Source: Document 4-5-6-7/TEMP/164 (edited)

**Annex 35 to**
**Document 4-5-6-7/715-E**
**22 August 2014**
**English only**

# Annex 35 to Joint Task Group 4-5-6-7 Chairman's Report

PRELIMINARY DRAFT NEW REPORT ITU R RS.[EESS RLAN 5 GHz]

## Sharing studies between RLAN and EESS (active) systems in the frequency range 5 350-5 470 MHz

## 1 Introduction/background

In order to support requirements for non-IMT broadband nomadic wireless access systems including radio local area networks (RLAN), sharing feasibility studies has been called for the frequency range 5 350-5 470 MHz .

The frequency range 5 350-5 470 MHz is comprised of two frequency bands: 5 350-5 460 MHz and 5 460-5 470 MHz. The 5 350-5 460 MHz band is allocated to the Earth exploration-satellite (EESS) (active), radiolocation, aeronautical radionavigation, and space research (active) services. The 5 460-5 470 MHz frequency band is allocated to the Earth exploration-satellite (active), radiolocation, radionavigation, and space research (active) services.

The present Report provides multiple analyses based on various scenarios (static/dynamic, probabilistic/with orbital simulation, over simulated areas/over countries) to address the compatibility between RLAN systems and EESS (active) systems in the frequency range 5 350-5 470 MHz. Potential interference from EESS (active) systems to RLANs is not analysed in this Report.

## 2 Technical characteristics

### 2.1 EESS (active)

### 2.1.1 Interference criteria

The EESS (active) interference criterion is given in Recommendation ITU-R RS.1166-4 as a value of –6 dB I/N with 99% data availability (equivalent to 99% of the time). i.e., the I/N = –6 dB criterion is not to be exceeded for more than 1% of the time.). These criteria are applied over data acquisition periods of time when the sensor is operating over the measurement area of interest.

The interference budget apportionment (radiolocation, aeronautical radionavigation) factor has not been considered in the studies, but may be considered as an aggravating factor.

### 2.1.2 Parameters

The following Table and the following antenna pattern descriptions provide the relevant EESS (active) system parameters to be used in the study.

| **Parameter** | **Radarsat-3 (RCM)** | **Sentinel-1 CSAR** |
|---|---|---|
| Sensor type | SAR | SAR |
| Orbital altitude (km) | 586.9-615.2 | 693 |
| Orbital inclination (degrees) | 97.74 | 98.18 |
| RF centre frequency (MHz) | 5 405 | 5 405 |
| Peak radiated power (W) | 1 490 | 4 140<br>(at ant input) |
| Polarisation | HH, VV, HV,VH, compact (circular on Tx, linear on Rx) | HH+HV, VV+VH |
| Antenna type | Phase array | Phase array |
| Antenna gain (dBi) | 40-45 | 43.5 to 45.1 |
| Antenna pattern steering capability | Steerable in elevation from 16 to 51 degrees | Steerable in elevation 18 to 40 deg |
| Antenna pattern | **See Below** | **See Below** |
| Antenna orientation (degrees from nadir) | $33^0$<br>(right-looking) | 20 to 47 deg |
| Receiver noise figure (dB) | 6 (system) | 3.2 |
| Pulse/Receiver bandwidth (MHz) | 14-100 (selectable) | Up to 100 MHz |
| Minimum pulse width (μs) | 10-50 | 5-62 |
| Pulse repetition frequency (kHz) | 2-7 | 1.45-1.94 |
| Noise power (dBW) | –128/14 MHz to –119/100 MHz | –121/100 MHz |
| Service area | Global | Global |
| Footprint ($km^2$) | 225 (avg) | 250 |
| Image swath width (km) | 20-500 | 20-250 |

Antenna pattern for Radarsat-3:

$$D(\theta_{el}) = (0.12\theta_0 + 39.2) + 10log_{10}\left[sinc^2\left(\frac{40\sqrt{2}}{cos^2\theta_0}sin(\theta_{el} - \theta_0)\right)\right], \quad (1)$$

(Range)

(Azimuth)

$$D(\theta_{az}) = 10log_{10}\left[sinc^2\left(\left(\frac{\pi L}{\lambda}sin\theta_{az}\right)\right)\right], \quad (2)$$

where:

$\theta_0$ is the elevation pointing angle of the main beam (in degrees);

$\theta_{el}$ is the elevation angle in the direction under consideration (in degrees);

$\theta_{az}$ is the azimuth angle under consideration;

L= 6.75 m;

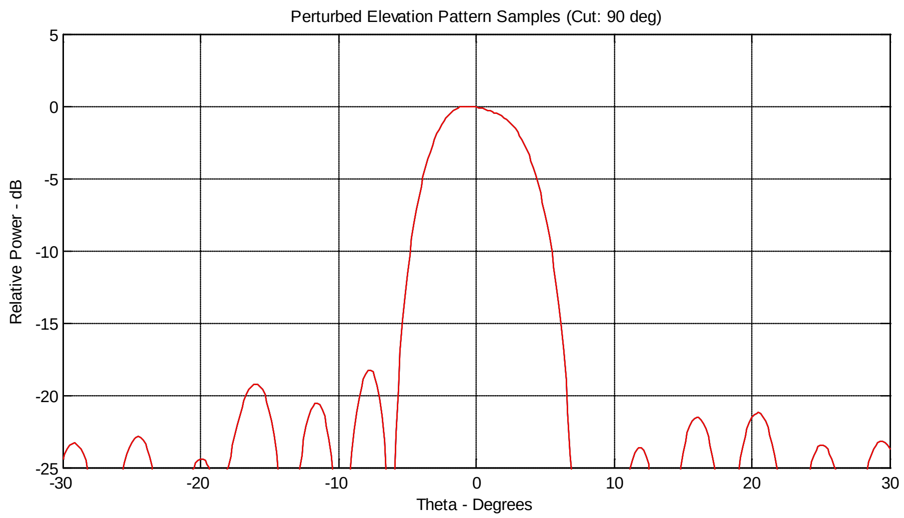
$\lambda$ is the wavelength (meters);

sinc(x) = sin(x)/x.

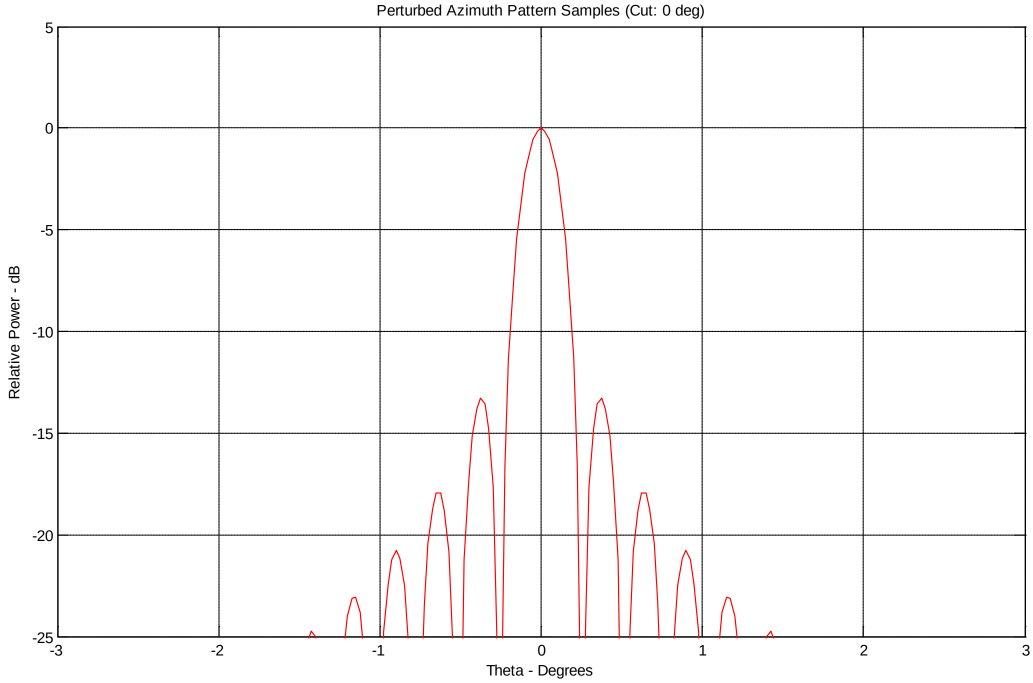
The overall gain is the product (sum in dB) of the elevation and azimuth antenna beam patterns, with a floor at 60 dB below the peak value.

Further characteristics of the RCM system are indicated in Annex C Antenna pattern for Sentinel-1 CSAR:

**Elevation (Directivity: 43.53 dBi)**



**Azimuth**




The Sentinel-1 antenna pattern is also well approximated using a sinc(x) function, using equations 3 and 4 for the elevation (vertical) and azimuth (horizontal) planes, respectively:

$$Gver = 10*\log10((sinc(coef\_V*sind(angle\_V))).\verb|^|2).*(abs(angle\_V)<=90)-1000.*(abs(angle\_V)>90) \quad (3)$$

$$Ghor = 10*\log10((sinc(coef\_H*sind(angle\_H))).\verb|^|2).*(abs(angle\_H)<=90)-1000.*(abs(angle\_H)>90) \quad (4)$$

$$G = \max(G\_min,G\_max+Gver+Ghor) \quad (5)$$

where:

Gver is the discrimination in the elevation plane (dB);

angle_V is the off-axis angle in the elevation plane in the direction under consideration (equation 3 is valid for angle V < 90°);

Ghor is the discrimination in the azimuth plane (dB);

angle_H is the off-axis angle in the azimuth plane in the direction under consideration (equation 4 is valid for angle H <90°);

coef_V is set equal to 9;

coef_H is set equal to 200;

G_min is the minimum gain (-10 dBi);

G_max is the main beam (peak) gain (44 dBi).

*Alternative text proposed by ESA:*

The Sentinel-1 antenna pattern is also well approximated using a sinc(x) function as below:

$$G = \max(G_{min}, G_{max} + G_{ver} + G_{hor});$$

With:

$G_{ver} = 10 \text{ x } \log (\text{sinc}(\text{coefV}.\sin(\text{Elev}))^2)$

$G_{hor} = 10 \text{ x } \log (\text{sinc}(\text{coefH}.\sin(\text{Az}))^2)$

coefV = 9

coefH = 200

$G_{min} = -10$

$G_{max} = 44$

*Note : the cardinal sine function is here used in its form :* $sinc(x) = \frac{\sin(\pi x)}{\pi x}$

## 2.2 RLAN systems parameters and deployment.

**e.i.r.p. level distribution**

| **RLAN e.i.r.p. Level** | **200 mW (Omni-Directional)** | **80 mW (Omni-Directional)** | **50 mW (Omni-Directional)** | **25 mW (Omni-Directional)** |
|---|---|---|---|---|
| RLAN device percentage | 19% | 27% | 15% | 39% |

NOTE - RLAN devices are assumed to be indoors only, based on the requirement to help facilitate coexistence. For the purposes of sharing studies, 5% of the devices should be modelled without building attenuation.

Alternatively administrations may choose to carry out a parametric analysis in any range between 2% and 10%.

These e.i.r.p. values apply across the entire RLAN channel bandwidth.

Alternatively administrations may choose to use a single e. i. r. p level.

**Channel bandwidths distribution**

| **Channel bandwidth** | **20 MHz** | **40 MHz** | **80 MHz** | **160 MHz** |
|---|---|---|---|---|
| RLAN device percentage | 10% | 25% | 50% | 15% |

### Building attenuation

Gaussian distribution with a 17 dB mean and a 7 dB standard deviation (truncated at 1 dB).

Alternatively administrations may choose to use a 17 dB fixed value.

**Propagation model**

The model sums losses (in dB) from the free space loss model in Recommendation ITU-R P.619, the angular clutter loss model in Recommendation ITU-R P.452 and the building attenuation model that is described above.

The angular clutter loss model provided by the “RLAN User Defined Height” column of the attached worksheet were used in conjunction with the antenna heights as described below. The clutter loss values calculated for the "sparse houses", "suburban" and "urban" clutter (ground-cover) categories were applied in the rural, suburban and urban zones of the RLAN deployment model, respectively.

Theta max (°) provides the angle from the RLAN transmitter to the top of the clutter height. Therefore, if the spacecraft is at an elevation angle at or below theta max (°), clutter loss should be added. If the spacecraft is above theta max (°) of the respective clutter category, there is no clutter loss.

Clutter calcs Rev 4.xlsx

**Antenna height**

| RLAN deployment region | Antenna height (metres) |
|---|---|
| Urban | 1.5 to 28.5 |
| Suburban | 1.5, 4.5 |
| Rural | 1.5, 4.5 |

The antenna heights are randomly selected using a uniform probability distribution from the set of floor heights at 3 meter steps.

**Antenna gain/discrimination**

Omnidirectional in azimuth for all scenarios.

**Option A1**: Omnidirectional in elevation with 0 dBi gain In one study this option was used as a baseline, but further considered losses by developing 3 dB cross-polarisation loss for systems without building attenuation, and then considered 0-4 dB random “other” losses.

**Option A2**: Use of a specific RLAN antenna elevation pattern.

This option is no longer considered.

**Option A3: An average 4 dB antenna discrimination is applied to the e.i.r.p. level distribution above in the direction of the satellite RLAN device density relevant to sharing studies**

The following RLAN device densities are to be used as simultaneously transmitting with the e.i.r.p. distribution as given above (no ranking implied).

**Option D1**: 9 365 active devices per 20 MHz channel or 11 279 active devices per 100 MHz channel per 5.25 million inhabitants (see Annex D).

**Option D2**: From 0.000 8 to 0.008 active devices per 20 MHz channel per inhabitant (0.004 to 0.04 per 100 MHz channel) (based on 3% to 30% activity factor) applied to any population size.

**Option D3**: Take into account the EESS interference threshold in order to determine the number of simultaneous RLAN connections which can be tolerated. The RLAN density can then be determined for a given population.(see Annex C).

## 2.3 Mitigating factors

### 2.3.1 Dynamic frequency selection

Studies performed in the ITU-R indicated that dynamic frequency selection (DFS) as currently specified in Recommendation ITU-R M.1652-1 would be ineffective to protect EESS(active) systems in the 5 350-5 470 MHz frequency range.

There was no agreement on whether changes to the current DFS parameters (e.g. timing and detection threshold) could enable sharing with EESS in this frequency range.

Further studies are required to determine, taking into account various EESS(active) parameters (e.g. beam dynamics), which specific DFS changes could enable such sharing and to examine the ability of RLAN to implement such changes.

### 2.3.2 Other mitigation techniques

The following mitigation techniques were considered and deemed inappropriate for further consideration with respect to sharing between RLANs and EESS in the 5 350-5 470 MHz frequency range:

1. ***SAR image post-processing*** (Ground post-processing of the SAR images to filter interference by other pulsed signals): Identified by the ITU-R expert group as not an effective mitigation technique for sharing between EESS(active) and RLAN
2. ***e.i.r.p mask*** (e.i.r.p. mask on the RLAN antenna to reduce emissions in the satellite direction): Identified as not an effective mitigation technique for sharing between EESS(active) and RLAN

The following additional mitigation techniques toward the protection of EESS (active) in the 5 350-5 470 MHz frequency range were initially considered but no conclusion could be drawn. Further studies are required: work is ongoing in the ITU-R:

3. ***Geolocation database*** (Use of a database to forecast the arrival of the EESS satellite in the RLAN area and instruct the RLAN AP’s not to use the relevant channels.): Could be a potential mitigation technique, but concerns were expressed with respect to the challenges that are still unresolved. Further studies are needed, taking into account the information currently being considered by ITU-R
4. ***Alternative channelisation*** (Reduce the RLAN use of the frequency range 5 350-5 470 MHz by excluding certain types of channels and/or use only part of this frequency range.)
5. ***Channel selection prioritisation algorithms*** (Change the spreading algorithms to ensure that the last channels chosen for use by RLANs are the channels available in the 5 350-5 470 MHz band)
6. ***e.i.r.p. reduction*** (Reduction of the max RLAN e.i.r.p. with a minimum TPC range)
   The mitigation techniques above (3 to 6) may be considered separately or in combination and, in addition, other mitigation techniques may be proposed.
   These issues would require further studies.

# 3 Analysis

Five sharing studies have been considered.

1 A parametric study simulating the satellite orbital passes over 2 mid-size countries and a metropolitan area (Annex A). It performs parametric dynamic simulations for low and high density deployments and shows large negative margins as given in the summary table below :

| | **Results for Sentinel-1 CSAR (with 20° off-nadir angle)** | |
|---|---|---|
| RLAN Antenna | **JTG Option A1** (0 dBi Omni) | **JTG Option A3** (–4 dBi discrimination) |
| **Scenarios** (No. of RLAN over the hypothetical city) | | |
| **JTG Option D1** (9870 RLAN in the city) | **Not assessed** | **Not assessed** |
| **JTG Option D2-low** (21000 RLAN in the city)(0.004 RLAN per inhabitant) | **14.5 to 18 dB** | **10.5 to 14 dB** |
| **JTG Option D2-high** (210000 RLAN in the city)(0.04 RLAN per inhabitant) | **23 to 26.5 dB** | **19 to 22.5 dB** |

The study concludes that the sharing between EESS and RLAN in the band 5 350-5 470 MHz is not feasible without some mitigation techniques which would enable to decrease the interference from RLANs to EESS by 10.5 to 26.5 dB.

2 A parametric study using the various options identified for the RLAN parameters. The dynamic analyses simulate the satellite orbital passes over 2 mid-size countries, a metropolitan area and an hypothetical area composed of 3 concentric zones: urban, sub-urban and rural (Annex B). It shows large negative margins as given in the summary table below :

| | **Results for Sentinel-1 CSAR (with 20° off-nadir angle)** | |
|---|---|---|
| RLAN Antenna | **JTG Option A1** (0 dBi Omni) | **JTG Option A3** (–4 dBi discrimination) |
| **Scenarios** (No. of RLAN over the hypothetical city) | | |
| **JTG Option D1** (9870 RLAN in the city) | **13.4 to 17.4 dB** | **9.4 to 13.2 dB** |
| **JTG Option D2-low** (21000 RLAN in the city)(0.004 RLAN per inhabitant) | **16.6 to 20.4 dB** | **12.6 to 16.3 dB** |
| **JTG Option D2-high** (210000 RLAN in the city)(0.04 RLAN per inhabitant) | **26.6 to 30.4 dB** | **22.6 to 26.5 dB** |

The study therefore concludes that RLANs cannot share the band 5 350-5 470 MHz with EESS (active). It further concludes that no potential mitigation techniques would be effective in filling these large negative margins and would also be enforceable/verifiable by administrations.

3 The study in Annex C shows that up to 43 simultaneously transmitting RLAN connections can operate within the Radarsat Constellation Mission (operating under the EESS (active) service) footprint of ~225 kilometres$^2$ without exceeding the interference threshold level specified in Recommendation ITU-R RS.1166-4. When compared to the other studies, it was shown that the expected number of simultaneously transmitting RLAN devices reported by those studies significantly exceed the number of RLAN devices that the RCM can tolerate (by a factor of 50 (or 17 dB) times in some cases). No practical and effective mitigation techniques have yet been found.

4 A dynamic analysis based on simulated passes of the EESS SAR antenna main beam over a distribution of RLANs within a hypothetical area composed of 3 concentric zones: urban, sub-urban and rural representing a typical scenario (Annex D). This study shows that the rules established in adjacent bands for RLAN are insufficient to enable sharing with incumbent systems in the 5 350-5 470 MHz frequency range. Further study is required to determine if changes to these DFS parameters or to see if other mitigation techniques can provide a compatible scenario. Initial studies indicate that a change to DFS detection threshold and the aggregate time for channel detection, channel closing, and channel move time could provide protection of EESS, however further study is required to examine the ability of RLAN to implement such changes and to define the specific levels required. Studies on alternate mitigation measures have not been completed in the ITU and further study is required to determine their applicability.

5 The study in Annex E contains various static and dynamic analyses looking at the sensitivity of the results for different outdoor usage assumptions taking account of the basic RLAN parameters presented in section 2.2. The analyses simulated the satellite orbital passes over the UK, London and a hypothetical area composed of 3 concentric zones: urban, sub-urban and rural. Below are some tables with a snapshot of results with some initial conclusions.

**Analysis 1 - Basic Parameters from section 2.2**

| Table 1 – No additional mitigation added | **Results for Sentinel-1 CSAR (with 20° off-nadir angle)** |
|---|---|
| RLAN antenna | **JTG Option A3** (–4 dBi discrimination) |
| **Simulation scenarios** | **Outdoor RLANs 2 – 5%** |
| **SIM City - Option D1** | **12.4 to 14.8 dB** |
| **UK - Option D1** | **13.6 to 16 dB** |
| **London – Option D1** | **17 to 19.4 dB** |

The results from table 1 show that sharing is unlikely to be possible in the 5 350 to 5 470 MHz band in the absence of additional mitigation.

**Analysis 2 - Basic parameters plus mitigation options**

Analysis 2 investigated using a combination of possible additional mitigations and lower RLAN maximum power levels with a minimum TPC range.

| Table 2 – additional mitigations combined and maximum power levels reduced | **Results for Sentinel-1 CSAR (with 20° off-nadir angle)** |
|---|---|
| RLAN antenna | **JTG Option A3** (–4 dBi discrimination) |
| **Simulation scenarios** | **Outdoor RLANs 2 – 5%** |
| **SIM City - Option D1 – combination of mitigations (max. 200mW)** | **0.7 to 3.1 dB** |
| **SIM City - Option D1 – combination of mitigations (max. 100mW)** | **–1.8 to 0.6 dB** |
| **SIM City - Option D1 – combination of mitigations (max. 50mW)** | **–3.2 to –0.8 dB** |

The results from Table 2 show if a maximum power level of 50 mW is implemented in addition to these other mitigations, the interference criterion can be met.

**Analysis 3 – Investigation of different RLAN activity factors**

In addition in order to place a realistic cap on the number of active devices the analysis investigated placing a limit on the maximum number of active RLAN networks within a given area ($km^2$) based on assumptions for minimum frequency re-use distances between 1 GBit RLAN networks using the same channel. The results of this analysis show that there is significant reductions in interference when applying mitigation and a realistic limit on the maximum number of devices within a given area based on the maximum frequency re-use distance for RLANs.

As a general conclusion, the results show that when taking account of the basic RLAN parameters presented in section 2.2 that sharing may only be feasible if additional RLAN mitigation measures are implemented. They show that there may be a possibility of sharing with lower power RLAN use (e.g. 50 mW or below). It also appears that if we assume that there will be more than 1% of RLANs operating outdoor then the only viable mitigation technique studied so far that would be able to protect EESS operations from higher power RLAN operations in urban areas would be mitigation techniques that can employ a temporal and geographical sharing technique that takes account of the Sentinel-1 CSAR satellite orbits (e.g. geo-location database).

# 4 Conclusions

Results of sharing studies in the annexes show that with the RLAN parameters presented in section 2.2, sharing between RLAN and EESS (active) systems in the 5 350-5 470 MHz range would not be feasible. Sharing may only be feasible if additional RLAN mitigation measures are implemented.

Two mitigation measures were deemed to be inappropriate for further consideration with respect to sharing between EESS(active) and RLANs. No agreement was reached on the applicability of other additional RLAN mitigation techniques and the studies contained herein. Some additional RLAN mitigation techniques to enable sharing with EESS (active) are being studied by the ITU-R, but no conclusions can be drawn at this time.

Some administrations are of the view that, based on the amount of studies conducted so far and their conclusions showing that the sharing is not feasible due to the considerable negative margins still to be accommodated even when considering some mitigation techniques, including a combination of them, there is no need to further work on this issue.

Some other administrations are of the view that based on studies showing that potential solutions for sharing between RLAN and EESS(active) may be achieved with additional study, and on-going work on RLAN mitigation techniques, there is a need for further study in the ITU-R.
These administrations support these efforts and will contribute studies to advance this work].

# ANNEX A (TO ATTACHMENT 2)

See Document 4-5-6-7/606 and 4-5-6-7/609

# ANNEX B (TO ATTACHMENT 2)

See Documents 4-5-6-7/ 664

# ANNEX C (TO ATTACHMENT 2)

See Document 4-5-6-7/478 and 4-5-6-7/624

# ANNEX D (TO ATTACHMENT 2)

See Document 4-5-6-7/704

# ANNEX E (TO ATTACHMENT 2)

See Document 4-5-6-7/632