**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) | |
| Title | IEEE P802.15-19-0143-00-004z  RLAN and UWB systems Coexistence Study  Dries Neirynck <dries.neirynck@decawave.com> | |
| Date Submitted | November 2018 | |
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| Re: | Analyze the coexistence of 802.15.4z and other 802 wireless systems | |
| Abstract | IEEE 802.15.4 Coexistence Document | |
| Purpose | Document coexistence analysis | |
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# Introduction

This contribution considers the impact of the potential introduction of RLAN systems in the 6 GHz band on UWB systems.

The RLAN deployment assumptions are based on those listed in the RKF study. However, as many of these assumptions, in particular with regards to market share, duty cycle and transmit power control, are not included in the regulations as currently proposed, alternative sets of assumptions are also evaluated.

# RLAN deployment assumptions

## RFK-like assumptions

In first instance, the RLAN deployment characteristics from the RKF study (<https://s3.amazonaws.com/rkfengineering-web/6USC+Report+Release+-+24Jan2018.pdf>) are followed. However, whereas the RKF study appears to have a time horizon of 2025 and therefore considers a market share of 45% for 6 GHz enabled RLAN, compatibility studies should give confidence to existing users much longer in the future and a market share of 95% 6 GHz enabled RLAN is therefore assumed. A further small modification takes into account that the current regulations don’t allow transmissions at 4 W.

For completeness, the relevant assumptions are listed below.

Each person is assumed to have 10 RLAN devices. Ten percent are high activity devices, with a duty cycle of 0.44%, while the remaining ninety percent of devices are low activity devices with a duty cycle of 0.00022%.

As discussed above, and unlike the RKF study, 95% of RLAN devices are assumed to 6 GHz enabled. Based on the ratio of available bandwidth, 68% of those devices is assumed to be actually operating in the 6 GHz band.

Only 2% of the devices operate outdoors, with the remaining 98% used indoors.

The RLAN power distribution was modified slightly to take into account that the proposed rules don't allow 4 W transmissions. It was therefore assumed that these transmissions will also take place at 1 W. Based on table 3-7 and 3-8 of the original RKF report, the power distributions then become:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **EIRP (mW)** | **1000** | **250** | **100** | **50** | **13** | **1** |
| **Indoor** | 0.67%+042% | 10.39% | 6.49% | 24.64% | 51.84% | 5.56% |
| **Outdoor** | 2.83%+2.02% | 9.45% | 9% | 32.13% | 41.99% | 2.58% |

In the frequency bands where the regulations don’t allow 1000 mW transmissions, it is assumed these will take place at 250 mW instead.

The RFK study assumes the RLAN devices will operate in compliance with IEEE 802.11 in bandwidths of 20, 40, 80 and 160 MHz. The probability of a certain bandwidth being used is given in table 3-9 in the RFK report, which is reproduced here for completeness:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bandwidth** | **20 MHz** | **40 MHz** | **80 MHz** | **160 MHz** |
| **Percentage** | 10% | 10% | 50% | 30% |

## Other assumptions

While the RKF assumptions are based on current IEEE 802.11 deployment scenarios, other RLAN systems and deployment scenarios are possible under the proposed regulations. In particular, the regulations don’t restrict transmit power and duty cycle.

The indoor/outdoor ratio and bandwidth distribution of the RKF studies have been preserved. It is currently not known whether these are representative of future applications. For example, one could easily imagine that augmented reality applications are more likely to be used outdoors and that as spectrum demand and modulation efficiency increases, the smaller bandwidths will become more popular. However, all other RLAN deployment assumptions, including the number of high and low activity devices per person, are not changed.

### No transmit power control

The proposed regulations don't require transmit power control and certainly can't specify the distribution assumed in the RKF study. The regulations can’t require system to comply with any version of the IEEE 802.11 standards either and even those systems often don’t use transmit power control. The transmit power distribution proposed in the RKF study is therefore highly questionable. As an alternative, in order to study the impact of transmit power control, the following alternative power distribution is therefore also considered and contrasted to the RKF-like results:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **EIRP (mW)** | **1000** | **250** | **100** | **50** | **13** | **1** |
| **Indoor** | 90% | 2% | 2% | 2% | 2% | 2% |
| **Outdoor** | 90% | 2% | 2% | 2% | 2% | 2% |

In the frequency bands where the regulations don’t allow 1000 mW transmissions, it is assumed these will take place at 250 mW instead.

All other RLAN deployment assumptions, in particular with regards to the bandwidth distribution and number of high and low activity devices per person are not changed.

### Increased duty cycle

The proposed regulations don’t contain any restrictions on the duty cycle of the RLAN access points. To evaluate the influence of duty cycle on interference to existing users, an alternative deployment scenario in which high activity devices are assumed to have 5% duty cycle, while low activity devices have a 1% duty cycle is also considered.

### Combining no TPC and increased duty cycle

While the previous two alternative deployment scenarios allow evaluation of the relative merits of duty cycle restrictions and transmit power control, neither are currently included in the regulations and a combination of both therefore represents the most realistic deployment assumption.

# Sharing studies

## Single interferer

In this section, the effect of the proposed RLAN transmissions on an UWB receiver is evaluated using a minimum coupling loss study. More detailed Monte Carlo simulations are performed in the next sections but in order to perform those an initial appreciation of the interference potential of the RLAN systems is helpful.

The UWB victim is assumed to have a 500 MHz bandwidth, centred on 6.5 GHz. The RLAN system transmits in-band, with an EIRP of either 250 or 1000 mW. The propagation between the two systems is assumed to be free space.

The I/N ratios shown in the figure below highlight that the RLAN system interferes over huge distances. An I/N ratio of 0 dB is only reach at a separation distance of 1.3 km for 250 mW and 2.6 km for 1000 mW transmissions. Close up, the I/N ratios at 1 metre separation reach 62 and 68 dB respectively.



## Apartment block

In this section, the aggregate interference of RLAN transmitters on UWB systems is evaluated using Monte Carlo simulations for an apartment block scenario.

The individual apartments are assumed to occupy an area of 10 by 8 metres. On average, there are 3 occupants per apartment. The apartment block consists of 10 floors, each 3.5 metres high, with two times ten apartments back to back.

For every iteration, the UWB receiver is randomly located within the building. Similarly, RLAN transmitters are randomly spread throughout the building according to the various deployment assumptions discussed above. The total RLAN interfering power at the UWB receiver is calculated using the indoor path loss model from IEEE 802.11ax channel model B (IEEE 802.11-14/0882r4), as was agreed with the RLAN community within CEPT ECC SE45. Following the model, a wall penetration loss of 5 dB is used. Only RLAN transmitters that overlap with the UWB bandwidth are considered. This conservative assumption implies physically impossible brick-wall filtering in the UWB receiver and infinite out-of-band suppression in the RLAN transmitters.

Every curve in the figure below is the result of half a million iterations of the Monte Carlo simulation.



Table 1: Numerical results 500 MHz UWB bandwidth apartment block scenario

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **I/N (dB)** | **RFK-like scenario** | **Increased Duty Cycle** | **No Transmit Power Control** | **Combination scenario** |
| -10 | 0.626% | 15.667% | 1.044% | 24.862% |
| 0 | 0.416% | 10.537% | 0.710% | 17.662% |
| 10 | 0.267% | 6.776% | 0.471% | 12.031% |
| 20 | 0.157% | 3.954% | 0.309% | 7.836% |
| 30 | 0.079% | 2.041% | 0.183% | 4.814% |
| 40 | 0.035% | 0.889% | 0.098% | 2.531% |

Table 2: Numerical results 1 GHz UWB bandwidth apartment block scenario

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **I/N (dB)** | **RFK-like scenario** | **Increased Duty Cycle** | **No Transmit Power Control** | **Combination scenario** |
| -10 | 1.009% | 23.954% | 1.679% | 36.859% |
| 0 | 0.652% | 16.148% | 1.130% | 26.539% |
| 10 | 0.404% | 10.232% | 0.739% | 18.110% |
| 20 | 0.224% | 5.716% | 0.463% | 11.712% |
| 30 | 0.105% | 2.843% | 0.267% | 6.869% |
| 40 | 0.039% | 1.079% | 0.129% | 3.465% |

The figure and summary table show that the RLAN transmissions cause significant levels of interference, even under the benign RKF-like deployment assumptions. When the other deployment assumptions, still within the proposed regulatory limits, are used, the interference probability quickly shoots up. In the worst case, without transmit power control and with higher duty cycle, I/N ratios of over 40 dB occur with a probability of more than 2 or 3 percent, depending on the bandwidth considered. To limit the potential of interference, it’s crucial that both transmit power control and especially duty cycle constraints are included in the regulations.

## London scenario

In this aggregate scenario, it is assumed that an inhabitant of a large urban city is using an UWB receiver. Since population statistics for London are publicly available (2017, <https://data.london.gov.uk/dataset/london-borough-profiles>), the characteristics of London will be used.

The results of the single interferer evaluation show that RLAN transmitters located close to the UWB victim receiver are most harmful. Therefore, Monte Carlo simulations are performed with the UWB receiver at the centre of a circle with an area of 1 km2.

RLAN devices are randomly spread throughout the area by combining the population density with the deployment assumptions listed above. Only RLAN transmitters that overlap with the UWB bandwidth are considered. This conservative assumption implies physically impossible brick-wall filtering in the UWB receiver and infinite out-of-band suppression in the RLAN transmitters.

The RLAN devices are distributed in height according to the urban distribution from the RKF study.

The site general path-loss model for propagation between terminals located from below roof-top height to near street level from ITU-R P.1411-9 is used as this has also been agreed with the RLAN community in CEPT ECC SE45. A fifth of the UWB receivers are assumed to be outdoors. As in the RKF study, buildings have 20% probability of being thermally efficient, with a building entry loss of 32.2 dB. Otherwise, the building entry loss is assumed to be 16.7 dB.

The results of the Monte Carlo are shown in the figure below. Five hundred thousand simulations have been performed per curve.



Table 3: Numerical results 500 MHz UWB bandwidth London scenario

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **I/N (dB)** | **RFK-like scenario** | **Increased Duty Cycle** | **No Transmit Power Control** | **Combination scenario** |
| -10 | 1.006% | 18.001% | 2.292% | 34.919% |
| 0 | 0.385% | 8.067% | 1.438% | 20.991% |
| 10 | 0.111% | 2.682% | 0.465% | 10.418% |
| 20 | 0.028% | 0.655% | 0.170% | 3.497% |
| 30 | 0.005% | 0.152% | 0.037% | 0.843% |
| 40 |  | 0.013% | 0.007% | 0.209% |

Table 4: Numerical results 1 GHz UWB bandwidth London scenario

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **I/N (dB)** | **RFK-like scenario** | **Increased Duty Cycle** | **No Transmit Power Control** | **Combination scenario** |
| -10 | 1.294% | 19.523% | 3.403% | 36.553% |
| 0 | 0.453% | 7.923% | 1.781% | 22.195% |
| 10 | 0.128% | 2.758% | 0.587% | 9.750% |
| 20 | 0.028% | 0.578% | 0.157% | 3.392% |
| 30 | 0.004% | 0.135% | 0.045% | 0.699% |
| 40 |  | 0.008% | 0.005% | 0.184% |

Compared to the apartment scenario, the probability of nearby RLAN transmitters is reduced. However, even under the RKF deployment assumptions, there is still a significant amount of interference. The level of interference becomes prohibitive under the other assumptions, again showing the need for duty cycle limitations and transmit power control in the regulations.

# Conclusions

* Lower power limits for the RLAN system
* Less bandwidth for the RLAN system
* Duty cycle limits for the RLAN system: 0.5% as proposed in RKF study.
* Transmit power control for the RLAN system: again at most as proposed in the RKF study

# Extra

Figures with limits from SE45, those that correspond to 3 dB sensitivity reduction (-65 dBm for 1 GHz and -78 dBm for 500 MHz UWB bandwidth)



