Report for the DECT Forum on coexistence studies between DECT NR+ (unsynchronised low power station) and other radio applications in the 3.8 to 4.2 GHz band

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# Summary

The studies discussed in this report have been performed by Transfinite Systems for the DECT Forum.

We have carried out Minimum Coupling Loss, Monte Carlo and other analyses in order to determine geographical and frequency separations required between DECT NR+ and other radio applications sharing the 3.8 ‑ 4.2 GHz frequency band or between DECT NR+ in this band and applications in adjacent bands. These studies include an intra-application interference analysis for DECT NR+.

Some example Block Edge Mask calculations have been performed, based on the results of these studies.

A large number of software simulations have been performed investigating a range of interference and compatibility problems with various configurations of the radio interference path considered. These analyses are extensive but with scope for development and further investigation.

# List of abbreviations

|  |  |
| --- | --- |
| Abbreviation | Explanation |
| DECT NR+ | Digital Enhanced Cordless Telecommunications New Radio+ |
| FS | Fixed Service |
| FSS | Fixed Satellite Service |
| ITU-R | International Telecommunication Union – Radiocommunication Sector |
| MCL | Minimum Coupling Loss |
| WBB LP/MP | Wireless Broadband Low Power/Medium Power |

# Technical parameters

## Background

Subcarrier spacing is defined by the subcarrier scaling factor, resulting either in 27 kHz, 54 kHz, 108 kHz or 216 kHz OFDM subcarriers spacing. In addition, the Fourier transform scaling factor can be set to allow different transmission bandwidths for each configuration of the subcarrier spacing. This results in the support of nominal RF bandwidth from 1.728 MHz, 3.456 MHz, 6.912 MHz up to 221.184 MHz. The modulation schemes are BPSK, QPSK, 16 QAM, 64 QAM, 256 QAM and 1024 QAM. Within this section only nominal RF bandwidths of 1.728 MHz, 3.456 MHz and 6.912 MHz are considered.

DECT parameters with channel raster 10 MHz are to be used and that Radiated power e.i.r.p. (dBm) is 23 per carrier, limited to 24 dBm/10 MHz.

## Equipment parameters

Table 1 summarises the technical parameters of DECT devices to be used in studies. These parameters are taken from the ETSI TS 103 636-2 v1.4.1, with modified noise figures due to higher frequencies. The parameters do not make a distinction between the Fixed Termination point and the Portable Termination point.

Table 1: Parameters of DECT NR+ providing local network connectivity in the 3.8-4.2 GHz band

|  |  |  |  |
| --- | --- | --- | --- |
| Parameter | Value | | |
| Nominal channel bandwidth (MHz) | 1.728 | 3.456 | 6.912 |
| Transmission channel bandwidth (MHz) | 1.539 | 3.051 | 6.075 |
| Transmitter power (dBm) | 23 | 23 | 23 |
| Radiated power e.i.r.p. (dBm) | 23 | | |
| Antenna gain | 0 dBi | | |
| Antenna height | Outdoor: Limited to a maximum of 10 m above ground  Indoor: Any height within building | | |
| Noise figure (dB) | 9 | 9 | 9 |
| Rx indoor receiving level | 20 dBm to reference sensitivity | | |
| Rx outdoor receiving level | 20 dBm to reference sensitivity | | |
| Rx sensitivity (dBm) | -97.7 | -94.7 | -91.7 |
| Protection criteria | 5 dB S/N+I | | |

## Transmitter spectrum emission requirements

### Out of band emissions

The spectrum emission mask of the device applies to frequencies (ΔfOOB) starting from the ± edge of the assigned channel. For frequency offsets greater than ΔfOOB the spurious emission requirements in Table 4 are applicable.

Table 2: Spectrum emission limit for 1.728 MHz channel bandwidth

|  |  |  |
| --- | --- | --- |
| Spectrum emission limit (dBm) | | |
| **ΔfOOB/MHz** | **1,728 MHz channel bandwidth** | **Measurement bandwidth** |
| ±0 to 0,0945 | -10 | 30 kHz |
| ±0,0945 to 1,6335 | -10 | 1 MHz |
| ±1,6335 to 1,8225 | -13 | 1 MHz |
| ±1,8225 to 3,3615 | -20 | 1 MHz |
| ±3,3615 to 3,456 | -23 | 1 MHz |

Table 3: Spectrum emission limit for 3.456 MHz channel bandwidth

|  |  |  |
| --- | --- | --- |
| Spectrum emission limit (dBm) | | |
| **ΔfOOB/MHz** | **3.456 MHz channel bandwidth** | **Measurement bandwidth** |
| ±0 to 0,2025 | -10 | 30 kHz |
| ±0,2025 to 3,2535 | -10 | 1 MHz |
| ±3,2535 to 3,6585 | -13 | 1 MHz |
| ±3,6585 to 6,7095 | -20 | 1 MHz |
| ±6,7095 to 6,912 | -23 | 1 MHz |

Table 4: Spectrum emission limit for 6.912 MHz channel bandwidth

|  |  |  |
| --- | --- | --- |
| Spectrum emission limit (dBm) | | |
| **ΔfOOB/MHz** | **6.912 MHz channel bandwidth** | **Measurement bandwidth** |
| ±0 to 0,4185 | -10 | 30 kHz |
| ±0,4185 to 6,4935 | -10 | 1 MHz |
| ±6,4935 to 7,3305 | -13 | 1 MHz |
| ±7,3305 to 13,4055 | -20 | 1 MHz |
| ±13,4055 to 13,824 | -23 | 1 MHz |

### Spurious emissions

The spurious emission limits apply for the frequency ranges that are more than ΔfOOB (MHz) in Table 2 from the edge of the channel bandwidth. The spurious emission limits in Table 5 apply for all transmitter bands and channel bandwidths.

Table 5: Spurious emission limits

|  |  |  |  |
| --- | --- | --- | --- |
| Spurious emission limit (dBm) | | | |
| **Frequency Range** | **Maximum Level** | **Measurement bandwidth** |
| 9 kHz ≤ f < 150 kHz | -36 | 1 kHz |
| 150 kHz ≤ f < 30 MHz | -36 | 10 kHz |
| 30 MHz ≤ f < 1 000 MHz | -36 | 100 kHz |
| 1 GHz ≤ f < 12,75 GHz | -30 | 1 MHz |
| 12,75 GHz ≤ f < 5th harmonic of the upper frequency edge in GHz | -30 | 1 MHz |

## Receiver characteristics

### Adjacent Channel Selectivity

Table 6: Adjacent Channel Selectivity

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Adjacent Channel Selectivity | | | | |
| **Rx Parameter** | **Channel bandwidth (MHz)** | | | **Unit** |
| **1.728** | **3.456** | **6.912** |
| Own signal input level | RXsensitivity + 14 dB | | | dBm |
| PInterferer | RXsensitivity + 39 dB | RXsensitivity + 39 dB | RXsensitivity + 39 dB | dBm |
| BWInterferer | 1.728 | 3.456 | 6.912 | MHz |
| FInterferer (offset) | 1.728 or -1.728 | 3.456 or -3.456 | 6.912 or -6.912 | MHz |

### In-band blocking characteristics

Table 7: In-band blocking

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| In-band blocking | | | | |
| **Rx Parameter** | **Channel bandwidth (MHz)** | | | **Unit** |
| **1.728** | **3.456** | **6.912** |
| Own signal input level | RXsensitivity + 6 dB | | | dBm |
| PInterferer | RXsensitivity + 52 dB | RXsensitivity + 52 dB | RXsensitivity + 52 dB | dBm |
| BWInterferer | 1.728 | 3.456 | 6.912 | MHz |
| FInterferer (offset from operating channel edge) | 2,592 + additional channel frequency step  Or  -2,592 - additional channel frequency step | 5,184 + additional channel frequency step  Or  -5,184 - additional channel frequency step | 10,368 + additional channel frequency step  Or  -10,368 - additional channel frequency step | MHz |

# Minimum Coupling Loss Analyses

MCL analyses have been performed in Visualyse Professional software order to assess the geographical or frequency separations required between interferer and victim. The software simulations are highly configurable and variations of the model were investigated including modelling of clutter loss at one end of the interference path and interference sourced from the victim receiver’s adjacent channel.

In addition, some early analyses calculated geographical separations using the method discussed in section 2.1.

## Early Analyses

Our approach can be presented mathematically. We first of all calculate the isolation loss required between interferer and victim receiver.

Equation 1

(dB)

where

* = required isolation loss (dB)
* = interferer’s transmitter power (dBm)
* = interferer’s antenna gain (dBi)
* = clutter losses at the interferer’s location (dB)
* = clutter losses at the victim receiver’s location (dB)
* = victim receiver’s antenna gain (dBi)
* = other losses at the receiver installation e.g. feeder losses (dB)
* = thermal noise level at the victim receiver (dBm)
* = interference-to-noise ratio at the victim receiver (dB)
* = Net Filter Discrimination (dB)

This particular formulation of the isolation loss equation uses an I/N protection criterion and allows for clutter loss at both ends of the interference path. We include Net Filter Discrimination (NFD) which is the discrimination available when interferer and victim receiver are tuned to different frequencies; this term also includes a simple bandwidth correction factor which is applied in both co-channel and adjacent scenarios.

With obtained we can then calculate the path length required to deliver this level of isolation exactly.

If we were to use a free space path loss model, this can be calculated using

Equation 2

where

* + = path length (km)
  + = frequency of the interfering signal (MHz)

and if we require = exactly, we can calculate the length of the interference path that will deliver this level of isolation

Equation 3

.

Some initial calculations were performed on this basis and a sample of our results are presented here in Table 7 and Table 8.

The Table 7 calculation shows that for co-channel interference between a DECT NR+ interferer and receiver, we require 0.579 km geographical separation when exercising equations (1), (2) and (3).

The second set of calculations in Table 8 includes the Net Filter Discrimination (NFD) available when the interferer resides in the victim receiver’s first adjacent channel; this is calculated following the method given in [1] and discussed in section 5. We can see that the required path length is now reduced to 0.03 km.

Table 7: Calculation for geographical distance

|  |  |  |
| --- | --- | --- |
| DECT NR+ interferer v DECT NR+ victim |  |  |
| Parameter | Unit | Value |
| interferer transmit power | dBm | 23 |
| interferer antenna gain | dBi | 0 |
| interferer clutter loss | dB | 0 |
| victim clutter loss | dB | 0 |
| victim receiver antenna gain | dBi | 0 |
| victim receiver other losses | dB | 0 |
| victim receiver bandwidth | MHz | 6.912 |
| victim Noise Figure | dB | 9 |
| victim thermal noise | dBm | -96.61 |
| Wanted signal level | dBm | -71.70 |
| victim S/(N+I) | dB | 5 |
| N+I threshold | dBm | -76.70 |
| Interference threshold | dBm | -76.74 |
| NFD (or ACIR) | dB | 0 |
| REQUIRED ISOLATION (Equation 1) | dB | 99.74 |
|  |  |  |
| interferer frequency | MHz | 4000 |
| wavelength | m | 0.075 |
|  |  |  |
| REQUIRED PATH LENGTH (Equation 3) | km | 0.579 |

Table 8: Calculation for geographical distance with NFD

|  |  |  |
| --- | --- | --- |
| DECT NR+ interferer v DECT NR+ victim |  |  |
| interferer transmit power | dBm | 23 |
| interferer antenna gain | dBi | 0 |
| interferer clutter loss | dB | 0 |
| victim clutter loss | dB | 0 |
| victim receiver antenna gain | dBi | 0 |
| victim receiver other losses | dB | 0 |
| victim receiver bandwidth | MHz | 6.912 |
| victim Noise Figure | dB | 9 |
| victim thermal noise | dBm | -96.61 |
| Wanted signal level | dBm | -71.70 |
| victim S/(N+I) | dB | 5 |
| N+I threshold | dBm | -76.70 |
| Interference threshold | dBm | -76.74 |
| NFD (or ACIR) | dB | 25.84 |
| REQUIRED ISOLATION (Equation 1) | dB | 73.90 |
|  |  |  |
| interferer frequency | MHz | 4000 |
| wavelength | m | 0.075 |
|  |  |  |
| REQUIRED PATH LENGTH (Equation 3) | km | 0.030 |

These initial calculations provided some insight into the geographical distances required for different interference paths and different pairings of interferer and victim receiver. Our studies were continued in Visualyse Professional software.

## Software simulations

Following our early MCL analyses, a set of software simulations were performed in Visualyse Professional. For interference between DECT NR+ radios and between DECT NR+ and WBB LMP radios, a software simulation was built which modelled single-entry or aggregate interference incident to a receiver with the path length between interferer and victim increasing at each step in the simulation. Interference is calculated at each step and the logged results used as a look-up table to find the shortest geographical separation between interferer and victim where the receiver’s interference protection criterion is satisfied.

These simulations are configurable and different runs were performed to take account of NFD and clutter losses on the interference path. The results of analyses using this approach including summaries of the input parameters and modelling used on the interference path are reported on in section 2.3.

For interference between DECT NR+ and FS and between DECT NR+ and FSS, we have taken a slightly different approach which takes account of the antenna patterns used by FS and FSS and the antenna discrimination available when interferers are off-axis. For these scenarios, we have a version of the MCL simulations that calculates single-entry interference incident to the FS or FSS receiver over a range of azimuths which include interference exposed to the maximum receiver antenna gain available on an interference path. Again, these simulations are configurable and different runs were performed to take account of NFD and clutter losses. The results of analyses using this approach are reported on in sections 2.4 and 2.5.

## DECT NR+ and WBB LMP

MCL analyses were performed in Visualyse Professional software. The simulations were designed using the radio system input parameter values given in Table 9 and Table 10 and Table 11. The modelling used on the interference path is summarised in Table 12 and a summary of the NFD values used is given in Table 13.

Table 9: DECT NR+ characteristics

|  |  |  |  |
| --- | --- | --- | --- |
| DECT NR+ parameter | Value | Unit | Comments |
| Bandwidth | 6.912 | MHz | Resides on a 10 MHz channel raster |
| Transmitter power | 23 | dBm |  |
| Antenna height | 10 | m |  |
| Antenna gain | 0 | dBi |  |
| Typical Wanted Receiving Signal level | -71.7 | dBm |  |
| Noise Figure | 9 | dB |  |
| Receiver Noise | -96.61 | dBm |  |
| S/(N+I) requirement | 5 | dB |  |
| N+I threshold | -76.7 | dBm |  |
| Interference threshold | -76.74 | dBm |  |

Table 10: WBB LP characteristics

|  |  |  |  |
| --- | --- | --- | --- |
| WBB LP parameter | Value | Unit/description | Comments |
| Bandwidth | 10 or 100 | MHz |  |
| Antenna height | 30 | m |  |
| Antenna gain | 12 | dBi |  |
| Noise Figure | 5 | dB | Macro cell |
| Total receiver Noise | -99.01 (10 MHz)  -89.01 (100 MHz) | dBm |  |
| I/N requirement | -6 | dB |  |
| Interference threshold | -105.01 (10 MHz)  -95.01 (100 MHz) | dBm  dBm |  |

Table 11: WBB MP characteristics

|  |  |  |  |
| --- | --- | --- | --- |
| WBB MP parameter | Value | Unit/description | Comments |
| Bandwidth | 10 or 100 | MHz |  |
| Antenna height | 30 | m |  |
| Antenna gain | 16 | dBi |  |
| Noise Figure | 5 | dB | Macro cell |
| Receiver Noise | -99.01 (10 MHz)  -89.01 (100 MHz) | dBm |  |
| I/N requirement | -6 | dB |  |
| Interference threshold | -105.01 (10 MHz)  -95.01 (100 MHz) | dBm  dBm |  |
| EIRP | 42 (10 MHz)  36 (100 MHz) | dBm  dBm/5 MHz |  |

Table 12: Modelling summary (interference path)

|  |  |  |
| --- | --- | --- |
| Model | Parameter/description | Unit |
| ITU-R P.2108 (50%, 30%) | Clutter loss | dB |
| ITU-R P.452 (50%) | Interference path | dB |
| ETSI TR 101 854 | Net Filter Discrimination | dB |

Table 13: Summary of NFD obtained

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Interferer | Interferer bandwidth  (MHz) | Victim | Victim bandwidth  (MHz) | Scenario | NFD  (dB) |
| DECT NR+ | 6.912 | DECT NR+ | 6.912 | First adjacent channel | 25.84 |
| DECT NR+ | 6.912 | WBB LP | 10 | First adjacent channel | 25.40 |
| DECT NR+ | 6.912 | WBB LP | 100 | First adjacent channel | 25.27 |
| DECT NR+ | 6.912 | WBB MP | 10 | First adjacent channel | 25.4 |
| DECT NR+ | 6.912 | WBB MP | 100 | First adjacent channel | 25.4 |
| WBB MP | 10 | DECT NR+ | 6.912 | Co-channel (Note 1) | 1.6 |
| WBB MP | 10 | DECT NR+ | 6.912 | First adjacent channel | 32.0 |
| WBB MP | 100 | DECT NR+ | 6.912 | Co-channel (Note 1) | 1.6 |
| WBB MP | 100 | DECT NR+ | 6.912 | First adjacent channel | 41.34 |

Note 1: NFD is dominated by a simple bandwidth correction factor in scenarios where the interferer’s bandwidth is greater than that of the victim receiver.

Table 14 to Table 17 report on the results of our MCL analyses. A total of 34 scenarios are covered with variations for clutter loss, first-adjacent channel interference and aggregate interference.

Table 14: Interference between 6.912 MHz DECT NR+

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario description | Interferer | Victim | Geographical separation (km) |
| Single-entry, co-channel | DECT NR+ | DECT NR+ | 0.582 |
| Single-entry, co-channel, clutter at one terminal (50% of locations) | DECT NR+ | DECT NR+ | 0.250 |
| Single-entry, co-channel, clutter at one terminal (30% of locations) | DECT NR+ | DECT NR+ | 0.250 |
| Single-entry, first adjacent channel interference | DECT NR+ | DECT NR+ | 0.03 |

Table 15: Interference from 6.912 MHz DECT NR+ into WBB LP

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario description | Interferer | Victim | Geographical separation (km) |
| Single-entry, co-channel | DECT NR+ | WBB LP 10 MHz | 30.2 |
| Single-entry, co-channel, clutter at one terminal (50% of locations) | DECT NR+ | WBB LP 10 MHz | 1.8 |
| Single-entry, co-channel, clutter at one terminal (30% of locations) | DECT NR+ | WBB LP 10 MHz | 2.2 |
| Single-entry, first adjacent channel interference | DECT NR+ | WBB LP 10 MHz | 3.3 |
| Single-entry, co-channel | DECT NR+ | WBB LP 100 MHz | 18.7 |
| Single-entry, co-channel, clutter at one terminal (50% of locations) | DECT NR+ | WBB LP 100 MHz | 0.7 |
| Single-entry, co-channel, clutter at one terminal (30% of locations) | DECT NR+ | WBB LP 100 MHz | 0.8 |
| Single-entry, first adjacent channel interference | DECT NR+ | WBB LP 100 MHz | 1.1 |
| Aggregate, co-channel | DECT NR+ | WBB LP 100 MHz | 30.2 |
| Aggregate, co-channel, clutter at the receiver (50% of locations) | DECT NR+ | WBB LP 100 MHz | 1.8 |
| Aggregate, co-channel, clutter at the receiver (30% of locations) | DECT NR+ | WBB LP 100 MHz | 2.2 |

Table 16: Interference from 6.912 MHz DECT NR+ into WBB MP

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario description | Interferer | Victim | Geographical separation (km) |
| Single-entry, co-channel | DECT NR+ | WBB MP 10 MHz | 33.4 |
| Single-entry, co-channel, clutter at one terminal (50% of locations) | DECT NR+ | WBB MP 10 MHz | 2.7 |
| Single-entry, co-channel, clutter at one terminal (30% of locations) | DECT NR+ | WBB MP 10 MHz | 3.5 |
| Single-entry, first adjacent channel interference | DECT NR+ | WBB MP 10 MHz | 5.0 |
| Single-entry, co-channel, | DECT NR+ | WBB MP 100 MHz | 25.4 |
| Single-entry, co-channel, clutter at one terminal (50% of locations) | DECT NR+ | WBB MP 100 MHz | 1.0 |
| Single-entry, co-channel, clutter at one terminal (30% of locations) | DECT NR+ | WBB MP 100 MHz | 1.2 |
| Single-entry, first adjacent channel interference | DECT NR+ | WBB MP 100 MHz | 1.7 |
| Aggregate, co-channel | DECT NR+ | WBB MP 100 MHz | 33.4 |
| Aggregate, co-channel, clutter at the receiver (50% of locations) | DECT NR+ | WBB MP 100 MHz | 2.7 |
| Aggregate, co-channel, clutter at the receiver (30% of locations) | DECT NR+ | WBB MP 100 MHz | 3.5 |

Table 17: Interference from WBB MP into 6.912 MHz DECT NR

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario description | Interferer | Victim | Geographical separation (km) |
| Single-entry, co-channel | WBB MP 10 MHz | DECT NR+ | 3.6 |
| Single-entry, co-channel, clutter at one terminal (50% of locations) | WBB MP 10 MHz | DECT NR+ | 0.29 |
| Single-entry, co-channel, clutter at one terminal (30% of locations) | WBB MP 10 MHz | DECT NR+ | 0.35 |
| Single-entry, first adjacent channel interference | WBB MP 10 MHz | DECT NR+ | 0.11 |
| Single-entry, co-channel | WBB MP 100 MHz | DECT NR+ | 0.81 |
| Single-entry, co-channel, clutter at one terminal (50% of locations) | WBB MP 100 MHz | DECT NR+ | 0.25 |
| Single-entry, co-channel, clutter at one terminal (30% of locations) | WBB MP 100 MHz | DECT NR+ | 0.25 |
| Single-entry, first adjacent channel interference | WBB MP 100 MHz | DECT NR+ | 0.028 |

Our tabulated results show, for each interference problem, the geographical separation required in the co-channel case when ITU-R P.452 is used to predict the interfering signal level exceeded for 50% of time and then variations of this basic interference path model including clutter at one end of the path associated with 30% and 50% of locations and the NFD available when the interferer is located in the victim receiver’s first adjacent channel.

In addition, when the victim receiver has a larger bandwidth, we consider the aggregate interference case where the entire receiver bandwidth is populated with interferers. That is, a 100 MHz bandwidth WBB receiver sees exactly ten DECT NR+ interferers.

These geographical separations are in the range 0.028 km to 33.4 km and highly dependent on the assumptions made regarding the clutter losses and NFD available on the interference path. Further variations are possible including clutter loss combined with the NFD available from adjacent channel interference.

## Results for DECT NR+ and FSS

MCL analyses were performed in Visualyse Professional software. The simulations were designed using the radio system input parameter values given in Table 18. The modelling used on the interference path is summarised in Table 19 and the NFD used is given in Table 20.

Table 21 and Table 22 report on the results of our MCL analyses.

Table 18: FSS parameters

|  |  |  |
| --- | --- | --- |
| FSS parameter | value | Unit/description |
| Bandwidth | 40 | MHz |
| Antenna height | 10 | m |
| Antenna inclination | 10 | degrees |
| Antenna model |  | ITU-R S.465-6 |
| Antenna dish diameter | 12 | m |
| Antenna peak gain | 52.5 | dBi |
| **Noise temperature** | **70** | **K** |
| Receiver Noise | -104.12 | dBm |
| I/N requirement | -10.5 (20%)  -1.3 (0.005%) | dB |

Table 19: Modelling summary (interference path)

|  |  |  |
| --- | --- | --- |
| Model | Parameter/description | Unit |
| ITU-R P.2108 (50%) | Clutter loss | dB |
| ITU-R P.452 (0.005%, 20%) | Interference path | dB |
| ETSI TR 101 854 | Net Filter Discrimination | dB |

Table 20: NFD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Interferer | Interferer bandwidth  (MHz) | Victim | Victim bandwidth  (MHz) | Scenario | NFD  (dB) |
| DECT NR+ | 6.912 | FSS | 40 | First adjacent channel | 16.13 |

Table 21: Long-term interference from 6.912 MHz DECT NR+ into FSS

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario  Note: In these scenarios we model the interfering signal exceeded for 20% of time and test an I/N = -10.5 dB | Geographical separation  (km) | | |
| **0 degrees azimuth** | **10 degrees azimuth** | **180 degrees azimuth** |
| Single-entry, co-channel | 51 | 43 | 15 |
| Single-entry, co-channel, clutter at one terminal (50% of locations) | 3 | 2 | 0.6 |
| Single-entry, first adjacent channel interference | 15 | 12 | 3 |
| Single-entry, first adjacent channel interference, clutter at one terminal (50%) | 0.6 | 0.5 | 0.3 |

Table 22: Short-term interference from 6.912 MHz DECT NR+ into FSS

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario  Note: In these scenarios we model the interfering signal exceeded for 0.005% of time and test an I/N = -1.3 dB | Geographical separation (km) | | |
| **0 degrees azimuth** | **10 degrees azimuth** | **180 degrees azimuth** |
| Single-entry, co-channel | 91 | 57 | 12 |
| Single-entry, co-channel, clutter at one terminal (50% of locations) | 1.2 | 0.8 | 0.4 |
| Single-entry, first adjacent channel interference | 13 | 6.3 | 0.9 |
| Single-entry, first adjacent channel interference, clutter at one terminal (50%) | 0.37 | 0.3 | 0.25 |

Our results show the geographical separation required when the interfering signal is incident to the victim receiver at 0, 10 and 180 degrees azimuth. At 0 degrees azimuth the interfering signal is exposed to the maximum gain available on an interference path when FSS antenna inclination is set equal to 10 degrees. At 10 and 180 degrees azimuth, further antenna discrimination is available. In the initial co-channel cases, ITU-R P.452 is used to predict the interfering signal level exceeded for 20% and 0.005% of time and then variations of this basic interference path model including clutter at one end of the path associated with 50% of locations and the NFD available when the interferer is located in the victim receiver’s first adjacent channel are modelled. For this problem, we also include results for the first adjacent signal with clutter loss at one end of the path.

Geographical separations are in the range 0.3 km to 51 km with respect to long-term interference and 0.25 km to 91 km for short-term interference. These separations are reduced when the interferer is off-axis and when clutter and frequency separation are included in the model.

## Results for DECT NR+ and FS

MCL analyses were performed in Visualyse Professional software. The simulations were designed using the radio system input parameter values given in Table 23. The modelling used on the interference path is summarised in Table 24 and the NFD used is given in Table 25.

Table 26 reports on the results of our MCL analyses.

Table 23: FS Parameters

|  |  |  |
| --- | --- | --- |
| FS parameter | value | Unit/description |
| Bandwidth | 40 | MHz |
| Antenna height | 50 | m |
| Antenna inclination | 0 | degrees |
| Antenna model |  | ITU-R F.699-8 |
| Antenna dish diameter | 3 | m |
| Antenna peak gain | 40 | dBi |
| Feeder Loss | 3 | dB |
| Receiver Noise | -125.98 | dBW/40 MHz |
| I/N requirement | -10 | dB |

Table 24: Modelling summary (interference path)

|  |  |  |
| --- | --- | --- |
| Model | Parameter/description | Unit |
| ITU-R P.2108 (50%) | Clutter loss | dB |
| ITU-R P.452 (20%) | Interference path | dB |
| ETSI TR 101 854 | Net Filter Discrimination | dB |

Table 25: NFD

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Interferer | Interferer bandwidth  (MHz) | Victim | Victim bandwidth  (MHz) | Scenario | NFD  (dB) |
| DECT NR+ | 6.912 | FS | 40 | First adjacent channel | 16.13 |

Table 26: Interference from 6.912 MHz DECT NR+ into FS

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario | Geographical separation (km) | | |
| **0 degrees azimuth** | **10 degrees azimuth** | **180 degrees azimuth** |
| Single-entry, co-channel | 130 | 41 | 7 |
| Single-entry, co-channel, clutter at one terminal (50% of locations) | 37 | 1.3 | 0.4 |
| Single-entry, first adjacent channel interference | 81 | 7 | 1 |
| Single-entry, first adjacent channel interference, clutter at one terminal (50%) | 5 | 0.4 | 0.3 |

Our results show the geographical separation required when the interfering signal is incident to the victim receiver at 0, 10 and 180 degrees azimuth. At 0 degrees azimuth the interfering signal is exposed to the maximum receiver antenna gain available (almost peak gain with the FS antenna set at 0 degrees elevation) while at 10 and 180 degrees, further antenna discrimination is available. in the initial co-channel case, ITU-R P.452 is used to predict the interfering signal level exceeded for 20% of time and then variations of this basic interference path model including clutter at one end of the path associated with 50% of locations and the NFD available when the interferer is located in the victim receiver’s first adjacent channel are modelled. For this problem, we also include results for the first adjacent signal with clutter loss at one end of the path.

Geographical separations are in the range 0.3 km to 130 km. These separations are reduced when the interferer is off-axis and when clutter and frequency separation are included in the model.

# Notes on Net Filter Discrimination

We investigate a number of scenarios where the interferer is present in the victim receiver’s first adjacent channel and beyond in the case of adjacent band compatibility problems. In order to model the discrimination available when interferer and victim receiver are separated in frequency, we make use of the well established method set out in ETSI TR 101 854 [2] which calculates the Net Filter Discrimination (NFD) available when transmitter and receiver spectrum masks are convoluted in the frequency domain. NFD includes a simple bandwidth correction factor which is applied when the interferer has a greater bandwidth than the victim receiver including in the co-channel case.

This method relies on models of the transmitter and receiver spectrum masks that specify attenuation relative to power in the transmitter or receiver wanted channel. Hence, the wanted channel attenuation level is normally set at 0 dB with the masks showing negative values (relative attenuation) at frequencies beyond the wanted channel.

This approach can make use of the ACS, in-band and out-of-band blocking values used in many radio services to define the receiver’s response to interfering signals.

Figure 2 illustrates an NFD calculation in Visualyse Professional where a 6.912 MHz DECT NR+ transmitter is tuned a 10 MHz WBB LP receiver’s first adjacent channel. The NFD obtained from this frequency offset is 25.4 dB.

Different radio services, or applications, have different approaches to specifying transmitter and receiver spectrum masks. The ETSI NFD calculation method can be used in all cases as long as the mask parameters are converted (where necessary) to an attenuation mask and we have followed this method.

In some cases where information on spectrum masks are yet to be discussed or included in the agreed set of input parameters, we have followed our normal practice of using a default Gaussian curve to represent the spectrum mask [3]. This is the case for the FSS and FS receivers in these studies. For each of the studies reported on here, we reference our source for the spectrum mask characteristics in Table 29.

A picture containing text, diagram, line, plot

Description automatically generated

Figure 2: Spectrum masks in Visualyse Professional

Table 29: Spectrum mask sources

|  |  |
| --- | --- |
| Radio System | Spectrum mask |
| DECT NR+ 6.912 MHz Tx | ECC Report 358 |
| DECT NR+ 6.912 MHz Rx | ECC Report 358 |
| WBB LP 10 MHz Rx | ECC Report 358 |
| WBB LP 100 MHz Rx | ECC Report 358 |
| WBB MP 10 MHz Tx | ECC Report 358 |
| WBB MP 10 MHz Rx | ECC Report 358 |
| WBB MP 100 MHz Tx | ECC Report 358 |
| WBB MP 100 MHz Rx | ECC Report 358 |
| FSS Rx | Gaussian curve |
| FS Rx | Gaussian curve |

# Block Edge Masks

Block Edge Masks are usually comprised of two parts: the in-block and out-of-block components. The in-block component extends over frequencies which capture the operator’s assigned channels while the out-of-block component extends into adjacent frequencies. There may be a transition from in the in-block to out-of-block baseline limit as illustrated in Figure 3.



Figure 3: Generic Block Edge Mask

We set out some example calculations and results for the Block Edge Mask (BEM) out-of-block baseline level. An important consideration here is whether the transmitter’s spectrum mask meets the calculated BEM baseline level; if so, then no further constraints are required for the out-of-block component of the mask.

In section 2.3 we report on the geographical distances required between DECT NR+ and WBB LMP radios in order that interference protection criteria are satisfied. Here, under the assumption that these distances are satisfied exactly, we calculate baseline BEM levels for some first adjacent channel interference scenarios.

Our method elaborates on that given in [3]. For these example calculations we calculate path gain for the geographical separation under consideration and, using the relevant interference threshold, calculate the BEM baseline level. We first of all calculate the path gain using

Equation 4

(dB)

where

= is a single-entry interference adjustment factor (dB). We are calculating our BEM baseline level in dBm/Hz. Hence the single-entry interference adjustment factor is required in order that we model exactly one DECT NR+ interferer incident to a wider bandwidth victim receiver.

Then the base line level can be calculated via

Equation 5

(dBm/Hz)

where

= interference threshold at the victim receiver (dBm/Hz).

Table 30 gives a summary of calculations exercising equations (4) and (5). We consider interference from a 6.912 MHz DECT NR+ interferer into a 10 MHz WBB LP victim receiver. Here we use the geographical distance reported on in Table 15 and the interference threshold associated with a 10 MHz WBB LP receiver specified in Table 10.

Table 30: BEM baseline calculation

|  |  |  |
| --- | --- | --- |
| DECT NR+ into WBB LP 10 MHz |  |  |
| interferer frequency | MHz | 4000 |
| speed of light | m/s | 300000000 |
| wavelength | m | 0.075 |
|  |  |  |
| Path length | km | 3.30 |
| NFD | dB | 25.4 |
| Clutter | dB | 0 |
|  |  |  |
| Antenna Gain | dBi | 12 |
| Path gain | dB | 129.86 |
| Interference threshold | dBm | -105.01 |
| Victim bandwidth | MHz | 10.00 |
| Single-entry adjustment | dB | 1.60 |
| Interference threshold | dBm/Hz | -175.01 |
| BEM baseline level | dBm/Hz | -45.15 |

Following this calculation, we investigate whether the DECT NR+ spectrum mask satisfies the level in it’s first adjacent channel. Table 31 sets out a comparison of the DECT NR+ out-of-band spectrum mask expressed as an emissions limit in dBm/Hz for each segment of the mask and the spurious domain beyond. We compare each segment’s emissions limit to the calculated BEM baseline level calculated in equation (5) and calculate the excess level

Equation 6

(dB)

where

= transmitter spectrum mask emissions limit (dBm/Hz).

We can see from Table 31 that the excess values are negative for all of the transmit mask out-of-band segments and the spurious domain segments meaning that the baseline level is higher than the spectrum mask or spurious emissions limits over all segments.

Table 31: Comparing spectrum mask with BEM baseline level

|  |  |  |  |
| --- | --- | --- | --- |
| DECT NR+ mask OOB mask segment | Transmitter mask limit  (dBm/Hz) | BEM baseline  (dBm/Hz) | Excess  (dB) |
| Transmitter Spectrum mask segment 1 | -54.8 | -45.15 | -9.62 |
| Transmitter Spectrum mask segment 2 | -70.0 | -45.15 | -24.85 |
| Transmitter Spectrum mask segment 3 | -73.0 | -45.15 | -27.85 |
| Transmitter Spectrum mask segment 4 | -80.0 | -45.15 | -34.85 |
| Transmitter Spectrum mask segment 5 | -83.0 | -45.15 | -37.85 |
| Spurious segment 1 | -66.0 | -45.15 | -20.85 |
| Spurious segment 2 | -76.0 | -45.15 | -30.85 |
| Spurious segment 3 | -86.0 | -45.15 | -40.85 |

Table 32 sets out a summary of the BEM baseline levels calculated for first-adjacent channel interference scenarios. In all cases the DECT NR+ spectrum mask satisfies the BEM baseline level with an excess value in mask segment 1 of -2.4 dB or lower and with lower excess values in the subsequent mask segments.

Table 32: Summary of BEM baseline results

|  |  |  |
| --- | --- | --- |
| Victim system | BEM baseline  (dBm/Hz) | DECT NR+ spectrum mask satisfies BEM baseline |
| WBB LP 10 MHz | -45.15 | YES |
| WBB LP 100 MHz | -44.82 | YES |
| WBB MP 10 MHz | -45.54 | YES |
| WBB MP 100 MHz | -44.91 | YES |
| FSS 40 MHz (0 degrees azimuth) | -45.88 | YES |
| FS 40 MHz (0 degrees azimuth) | -52.39 | YES |

These calculations can be thought of as a check or verification of the Visualyse simulation results. That is, if the geographical distances found in our MCL analysis for these adjacent channel interference scenarios are satisfied exactly, then the gain on the interference path is such that no excess interference occurs. Further, the calculated BEM baseline level is always satisfied by the DECT NR+ spectrum mask. Clearly, if the geographical separations were not satisfied then at some distance, the spectrum mask would no longer satisfy the BEM baseline level.

# Summary of results

## Summary of in-band studies

### DECT NR+ into DECT NR+ (scenario 4 in table 1)

The maximum separation distance needed between DECT NR+ deployments is 0.582 km when considering the co-channel operation with no clutter. This distance reduces to 0.250 km when assuming clutter at one terminal. Separation distances for the first adjacent channel are 30 metres.

### DECT NR + into 3GPP WBB (scenarios 1 and 2 in table 1)

Two 3GPP WBB bandwidths have been assumed within these studies, i.e.10 MHz and 100 MHz victim bandwidths. In the co-channel case with 100 MHz 3GPP WBB channels, a 6.912 MHz DECT NR+ interferer has been assumed to be operating in each 10 MHz to assess the effect of aggregated interference from DECT NR+.

For co-channel, when clutter is applied separation distances of the order of 2 to 3 km are seen. When no clutter is applied, separation distances increase to approximately 30 to 33 km. There is no discernible increase in separation distances when considering aggregation.

For adjacent channel studies, separation distances between 5 and 1.1 km are derived, depending on LP or MP 3GPP WBB and their receiver bandwidths.

### Interference from 3GPP WBB MP into DECT NR+ (scenarios 3 in table 1)

As noted in the introduction, only the case of 3GPP WBB MP into DECT NR+ has been modelled as the worst case. It is reasonably expected that 3GPP WBB LP would yield smaller separation distances.

Studies show in the co-channel case separation distances range from 0.25 to 3.6 km depending on assumed clutter losses and bandwidth of the interferer. In the adjacent channel case, separation distances are approximately 100 m or less.

It is noted that the difference in required separation distances between DECT NR+ into 3GPP WBB and vice versa is primarily a consequence of the assumed operation and protection criteria which are more conservative when considering protection of 3GPP WBB.

### DECT NR+ into the Fixed satellite service (scenario 8 in table 1)

The studies of DECT NR+ into the FSS considers both long-term and short-term interference scenarios. The effect of applying clutter at one terminal significantly reduces the required separation distances. Studies consider the DECT NR+ interferer at 0, 10 and 180 degrees azimuth.

For long-term interference, at 0 degrees azimuth, i.e. the DECT NR+ interferer is on the maximum FSS antenna gain with the inclination set to 10 degrees, the separation distances range from 3 to 51 km depending on the application of clutter. In the adjacent channel separation distances range between 15 and 0.6 km. Outside the main beam separation distances reduce as would be expected.

In the short-term scenario, separation distances vary between 91 and 1.2 km in the co-channel, 0 degree azimuth case. In the adjacent channel, separation distances vary between 13 and 0.37 km, and reduce further when azimuth separation increases.

### DECT NR+ into the Fixed service (scenario 7 in table 1)

The study assesses the geographical separation required when the DECT NR+ interfering signal is incident to the victim receiver at 0, 10 and 180 degrees azimuth. The largest separation distance for a single-entry interferer at 0 degrees without clutter is 130 km. This reduces to 37 km when clutter is assumed.

In the adjacent channel case, separation distances reduce to between 81 and 5 km depending on applying clutter. In off-axis geometries separation distances reduce significantly, for example down to 1.3 km when clutter is applied in the co-channel, 10 degree azimuth case.

## Conclusion

Studies are based on the assumption that base stations (in the 3.8 to 4.2 GHz band) are at known locations. This implies that all frequency assignments and their locations are recorded to enable coordination between new and existing assignments.

The separation distances derived in the compatibility studies between DECT NR+ and other applications within the 3.8 to 4.2 GHz band indicate that the use of DECT NR+ for local vertical applications in the band is feasible and could be incorporated in a coordination and authorisation framework.

# references

1. ETSI, ETS TR 101 854 V2.1.1, (2019), Fixed Radio Systems; Point-to-point equipment; Derivation of receiver interference parameters useful for planning fixed service point-to-point systems operating different equipment classes and/or capacities.
2. Parker, J. R., Flood, I. D., & Carter, G. D, (2020), Adjacent channel compatibility between IMT and ubiquitous FSS earth stations in the 3.4–3.8 GHz frequency band. Wireless Networks, 27, 1103–1110.
3. ECC Report 131, Derivation of a Block Edge Mask (BEM) for Terminal Stations in the 2.6 GHz frequency band (2500-2690 MHz).