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| ACP-WG-F30/WP-14 |
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**AERONAUTICAL COMMUNICATIONS PANEL (ACP)**

**30TH MEETING OF THE WORKING GROUP F (WG F)**

**Pattaya, Thailand 13 – 19 March 2014**

Agenda Item 7: WRC Agenda Items

**Preliminary Study into Radio Altimeter Adjacent Band Compatibility**

(Presented by *Andrew Roy*)

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| **SUMMARY**Multiple frequency bands are being considered for new IMT allocations under WRC-15 Agenda Item 1.1. This is a preliminary study into the compatibility of radio altimeter receivers with IMT transmitters potentially operating in adjacent frequency band allocations. |
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| **ACTION** The Working Group is invited to note the results of the study, and seek clarification from subject matter experts on additional system information and mitigation methods. |
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# Introduction

1. At the previous WG-F Meeting 29 in Nairobi (Sept 2013), there was a discussion about the potential for interference to radio altimeters from any new IMT allocations in the adjacent bands under WRC-15 Agenda Item 1.1. However, given the limited information available, concerns were expressed about the practicality of submitting a credible study into the ITU-R JTG 4-5-6-7 (JTG). This work intends to further investigate possible interference to the radio altimeter by adjacent IMT allocations, and the required Out Of Band (OOB) rejection required by the radio altimeter receiver.

# Background

1. The JTG process for WRC-15 Agenda Item 1.1 has proposed multiple frequency bands between 500 MHz and 6 GHz for new IMT allocations. The proposals include the frequency bands 3400-4200 MHz and 4400-4500 MHz, and are adjacent to the ARNS allocation for radio altimeters in the 4200-4400 MHz.
2. The frequency band 4200-4400 MHz is allocated on a primary basis to the aeronautical radionavigation service (ARNS) is reserved exclusively for radio altimeters installed on board aircraft and for the associated transponders on the ground under footnote RR 5.438. However, passive sensing in the Earth exploration-satellite and space research services may be authorized in this band on a secondary basis (no protection is provided by the radio altimeters).
3. This initial study investigates the potential adjacent band effects of both IMT Base Stations (BS) and User Equipment (UE) on an aircraft’s radio altimeter during the final stages of approach. The study models the IMT signal power received by the radio altimeter in the adjacent band. The level of received power will then indicate any OOB rejection required by the radio altimeters[[1]](#footnote-1) if an IMT allocation was made adjacent to the radio altimeter frequency band.
4. The parameters and technical characteristics for the systems are taken from ITU-R Recommendations:-
5. ITU-R Working Party 5D Liaison statement – IMT sharing parameters for WRC-15 Agenda item 1.1 (dated 18 July 2013).
6. ITU-R Draft Revision of Recommendation ITU-R F.1336-4 - Reference radiation patterns of omnidirectional, sectoral and other antennas in point-to-multipoint systems for use in sharing studies in the frequency range from 1 GHz to about 70 GHz (dated 13 December 2013).
7. ITU-R Recommendation M.5\_BL\_6 : Operational and technical characteristics and protection criteria of radio altimeters utilizing the band 4 200-4 400 MHz
8. ITU-R Working Party 5B Document 5B/475 Annex 28. Working document towards a preliminary draft new Report ITU-R M.[WAIC\_SHARING\_4 200-4 400MHZ]- Compatibility analysis between wireless avionics intra-communication systems and systems in the existing services in the frequency band 4 200-4 400 MHz.
9. ITU-R Recommendation P.525-2 (08/94): Calculation of free-space attenuation
10. ICAO Annex 14 to the Convention on International Civil Aviation. Aerodrome design and operations. (Fifth edition, July 2009).

# Technical characteristics used

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| BS Characteristics |
| Parameter | Units | Value |
| Downlink frequency FDD | MHz | 4200 |
| Bandwidth | MHz | 5, 10 or 20 |
| Maximum transmitter power | BW=5 MHz | dBmdBm/MHz | 43 |
| BW = 10 MHz | 46 |
| Power density | 36 |
| Spurious emission limits | Limit | dBm/MHz | -30 |
| Max Antenna gain (G0) | dBi | 18 (Rural)/16 (Urban/Suburban) |
| Feeder loss | dB | 3 |
| Typical antenna height  | m | 30 (Rural),25(Suburban), 20 (Urban) |
| Antenna down tilt | degrees | 3 (Rural), 6 (Suburban),10 (urban) |
| Antenna type |  | Sectorial (3 sectors) |
| Antenna Pattern (peak improved pattern for 400 Mhz – 6 GHz) |  | Rec. ITU-R F.1336 - 2 (peak) |
| kp | 0.7 |
| kv | 0.3 |
| Polarization  |  | ± 45° cross-polarized |
| 3 dB antenna beamwidth (elevation) | degrees | 2.702 |

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| UE Characteristics |
| Parameter | Units | LTE |
| Downlink frequency FDD | MHz | 4200 |
| Bandwidth | MHz | 5, 10 or 20 |
| Maximum transmitter power  | dBm | 23 |
| Antenna gain | dBi | -3.0 |
| Antenna height  | m | 1.5 |
| Antenna type |  | Omnidirectional |
| Polarization  |  | Linear |

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| **Radio Altimeter** |
| Parameter | Units | LTE |
| Antenna Max Gain | dBi | 13 |
| 3dB Beamwidth | Degrees | 60 |
| Feeder loss | dB | 6 |
| Protection Criteria for Desensitization (I/N) | dB | -6 |
| Protection Criteria False Altitudes for FMCW Altimeters only (*ID* < *IT,FA)* *where IT,FA = following the instantaneous altimeter local oscillator*  | dBm/100 Hz | –143  |

# Scenario

1. To simulate an assumed worst case scenario, a model was produced of an aircraft on final approach in a Cat III landing. The approach path passes directly overhead of a simulated sectorized BS, and again over a UE. This would present the minimum possible distance between the aircraft and base station while the altimeter is providing height information to the autopilot during landing.

UE

Start aircraft touchdown point

3000m

First approach section

350m

Runway threshold and altimeter operational areas

3⁰

1.14⁰

Aircraft Cat III glide slope

BS

Figure 1

ICAO limit of obstruction height

1. Figure 1 shows the airport obstruction height limits set by ICAO Annex 14 for a straight line approach path for landing aircraft. These limits allow a 25m suburban BS to be placed 1,600.1m at its closet location to the aircraft touchdown point along the approach path. Given the variation in airport operating areas and public access, a single UE is assumed to be operated 500m from the aircraft touchdown point at a height of 1.5m.

# Assumptions

1. The following assumptions have been made in the analysis:
	1. The BS is configured for a suburban environment with a sectorized antenna pointing in the direction of the aircraft.
	2. The UE is held 1.5m high and points directly towards the aircraft at all times, simulating an aircraft ‘spotter’ taking a picture with a camera phone.
	3. The aircraft follows a 3 degrees Cat III glide slope approach, with a pitch of 2 degrees, at all times during landing.
	4. The radio altimeter antenna pattern from the current draft WAIC radio altimeter sharing study accurately represents the radio altimeter antenna pattern[[2]](#footnote-2), including at angles of incidence greater than 90 degrees where aircraft shielding may be factor.
	5. The received signal from the radio altimeter transmitter at low altitude is significantly higher than any other signal due to the decreased path loss, and therefore does not exceed the I/N protection criteria.

* 1. An IMT downlink/uplink allocation is in the adjacent 4000-4200 MHz frequency band, operating a uniform and continuous OFDM signal up to the band edge at 4200 MHz.
	2. The propagation environment is from a single point source with no aggregate power, diffraction, multipath or clutter accounted for.

# Modelling

## Link budget

1. The analysis focuses on a link budget to calculate the power received at the radio altimeter. The overall equation is:

$$P\_{Rx}=P\_{Tx}+Fl\_{Tx}+G\_{Tx}\left(∅\right)+FSL+G\_{Rx}\left(∅\right)+Fl\_{Rx}$$

Where:

$P\_{Rx}$= Power at the receiver input

$P\_{Tx}$= Power at the transmitter output

$Fl\_{Tx}$= Feeder loss at transmitter

$G\_{Tx}\left(∅\right)$=Transmitter antenna gain at incident angle $∅$

$FSL$=Freespace loss propagation (ITU-R Recommendation P.525-2)

$G\_{Rx}\left(∅\right)$=Receiver antenna gain at incident angle $∅$

$Fl\_{Rx}$= Cable loss at receiver

## Tx outputs

1. The maximum output of a suburban BS was made equivalent to -4 dBm/100Hz to match the FMCW altimeters’ false altitude detection bandwidth. Similarly, the maximum instantaneous power from a single UE was equivalent to -23.9 dBm/100Hz. A feeder loss of 3dB is used for the BS in accordance with the IMT parameters provided; however, no losses are specified for the UE and these are assumed to be zero.

## Antenna modelling

1. BS reference antenna pattern was modelled with the recently approved ITU-R F.1336-4, using suburban BS parameters to measure antenna directivity in the elevation plane of the main lobe of a sectorized antenna. As the UE tracks the aircraft at all times, its gain is -3dBi throughout the aircraft’s approach.
2. Using the slant angle form the BS or UE, the reciprocal angle at the approaching aircraft was used to calculate the directivity of the radio altimeter antenna using the reference model provided. This was then modified for the aircraft’s pitch while landing.

## Propagation

1. Using the slant range between BS and aircraft, a FSL was calculated using ITU-R Recommendation P.525-2 for the LOS transmission from the BS and UE, to the aircraft.

# Analysis

## Received power from the BS

1. Figure 2 shows the received power at the radio altimeter Rx as the aircraft approaches the touchdown point over a BS. The -143 dBm/100Hz false altitude detection threshold is exceeded at a range of 9,215.9 m from the touchdown point, and continues for the remaining duration of the flight until touchdown. An aircraft approaching at 140 knots would exceed this threshold for approx. 2 mins 7 secs without any OOB rejection by the radio altimeter receiver.

Figure 2

1. The maximum power of -97.6 dBm/100 Hz is received at a range of 1,614.3m from the touch down point, where the radio altimeters antenna has maximum gain from the 2 degrees pitch of the aircraft and the path loss is almost at a minimum. Therefore, an OOB rejection of at least 45.4 dB would be required at 4200 MHz to prevent a false altitude reading by the radio altimeter from a BS.

## Received power from the UE

1. Figure 3 shows the received power as the aircraft approaches the touchdown point over a UE. The false altitude detection threshold is exceeded at a range of 2,827.3m from the touchdown point. An aircraft approaching at 140 knots would exceed this threshold for approx. 39 secs without any OOB rejection by the radio altimeter receiver.

Figure 3

1. The maximum power of -79.8 dBm/100 Hz is received at a range 500.3m from the touch down point, where the path loss is at a minimum. Therefore, an OOB rejection of at least 63.2 dB would be required at 4200 MHz to prevent a false altitude reading by the radio altimeter from a UE.

# Conclusions

1. Although this preliminary study using a basic model to simulate an aircraft in one of its most critical phases of flight, the power levels received at the radio altimeter receiver are higher than desired. If an IMT allocation was made in the adjacent frequency band to the radio altimeters, there is the potential requirement for nearly 64 dB of OOB isolation at the band edge to properly protection the receiver from false altitude errors. This estimate does not include any required safety margin, which would be recommended given the assumed antenna patterns for both BS and radio altimeter, and the potential variation in the scenario for different airports.
2. This initial study does not accurately model the effect of an aircraft flying beyond a BS and passing through its main beam pointed towards the airport while accounting for the effect of aircraft shielding. Critically, it does not include possible multipath effects or aggregate power from multiple BSs or UEs situated at different points around the approach path or airport. More complex approach paths over urban environments with multiple BSs located on top of buildings would be of particular concern. Such a comprehensive analysis would require a more advancing modelling environment and also an accurate radio altimeter antenna pattern inclusive of aircraft shielding.

# Actions for the Meeting

1. The meeting is invited to:
	1. Note the results of this study.
	2. Seek guidance from radio altimeter experts to provide further refinements to modelling assumptions, and mitigation methods employed by radio altimeters for OOB rejection of adjacent band signals.

ANNEX A – ANtenna Patterns

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| **Assumed Radio Altimeter Antenna Pattern** |
| $$G\_{RA,dB}\left(ϕ\right)=-\frac{12}{ϕ\_{3dB}^{2}}ϕ^{2}+G\_{RA,dBi}$$Where:$G\_{RA,dB}\left(ϕ\right)$= The radio altimeter gain at an angle $ϕ$ measured from the vertical axis.$ϕ\_{3dB}$ = The 3dB beamwidth of the antenna.$G\_{RA,dBi}$ = The maximum antenna gain. |

1. Given the parameters and data available in the ITU-R and ICAO, assessment of the altimeter’s filtering, error correction capabilities, or other internal receiver mitigation methods are not included at this time. [↑](#footnote-ref-1)
2. The radio altimeter ITU-R characteristics recommendation does not specify a reference antenna pattern model, only providing maximum values and the 3dB beam width. The current draft WAIC radio altimeter sharing study in 4200-4400MHz report has derived a basic model that uses these parameters. [↑](#footnote-ref-2)