by constructing a rectangular grid of base stations at 1.2 kilometre separations corresponding to the 0.6 kilometre radius for suburban macro cells, with each base station operating at a 58 dBm average e.i.r.p.

Figure 2 displays a plot of these grid cells, with the colour of grey, red or green assigned to each pixel. A pixel is coloured grey if the I/N produced by a base station at the location of the pixel exceeds the AMS service I/N threshold of -6 dB and is not included in the calculation of the aggregate interference. An initial aggregate I/N from base stations at the other grid points is then calculated. In this case the initial aggregate I/N from base stations located outside of the grey area was 39.1 dB.

In order to achieve an aggregate I/N interference level of -6 dB, the remaining grid cells were sorted by the I/N produced by the base station at the airborne receiver in the order of highest I/N to lowest I/N. Cells were then removed one-by-one from the aggregate I/N calculation, starting with the highest I/N and working downwards, until the aggregate I/N reached -6 dB. These removed cells are coloured red in Figure 2. The remaining cells are coloured green to indicate that base stations could be operated at these points without the aggregate I/N exceeding the I/N threshold.

FIGURE 2

**Potential IMT base station exclusion area
to protect an airborne receiver at 19 km altitude**



I/N contours for airborne station at 19 km altitude and average IMT base station power	Area (Green) outside of which IMT base station operations satisfy aggregate I/N criterion

The dimensions of the affected areas around the airborne receiver are presented in Table 3. The maximum distance for a single interferer (162 kilometres) is slightly smaller than the corresponding distance in Table 6 (170 kilometres) because the average IMT base station e.i.r.p. is used instead of the maximum e.i.r.p.

TABLE 3

Dimensions of base station excluded areas to protect airborne receiver

Aircraft Altitude	2,400 m	19,000 m
Distance from an airborne receiver where I/N threshold could be exceeded by a single terminal	162 km	509 km
Area covered by cell sites producing interference exceeding I/N threshold	86,289 km^2	813,612 km^2
Distance from an airborne receiver where cell site excluded in order to satisfy aggregate I/N threshold	446 km	>706 km
Area covered by cell sites not exceeding single entry I/N threshold but excluded in order to satisfy aggregate I/N threshold	537,029 km^2	>702,908 km^2
Total exclusion area needed to protect an airborne receiver	623,318 km^2	>1,516,521 km^2

Aggregate analyses were performed for the other mobile systems listed in Table 3 and the results are presented in Table 4.

TABLE 4

Dimensions of base station excluded areas to protect mobile receivers

Mobile System	**AMS Ground**	**Mobile Ground**	**Mobile Transportable**	**AMT Ground (1)**
Distance from the mobile service receiver where I/N threshold could be exceeded by a single terminal	208 km	192 km	339 km	132 km
Area covered by cell sites producing interference exceeding I/N threshold	135,171 km^2	117,184 km^2	359,259 km^2	54,752 km^2
Distance from the mobile service receiver where cell site are excluded in order to satisfy aggregate I/N threshold	438 km	435 km	526 km	307 km
Area covered by cell sites not exceeding single entry I/N threshold but excluded in order to satisfy the aggregate I/N threshold	461,227 km^2	469,846 km^2	503,903 km^2	235,589 km^2
Total exclusion area needed to protect the mobile system	596,398 km^2	587,031 km^2	863,162 km^2	290,341 km^2

(1) The aggregate interference analysis for the AMT ground station was performed for a 5º elevation angle.

The separation distances required for protecting a mobile receiver from a single IMT user equipment operating at maximum power is less than the corresponding single entry separation distance for an IMT base station. Consequently, the area within which aggregate interference from use terminals exceeds the mobile receiver interference threshold will also be small than the corresponding exclusion area identified for a base station.

5 Summary

Large separation distances are required to protect certain types of mobile service stations. In the case of protecting airborne station receivers from IMT base station interference, the required single entry separation distances vary between 162 kilometres for an aircraft at 2 400 metre altitude to 509 kilometres at 19 000 metre altitude. Aggregate interference analyses indicate that base station operations may be precluded within a distance of 446 kilometres from the aircraft encompassing an area of about 623 318 km^2 when the aircraft is at 2 400 metre altitude. For an aircraft at 19 000 metre altitude, the corresponding distance and area are greater than 706 kilometres and 1.5 million km^2, respectively. Separation distances between about 300 to 500 kilometres may be required to satisfy the aggregate I/N protection requirement of ground based stations in the mobile service from IMT base stations. The area within which aggregate interference from IMT user equipment exceeds the mobile service receiver interference threshold will be smaller than the corresponding exclusion area identified for a base station. Co-channel sharing between aeronautical mobile applications and IMT systems in the 4 400-4 990 MHz is not practical in the geographic areas located within the exclusion zones required up to 706 kilometres.