



ECC Report **352**

Harmonised conditions and spectrum bands for the operation of governmental Unmanned Aircraft System (UAS)

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0 EXECUTIVE SUMMARY

This Report addresses the assessment on the feasibility of spectrum solutions for the operational needs for governmental use of unmanned aircraft systems (UAS) and establishes the relevant technical conditions. Governmental use does not address military usage (which is considered as a national matter). This Report does not address the regulatory and operational aspects or electromagnetic compatibility (EMC) issues related to the UAS avionics. It is important to note that in this Report, UAS aerial UE and UAS UE, both terms refer to the flying device of the UAS.

Co-channel operation between governmental UAS and Railway Mobile Radio (RMR) in the 1900-1910 MHz band at the same location is not feasible independently of the technology used by the UAS and will lead to a significant interference risk towards the RMR operation. Therefore, the frequency bands assessed for UAS in this Report are 1880-1900 MHz and 1910-1920 MHz.

It is noted that, according to ERC Decision (98)02 [14], DECT in the band 1880-1900 MHz is under a general authorisation regime, and therefore no priority can be given to any particular application using DECT (including governmental UAS).

For UAS using LTE based technology, the outlined separation distances needed to protect the incumbent services from interference in these bands are such that it will be necessary to impose strong limitations on the operation of governmental UAS. With these limitations, the usage of governmental UAS using LTE based technology will not be feasible.

Co-channel operation between DECT-2020 NR based UAS and DECT in 1880-1900 MHz band is already feasible through DCS (Dynamic Channel Selection) which is a mechanism to access to the spectrum already implemented in both technologies. Due to this technology features the co-channel operation of DECT-2020 NR based governmental UAS and DECT is feasible under the following conditions:

- DECT-2020 NR based UAS should implement Transmit Power Control (TPC) in both UAS GS and UAS UE with a maximum e.i.r.p. of 24 dBm;
- Coexistence between UAS and DECT in 1880-1900 MHz band may be improved if UAS start deployment in the 1910-1920 MHz band prior to the use of the 1880-1900 MHz band;
- In critical mission, the maximum number of UAS should be limited to 3 UAS in the same area;
- UAS in the same area should together not use more than 6.912 MHz in the frequency band 1880-1900 MHz and 6.912 MHz in the frequency band 1910-1920 MHz;
- The maximum operating range for UAS shall be limited to 500 m in urban scenario and 3.5 km in rural scenario.

The compatibility between DECT-2020 NR based UAS and services in the adjacent bands is feasible under the following conditions:

- For the protection of RMR (1900-1910 MHz band) a separation distance between the railways and UAS in the adjacent bands (1880-1900 MHz and 1910-1920 MHz) is required. It is proposed to consider in first approach and as estimated conclusion an average value of 200 m¹ as minimum horizontal separation distance between UAS and railways, this value needs to be adjusted case by case according to the environment (rural or urban). This value is also still subject to be reviewed during the preparation of a possible future ECC Recommendation on governmental UAS. In case that the deployment area of UAS lays within the minimum separation distance between UAS equipment and railways, there is a risk of interference on RMR that could lead to security issues in the rail operation. In this situation, when the separation distance between the UAS GS / UE and the railways is less than the separation distance defined above, a notification process shall be implemented between the involved parties: administration(s), the UAS operator(s) and the railway infrastructure manager(s) (IM). The detailed workflow (contact persons, notification time...) of this process shall be defined between UAS operator(s), administration(s) and railway IM(s). This process has also to address cross border coordination situation regarding coexistence issues between UAS operation and railways (see Annex 3).
- The possible interference into MFCN UL BS above 1920 MHz will be limited due to the reduced DECT-2020 NR max output power leading to shorter separation distances than those calculated for LTE based UAS.

¹ This separation distance could be reviewed according to experience / feedback from railway IM(s).

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
ACS	Adjacent Channel Selectivity
ARQ	Automatic Repeat Request
BPSK	Binary Phase-Shift Keying
BS	Base Station
CEPT	European Conference of Postal and Telecommunications Administrations
CP-OFDM	Cyclic Prefix – Orthogonal Frequency Division Multiplexing
CRC	Cyclic Redundancy Check
C2	Command and Control
DCS	Dynamic Channel Selection
DECT	Digital Enhanced Cordless Telecommunications
DECT2020 NR	Digital Enhanced Cordless Telecommunications 2020 New Radio
ECADL	European Common Allocation Downlink
ECC	Electronic Communications Committee
EMC	Electromagnetic Compatibility
FDMA	Frequency Division Multiple Access
FFT	Fast Fourier Transformation
FPs	Fixed Parts
FT	Fixed Termination point
FRMCS	Future Railway Mobile Communication System
GI	Guard Interval
GS	Ground Station
GSM-R	Global System for Mobile Communications – Rail
iDCS	Instant Dynamic Channel Selection
IM	Infrastructure Manager (railways)
ITU	International Telecommunications Union
IMT-2000	International Mobile Telecommunications - 2000 (3G)
I/N	Interference-to-Noise ratio
LBT	Listen Before Talk
LoS	Line-of-Sight
MAC	Media-Access-Control-Address
MCL	Minimum Coupling Loss
MCS	Modulation Coding Scheme
MFCN	Mobile/Fixed Communications Network
MIMO	Multiple-Input and Multiple-Output

Abbreviation	Explanation
MPEG	Moving Picture Experts Group
NR	New Radio (5G)
OFDM	Orthogonal Frequency Division Multiplexing
OOBE	Out-of-Band Emission
PPs	Portable Parts
PT	Portable device
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase-Shift Keying
RACH	Random-access channel
RD	Radio Device
RF	Radio Frequency
RMR	Railway Mobile Radio
RSSI	Received Signal Strength Indicator
eRTCP	(MPEG) RTP Control Protocol
RTP	(MPEG) Real-Time Transport Protocol
RTSP	Real-Time Streaming Protocol
Rx	Receiver
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TPC	Transmit Power Control
VLOSTx	Visual Line of Sight Transmitter
UA	Unmanned Aircraft
UAS	Unmanned Aircraft System
UE	User Equipment
UL	Uplink
ULE	Ultra-low Energy
URLLC	Ultra-Reliable Low-Latency Communications
VLOS	Visual -Line -of -Sight
WLL	Wireless Local Loop

1 INTRODUCTION

In February 2018, ECC Report 268 [1] on "Technical and Regulatory Aspects and the Needs for Spectrum Regulation when it comes to professional for Unmanned Aircraft Systems (UAS)" was published. Following ECC Report 268 and discussions at the CEPT Workshop on Spectrum for Drones / UAS in 2018 [13], it was found that the focus on professional UAS in both open and specific categories seemed appropriate.

In October 2018, WG FM tasked its Project Team FM59 with the development of this Report aimed at assessing the feasibility of spectrum solutions for the operational needs for the commercial and governmental use of UAS and establishing the relevant technical conditions. As no contributions were forthcoming to the work on the use of commercial drones, WG FM subsequently decided to discontinue work on this aspect. Therefore, commercial drones are not part of this Report.

Governmental use does not address military usage (which is considered as a national matter).

ECC Report 332 [3] on "Technical compatibility studies related to UAS (Unmanned Aircraft System) in the 1880-1920 MHz band" presents results for the technical compatibility studies related to the UAS for governmental use of command and control links as well as payload links in the 1880-1900 MHz and 1900-1920 MHz.

According to ERC Decision (98)02 [14], the frequency band 1880-1900 MHz is designated for DECT (Digital Enhanced Cordless Telecommunications) under a general authorisation regime.

The frequency band 1900-1910 MHz is designed for Railway Mobile Radio (RMR) use according to the ECC Decision 20(02) [15] and the EU Implementation Decision 2021/1730 [16].

UAS currently on the market are developed in frequency bands that benefit from a general authorisation regime. However, the lack of individual licenses does not allow effective control of uses in these bands and that may hinder the use of these bands by security forces, in a critical situation. In addition, as part of the fight against malicious systems, authorities are led to request the implementation of neutralisation measures in these bands, which would lead also to neutralising the use of these bands by the authorities themselves.

2 OPERATIONAL REQUIREMENTS

Operation of UAS in terms of the use of radio spectrum is sub divided into command and control (C2) and payload transmissions (e.g. on-board cameras sending information to the ground) within the same envelope.

2.1 GOVERNMENTAL USE OF UAS

The term "governmental use" refers to operations for carrying out the maintenance of law and order, protection of life and property, disaster relief and emergency response activities or services undertaken in the public interest excluding military operations/activities. These operations are carried out by or on behalf of a public authority.

In some jurisdictions, UAS have already become vital tools in disaster situations. They are sent up to the sky at forest fires, damage or accident traffic inspection, flooding, maritime rescue, large scale monitoring and situational awareness, search and rescue of persons, transport of medical/ blood, life-saving equipment, fast deployed support of communications (flying com platform/ hot spot) or providing simply light, for example.

The need for governmental UAS frequencies is as important for the command and control as it is for the payload.

2.1.1 Intervention framework

The dominant use of UAS is to provide aerial views for the surveillance of zones, events or interventions, search for information (facial identification, reading license plates...) or prior recognition, in support of operational decisions, which contribute to the safety and efficiency of the interventions of the various services.

UAS can also provide help on interventions such as searching for people, operations in a "polluted" environment, carrying equipment, mapping, surveys.

Such applications require reliable frequency use. The operating range depends on the scenario of deployment (urban or rural) as described hereafter.

2.1.2 Terms of use

Governmental UAS are dedicated to specific activities including maintenance of law and order, protection of life and property, emergency situations and disaster relief.

Deployment of governmental UAS, is considered in either one of the two following missions: routine or critical:

- Routine missions are limited in time (up to a few hours), the maximum operation range for UAS shall be limited to 500 m in urban scenario and 3.5 km in rural scenario, in this case only one UAS is deployed;
- Critical missions cover exceptional situations (such as natural disasters), where multiple actors (police, firefighters, etc.) would need aerial coverage, up to three UAS can be deployed. The maximum operating range will be limited to 500 m in urban and rural scenarios.

Independently of the type of mission of governmental UAS, the following operational conditions apply:

- Operation of UAS in visual line of sight (VLOS);
- UAS GS pilot is always on the ground/building for safety of flight;
- Maximum attainable height of the UAS UE is limited to 120 m above ground level;
- Flight plan to manage the aerial space operation;
- Designation of a 3D coordinator with the aim to manage the sharing of aerial space amongst the users of the aerial space (UAS, helicopter...);
- Control, command and payload are working permanently during the deployment;
- Control, command and payload (data) are on the same link, furthermore each UAS has their specific User Equipment (UE) and Ground Station (GS);

- Depending on the geographical area of the UAS operation, coordination protocol with certain spectrum incumbents shall be carried out.

Two specific scenarios are envisaged in terms of geographical zones covered during interventions: urban scenario and rural scenario.

The quality of the video is crucial for the operational processing of the images. These needs are described in ECC Report 332, section 3.2.2 (Table 7) and section 3.2.3 (Table 8) [3].

3 SPECTRUM REQUIREMENTS

For the typical missions above, a spectral resource requirement has been determined already in ECC Report 332, section 3.3.2.2 [3]. The calculation method considers the need for command and control as well as for the payload, mainly based on the video quality. The overall requirement was determined by the terms of use defined by the security and relief forces.

3.1.1 Unit requirements

The need for spectral resources considered indifferently of the technology assessed in ECC Report 332 (i.e. LTE or DECT-2020 NR) is determined by:

- Control and command bit rate: 300 kbps;
- Payload bit rate: 5 Mbps for HD video streaming or 10 Mbps for Full HD video streaming.

3.1.2 Common needs

3.1.2.1 LTE technology

Considering ECC Report 332, section 3.2.2 the common spectral needs adopting LTE technology are:

- Routine missions (only one UAS is deployed): 5 MHz;
- Critical missions (up to three UAS can be deployed): 2 x 5 MHz + 1 x 10 MHz.

3.1.2.2 DECT-2020 NR technology

Considering ECC Report 332, section 3.2.3 and the DCS (Dynamic Channel Selection) for the access to the spectrum used by DECT-2020 NR the common spectral needs adopting DECT-2020 NR technology are:

- Routine missions (only one UAS is deployed): 3.456 MHz;
- Critical missions (up to three UAS can be deployed): 2 x 3.456 MHz + 1 x 6.912 MHz.

4 CANDIDATE BANDS, ALLOCATIONS AND APPLICATIONS

Technical studies were performed and published in ECC Report 332 [3] on technical compatibility studies to UAS in the 1880-1920 MHz band. Incumbent services and applications in 1880 - 1920 MHz band and in adjacent bands are provided in this section.

Information contained in the table below reflects upon the current status and usage in the band as drawn from a number of CEPT sources.

Table 1: Extract of the European Common Allocation (ECA) Table [5]

RR Region 1 Allocation and Footnotes applicable to CEPT	European Common Allocations and ECA Footnotes	ECC/ERC harmonisation measure	Applications	Standards	Notes
FIXED MOBILE 5.384A 5.386 5.388A 5.388B 5.388	MOBILE 5.384A Fixed 5.388	ECC/DEC/(05)08 ECC/DEC/(08)02 ECC/DEC/(95)03	GSM	EN 301 502 EN 301 511 EN 303 609	Within the band 1805-1880 MHz
		ECC/DEC/(06)13 ECC/DEC/(08)02	IMT	EN 301 908	Within the band 1805-1880 MHz
		ECC/DEC/(06)07	MCA	EN 302 480	Within the band 1805-1880 MHz
		ECC/DEC/(08)08	MCV		Within the band 1805-1880 MHz
		ECC/DEC/(94)03 ECC/DEC/(98)22	DECT	EN 300 700 EN 301 406 EN 301 908	Within the band 1880-1900 MHz
		ECC/DEC/(20)02 ECC/REC/(23)01	RMR		Within the band 1900-1910 MHz
		ECC/DEC/(06)07	MCA		Within the band 1920-1980 MHz
		ECC/REC/(08)08	MCV		Within the band 1920-1980 MHz
		ECC/REC/(06)01 ECC/REC/(01)01	MFCN	EN 301 908	Within the band 1920-1980 MHz

5 RESULTS OF COMPATIBILITY STUDIES

This section is an exact copy of the executive summary of ECC Report 332 [3]. However, all references in this chapter are related to ECC Report 332 and can be found in that Report.

The purpose of ECC Report 332 is to present results for the technical compatibility studies related to the UAS (Unmanned Aircraft System) for governmental use of command and control (C2) links as well as payload links in the 1880-1900 MHz and 1900-1920 MHz bands:

The UAS consists of ground station (GS) ("controller") and User Equipment (UE) ("drone"). Single GS-UE pair uses single frequency block with TDD (Time Domain Duplex) principle. The GS is assumed to be at ground level (1.5 m), and the maximum height of the UE is assumed to be 120 m.

Up to three drones are simultaneously deployed in an operational zone with radius of up to 5650 m in rural areas, and up to 1000 m in urban areas. Each drone is controlled by a dedicated GS. The drone and controller are assumed to constantly be in visual line of sight.

The frequency band 1880-1900 MHz is designated for DECT (Digital Enhanced Cordless Telecommunications) on licence-exempted basis, originally used for cordless phones, but which nowadays consists of huge variety of different enterprise and professional applications including voice and data services. The frequency band 1900-1910 MHz has been lately designated and harmonised for the RMR (Railway Mobile Radio). Adjacent frequency bands are harmonised for MFCN (Mobile Fixed Communication Network): 1710-1785/1805-1880 MHz and 1920-1980/2110-2170 MHz. This Report considers in-band and adjacent band coexistence studies between UAS and these systems.

This Report suggests different interference mitigations possibilities for improving coexistence of UAS with systems operating in the band 1880-1920 MHz and in adjacent bands. Noting that the UAS controller to drone (C2) only requires low bitrate, it has been shown that lowering the power of the UAS GS to 10 dBm improves coexistence with all involved systems. This however comes with a higher susceptibility of the drone to interference (see coexistence with MFCN in ECC Report 332, section 5.3). Power control applied to the UAS drone also showed improved coexistence with other systems. Similar gain could be expected by also applying power control to the UAS controller, although this has not been studied. Coexistence gain can also be obtained by ensuring separation distances where feasible, or by imposing additional constraints on UAS spectrum emission (see FRMCS studies in ECC Report 332, annex 13) and/or UAS spectrum selectivity (see MFCN studies in ECC Report 332, section 5.3). Potential use of DECT-2020 NR technology based UAS is expected to improve coexistence, but is has not been fully studied.

5.1 UAS AND DECT

MCL (Minimum Coupling Loss) study on impact from UAS GS and UE for DECT indoor, outdoor and DECT WLL (Wireless Local Loop, which assumes the drone is in the main lobe of a 12 dBi DECT antenna) is in ECC Report 332, sections 5.1.2 and 5.1.6. Separation distance are calculated for two different DECT wanted signal levels -75 dBm and -65 dBm². An UAS GS transmit power of 10 dBm and 30 dBm, and an UAS UE transmit power of 28 dBm is assumed.

The results of the MCL studies are presented in the table below.

² -65 dBm being a typical receiving level for low range indoor applications, while -75 dBm is considered for a typical receiving level for more sensitive indoor and outdoor applications. DECT devices have a sensitivity level down to -93 dBm

Table 2: Summary of MCL separation distances between UAS using LTE and DECT

DECT Protection criterion	UAS GS or UE	UAS Tx power	DECT Rx power	DECT Indoor (km)	DECT outdoor (km)	DECT WLL (km)
SINR of 21 dB	GS	10 dBm	-65 dBm	0.08-0.12	0.48-0.67	1.9-2.68
			-75 dBm	0.27-0.38	1.51-2.14	6.05-8.56
		30 dBm	-65 dBm	0.85-1.2	4.8-6.8	Not studied
			-75 dBm	2.68-3.82	15.1-21.4	Not studied
	UE	28 dBm	-65 dBm	0.36-0.53	2.14-3.03	8.52-12.06
			-75 dBm	1.20-1.70	6.77-9.60	27.0-37.88
Measured C/I	GS/UE	30 dBm	-65 dBm	0.05-0.75	0.53-3.3	Not studied
			-75 dBm	0.17-2.1	1.7-9.42	Not studied

SEAMCAT study (ECC Report 332, annex 5) shows the probability that DECT is interfered, dBm for various values of DECT transmit power (between 4 and 24 dBm). Due to transmit power control, the worst situation is when the UE is furthest away from the GS. The following probabilities of interference were computed for outdoor DECT distributed between 0 and 300 m from the UAS GS:

- Equal or less than 10.3%, UAS GS transmit power of 10 dBm, urban environment;
- 14% (random distribution of DECT channels) and 42% (co-channel) , UAS GS transmit power of 30 dBm, urban environment;
- 80% (random distribution of DECT channels) and 100% (co-channel), UAS GS transmit power of 30 dBm, rural environment.

For indoor DECT, the following probabilities of interference were computed for indoor DECT distributed between 0 and 300 m from the UAS GS:

- 0.8% (random distribution of DECT channels) and 2.2% (co-channel), UAS GS transmit power of 10 dBm, urban environment;
- 2.8% (random distribution of DECT channels) and 7.9% (co-channel), UAS GS transmit power of 30 dBm, urban environment.

Monte Carlo study (ECC Report 332, annex 6) with residential DECT presented stakes into account the instant Dynamic Channel Selection (iDCS) capability of DECT were carried out. It is assumed that. 5% of DECT devices are located outdoor. In this context, DECT devices are able to avoid channels occupied by nearby UAS. The interference probability is:

- between 0.1% and 2.3% when one drone is deployed in the 1880-1900 MHz band;
- between 0.2% and 6.5% when two drones are deployed in the 1880-1900 MHz band.

In the other direction, there is negligible interference from DECT devices to UAS GS and UE.

Monte Carlo study (ECC Report 332, annex 6) with a call-centre (indoor only) deployment of DECT in an urban environment shows that interference mainly comes from the UAS GS, and its probability can be lower than 1% for distances:

- higher than 100 m for single and double (two) UAS deployments and UAS GS transmit power of 30 dBm;
- as low as 10 m for single UAS deployments and UAS GS transmit power of 10 dBm;
- higher than 20 m for double (two) UAS deployment and UAS GS transmit power of 10 dBm.

The results presented here are based on UAS using LTE technology and its impact on legacy DECT, not on DECT-2020 NR. There are also initial studies (see section ECC Report 332, section 6 and annex 13) assuming UAS using DECT-2020 NR technology.

5.2 UAS AND RMR/FRMCS (FUTURE RAILWAY MOBILE COMMUNICATION SYSTEM)

5.2.1 Co-channel operation

The MCL studies (ECC Report 332, annex 11) show that a co-channel operation of UAS in the FRMCS band 1900-1910 MHz is not feasible and will lead to a significant interference risk towards the FRMCS operation. Under a free space loss model, all UAS in distances up to 354 km to a FRMCS BS will lead to a desensitization of at least 3 dB. In practice, the radio horizon would limit the separation distance but that does not change the conclusion. For the cab radio the separation distance is 63 km.

5.2.2 Adjacent channel operation

Monte Carlo study of the possible impact of an UAS deployed in the frequency band 1910-1920 MHz to an FRMCS deployment in the band 1900-1910 MHz is presented in ECC Report 332, annex 10. Because of the symmetry of the FRMCS BEM and UAS SEM, these results at 1915 MHz also apply for interference from an UAS deployed at 1895 MHz. Simulations show that interference from UAS to FRMCS UE is negligible. On the contrary, interference to the FRMCS BS is more likely.

When using a UAS GS transmit power of 10 dBm, the probability of interfering the FRMCS BS is:

- less than 1% when the distance to the tracks is between 100 and 300 m in urban areas;
- less than 1% when the distance to the tracks is between 300 and 500 m in rural areas.

When using a UAS GS transmit power of 30 dBm, the probability of interfering the FRMCS BS is:

- less than 1% when the distance to the tracks is between 300 and 500 m in urban areas;
- around 10% when the distance to the tracks is between 500 and 1000 m in rural areas.

Considering the impact of the UAS UE, the probability of interfering the FRMCS BS is:

- lower than 1% when the UAS UE is between 300 and 500 m from the tracks (horizontal distance) if the range is limited to 500 m in rural areas (1000 m if 10 MHz channel is used);
- lower than 1% when the UAS UE is between 300 and 500 m from the tracks (horizontal distance) in urban areas.

5.3 UAS AND MFCN

5.3.1 Coexistence between UAS and MFCN below 1880 MHz

- 1 SEAMCAT simulations (ECC Report 332, annex 5) show that important levels of interference may happen from MFCN DL (1860-1880 MHz) to both UAS aerial UE and GS 10 MHz channel operating in 1880-1890 MHz. Noting that these levels of interference translate to UE (drone) throughput loss between 87.7% and 99.5% and GS (controller) throughput loss between 50% and 88%, considering the UAS channel centred at 1885 MHz and a UAS in the range of 1000 m.
- 2 SEAMCAT simulations (ECC Report 332, annex 5) show that the interference from MFCN DL (1860-1880 MHz) to both UAS aerial UE and GS 10 MHz channel operating in 1890-1900 MHz is reduced. If the UAS UE/GS receiver selectivity can be improved with an additional filter (ACS₂ = 66 dB), the interference from MFCN1800 DL can be reduced, as shown in ECC Report 332, section 5.3.1.
- 3 Interference from UAS aerial UE to MFCN1800 DL (UE reception) does not appear as a problem, including flying MFCN UE, as it translates to downlink throughput loss less than 0.1%.

- 4 Monte Carlo studies (ECC Report 332, annex 8) taking into account UAS protection criterions in-line with UAS bitrate requirements (300 kbps for controller to drone, 5 Mbps for drone to controller) show an interference probability of the UE and the GS by MFCN DL lower than 10% (but the range has to be limited to 1000 m in rural environments), assuming a GS transmit power of 30 dBm.
- 5 MCL computations (ECC Report 332, section 5.3) has been performed to assess the interference from UAS GS to MFCN1800 DL (UE reception). For an UAS GS transmitting at 10 dBm, the I/N protection criterion of an MFCN UE is not exceeded at 50 m (urban environment) or 100 m (rural environment). For an UAS GS transmitting at 30 dBm however, the MFCN UE protection criterion can be exceeded even when the separation distance is above 100 m.
- 6 Considering that, for a governmental drone, the highest data rate is transmitted from UAS UE to UAS GS, and in order to further protect the command and control signals received by UAS UE from MFCN interference, UAS command and control channel of a single drone deployment could be placed in the frequency range 1890-1900 MHz.

5.3.2 Coexistence between UAS and MFCN above 1920 MHz

SEAMCAT simulations (ECC Report 332, section 5.4) of interference from UAS UE to MFCN UL above 1920 MHz show a throughput loss between 8% and 25% for a UAS carrier frequency of 1917.5 MHz (5 MHz bandwidth).

- 1 SEAMCAT simulations show that interference from MFCN UEs to UAS GS and UAS UE translate to throughput losses between 0.1% to 1.6%.
- 2 Monte Carlo simulations (ECC Report 332, annex 9) of interference from UAS UE show that the interference probability of the most impacted MFCN BS in the simulation area, considering a carrier frequency of 1915 MHz, can be limited to about 15% if the rural range is limited to 1000 m, and to 7% if the urban range is limited to 250 m.
- 3 MCL computations (ECC Report 332, section 5.4.1.3) has been performed to assess the interference from UAS GS to MFCN UL. For an UAS GS with a maximum transmit power of 10 dBm and maximum antenna gain of 5 dBi, the I/N protection criterion is generally not exceeded for a separation distance of 100 m (criterion is exceeded in urban settings using propagation model of Recommendation ITU-R P.1546 [11]). The interference from a UAS GS with a transmit power of 30 dBm, however, is above the MFCN UL protection criterion at a separation distance of 100 m.
- 4 Monte Carlo simulations (ECC Report 332, annex 9) show that interference probability of the most impacted MFCN BS in the simulation area is around 0.4% for an UAS GS transmit power of 10 dBm³, and around 5% to 6% for an UAS transmit power of 30 dBm.

5.4 UAS USING DECT-2020 NR

Initial MCL compatibility studies were carried in order to quantify the feasibility of deploying UAS using DECT-2020 in 1880-1900 MHz and 1910-1920 MHz.

Given the similarities between LTE and DECT-2020 waveforms, considering the lower transmit power of DECT-2020 (24 dBm), dynamic selection of time slots and frequency channels, and transmit power control on both UAS GS and UAS UE, it is expected that probabilities of interference of UAS using DECT-2020 NR to systems in adjacent bands would be lower than those computed using Monte Carlo studies with UAS using LTE.”

³ Here, when the UAS GS transmit power is reduced from 30 dBm to 10 dBm, it is assumed that the out of band radiations are also attenuated by 20 dB.

6 SUMMARY OF THE COMPABILITY STUDIES

ECC Report 332 [3] on technical compatibility studies related to UAS (Unmanned Aircraft System) in 1880-1920 MHz band assessed two technologies as candidates to be used for the governmental UAS operation. The two technologies are LTE and DECT-2020 NR. This section shows the analysis of the results obtained in ECC Report 332 for both technologies.

The study results in ECC Report 332 show that co-channel operation of governmental UAS and FRMCS in the frequency band 1900-1910 MHz is not feasible, independently of the technology used by the UAS.

6.1 FINDINGS FOR THE USE OF A LTE BASED TECHNOLOGY FOR UAS

The co-channel operation of governmental UAS and DECT in the band 1880-1900 MHz would only be feasible if a separation distance of up to 3 km for indoor DECT and up to 20 km for outdoor DECT could be ensured. As DECT is implemented under a license exempt regime, the location of DECT devices are not known and therefore a separation distance as possible mitigation measure cannot be imposed.

MFCN DL operating in the last channel below 1880 MHz will not receive interference by governmental UAS but will cause serious interference on the governmental UAS in the frequency band 1880-1890 MHz. The usage of governmental UAS in the vicinity of MFCN BS operating in last channel of the frequency band below 1880 MHz will only be possible in the frequency band above 1890 MHz.

MFCN BS UL using the first channel in the frequency above 1920 MHz would be interfered with a high probability by governmental UAS using a centre frequency of 1915 MHz for separation distances below 100 m.

RMR BS operating in 1900-1910 MHz will be interfered by governmental UAS based on LTE technology operating in adjacent bands below 1900 MHz and above 1910 MHz within a distance between 300 m and 500 m. Implementation of operational conditions such as separation distance between UAS and RMR and limitation on the maximum deployment range of UAS are required to avoid additional technical requirements on UAS equipment such as specific OOB limits (see Annex 1).

In addition, the results of the studies show that a deployment of governmental UAS using LTE based technology will not be feasible in the frequency band 1880-1900 MHz. The UAS cannot share the band with DECT and have to keep separation distances to protect RMR BS. The operation of governmental UAS will also be interfered by MFCN DL below 1880 MHz. In the frequency band 1910-1920 MHz, governmental UAS have to keep separation distances to RMR operation below 1910 MHz and MFCN UL above 1920 MHz.

Due to the outlined separation distances needed to protect the incumbent services from interference in this band it will be necessary to impose strong limitations on the operation of governmental UAS. With these limitations the usage of governmental UAS based on LTE technology would not be feasible.

6.2 RESULTS BASED ON THE USE OF A DECT-2020 NR BASED TECHNOLOGY FOR UAS

Given the similarities between LTE and DECT-2020 NR waveforms, considering the lower transmit power of DECT-2020 NR (24 dBm), dynamic selection of time slots and frequency channels, and transmit power control on both UAS GS and UAS UE, it is expected that probabilities of interference of UAS using DECT-2020 NR to systems in adjacent bands would be lower than those computed using Monte Carlo studies with UAS using LTE.

There have been MCL studies for governmental UAS using DECT-2020 NR technology in ECC Report 332. DECT-2020 NR would use a max transmit power of up to 24 dBm for both UAS GS and UE compared to 30 dBm for the GS and 28 dBm for the UE assumed for LTE.

The study results founded on LTE technology based UAS are still valid for MFCN UL BS above 1920 MHz, but the separation distance might be reduced.

The basic results founded on the use of a LTE based technology for the UAS, are valid except those referring to co-channel operation in 1880-1900 MHz between DECT and UAS. With the reduction of the maximum

e.i.r.p. to 24 dBm and TPC (Transmit Power Control) implemented in both UAS GS and UAS UE operating with DECT-2020 NR, plus limiting the UAS range deployment to 500 m in urban scenario and 3.5 km in rural scenario, the risk of interference to the services in the adjacent bands is expected to be reduced.

6.2.1 RMR

For the protection of RMR (1900-1910 MHz band) a separation distance between the railways and UAS in the adjacent bands (1880-1900 MHz and 1910-1920 MHz) is required. It is proposed to consider in first approach and as estimated conclusion an average value of 200 m⁴ as minimum horizontal separation distance between UAS and railways, this value needs to be adjusted case by case according to the environment (rural or urban). This value is also still subject to be reviewed during the preparation of a possible future ECC Recommendation on governmental UAS. In case that the deployment area of UAS lays within the minimum separation distance between UAS equipment and railways, there is a risk of interference on RMR that could lead to security issues in the rail operation. In this situation, when the separation distance between the UAS GS / UE and the railways is less than the separation distance defined above, a notification process shall be implemented between the involved parties: administration(s), the UAS operator(s) and the railway infrastructure manager(s) (IM). The detailed workflow (contact persons, notification time...) of this process shall be defined between UAS operator(s), administration(s) and railway IM(s). This process has also to address cross border coordination situation regarding coexistence issues between UAS operation and railways (see Annex 3).

Additionally, ECC Report 332, annex 13 contained some conclusions of coexistence of UAS based on DECT 2020 NR (MCL Study of the possible impact of DECT-2020-Based UAS Deployment in 1880-1900 MHz and 1910-1920 MHz to adjacent services) (see Annex 6).

6.2.2 DECT

Co-channel operation between DECT legacy and DECT-2020 NR in 1880-1900 MHz band is feasible through DCS (Dynamic Channel Selection) which is already implemented in both technologies and enables compatibility between them (see Annex 5). For coexistence between DECT-2020 NR systems, the standard supports advanced features enabling autonomous, time-accurate interference avoidance schemes between DECT-2020 NR systems and over-the-air synchronisation of different parts of the network. TPC (Transmission Power Control) implemented in both UAS GS and UAS UE DECT-2020 NR based allows a better compatibility with services in adjacent bands.

With the aim to allow efficient and flexible use of the spectrum for both DECT legacy and DECT-2020 NR, the spectrum use of all UAS deployed in one area is limited to 6.912 MHz in the 1880-1900 MHz band.

DECT internal resource management can be improved by using the upper or lower edge of the 1880-1900 MHz band, minimising the internal interference within the DECT spectrum. The UAS deployment scenario is very different from typical DECT installations due to the speed and distance from the base, impacting any fixed DECT installation it overflies as well as its own communication.

The physical layer of DECT-2020 NR supports transmit and receiver diversity and MIMO operations up to 8 streams enabling efficient spectrum use for higher bit rates. With 2x2 MIMO operation 2 UAS can time share the same 3.456 MHz frequency channel and with 4x4 MIMO operation 4 UAS can operate/share the same 3.456 MHz frequency channel. MIMO operation and multiplexing UAS operation into the same frequency channel removes the UAS to UAS interference, as the transmission are separated in time domain. (More details on MIMO operation are provided in Annex 4 and Annex 5.)

Technical studies performed in ECC Report 332 to assess the co-channel operation and compatibility with services in adjacent band assumed 2x2 MIMO for DECT-2020 NR UAS based, MCS-2 over 5 subslots for C2, and MCS-4 over 6 subslots for payload (ECC Report 332, table 8).

It is recommended that UAS always start deployment in the 1910-1920 MHz band prior to the use of the 1880-1900 MHz band.

⁴ This separation distance could be reviewed according to experience / feedback from railway IM(s).

6.2.3 MFCN

The possible interference into MFCN BS from the DECT-2020 NR based GS will be limited due to the reduced maximum e.i.r.p. leading to shorter separation distances. However, the potential interference from the UAS UE could lead to a UL throughput loss, especially from the UAS UE operating in 1917.5 MHz.

7 CONCLUSIONS

This Report addresses the assessment on the feasibility of spectrum solutions for the operational needs for governmental use of unmanned aircraft systems (UAS) and establishes the relevant technical conditions. Governmental use does not address military usage (which is considered as a national matter). This Report does not address the regulatory and operational aspects or electromagnetic compatibility (EMC) issues related to the UAS avionics. It is important to note that in this Report UAS, aerial UE and UAS UE, both terms refer to the flying device of the UAS.

Co-channel operation between governmental UAS and Railway Mobile Radio (RMR) in the 1900-1910 MHz band at the same location is not feasible independently of the technology used by the UAS and will lead to a significant interference risk towards the RMR operation. Therefore, the frequency bands assessed for UAS in this Report are 1880-1900 MHz and 1910-1920 MHz.

It is noted that, according to ERC Decision (98)02 [14], DECT in the band 1880-1900 MHz is under a general authorisation regime and therefore no priority can be given to any particular application using DECT (including governmental UAS).

For UAS using LTE based technology, the outlined separation distances needed to protect the incumbent services from interference in these bands are such that it will be necessary to impose strong limitations on the operation of governmental UAS. With these limitations, the usage of governmental UAS using LTE based technology will not be feasible.

Co-channel operation between DECT-2020 NR based UAS and DECT in 1880-1900 MHz band is already feasible through DCS (Dynamic Channel Selection) which is a mechanism to access to the spectrum already implemented in both technologies. Due to this technology features the co-channel operation of DECT-2020 NR based governmental UAS and DECT is feasible under the following conditions:

- DECT-2020 NR based UAS should implement Transmit Power Control (TPC) in both UAS GS and UAS UE with a maximum e.i.r.p. of 24 dBm;
- Coexistence between UAS and DECT in 1880-1900 MHz band may be improved if UAS start deployment in the 1910-1920 MHz band prior to the use of the 1880-1900 MHz band;
- In critical mission, the maximum number of UAS is limited to 3 UAS in the same area;
- UAS in the same area should together not use more than 6.912 MHz in the frequency band 1880-1900 MHz and 6.912 MHz in the frequency band 1910-1920 MHz;
- The maximum operating range for UAS shall be limited to 500 m in urban scenario and 3.5 km in rural scenario.

The compatibility between DECT-2020 NR based UAS and services in the adjacent bands is feasible under the following conditions:

- For the protection of RMR (1900-1910 MHz band) a separation distance between the railways and UAS in the adjacent bands (1880-1900 MHz and 1910-1920 MHz) is required. It is proposed to consider in first approach and as estimated conclusion an average value of 200 m⁵ as minimum horizontal separation distance between UAS and railways, this value needs to be adjusted case by case according to the environment (rural or urban). This value is also still subject to be reviewed during the preparation of a possible future ECC Recommendation on governmental UAS. In case that the deployment area of UAS lays within the minimum separation distance between UAS equipment and railways, there is a risk of interference on RMR that could lead to security issues in the rail operation. In this situation, when the separation distance between the UAS GS / UE and the railways is less than the separation distance defined above, a notification process shall be implemented between the involved parties: parties: administration(s), the UAS operator(s) and the railway infrastructure manager(s) (IM). The detailed workflow (contact persons, notification time...) of this process shall be defined between UAS operator(s), administration(s) and railway IM(s). This process has also to address cross border coordination situation regarding coexistence issues between UAS operation and railways (see Annex 3).
- The possible interference into MFCN UL BS above 1920 MHz will be limited due to the reduced DECT-2020 NR max output power leading to shorter separation distances than those calculated for LTE based UAS.

⁵ This separation distance could be reviewed according to experience / feedback from railway IM(s).

ANNEX 1: ANALYSIS ON OOB LIMITS NEED FOR UAS UE/GS

ECC Report 332 [3] assessed the coexistence and compatibility between RMR in 1900-1910 MHz and governmental UAS in adjacent bands. These assessments concluded that:

“Monte Carlo study of the possible impact of a UAS deployed in the frequency band 1910-1920 MHz to an FRMCS deployment in the band 1900-1910 MHz is presented in Annex 10. Because of the symmetry of the FRMCS BEM and UAS SEM, these results at 1915 MHz also apply for interference from an UAS deployed at 1895 MHz. Simulations show that interference from UAS to FRMCS UE is negligible. On the contrary, interference to the FRMCS BS is more likely.

When using a UAS GS transmit power of 10 dBm, the probability of interfering the FRMCS BS is:

- less than 1% when the distance to the tracks is between 100 and 300 m in urban areas;
- less than 1% when the distance to the tracks is between 300 and 500 m in rural areas.

When using a UAS GS transmit power of 30 dBm, the probability of interfering the FRMCS BS is:

- less than 1% when the distance to the tracks is between 300 and 500 m in urban areas;
- around 10% when the distance to the tracks is between 500 and 1000 m in rural areas.

Considering the impact of the UAS UE, the probability of interfering the FRMCS BS is:

- lower than 1% when the UAS UE is between 300 and 500 m from the tracks (horizontal distance) if the range is limited to 500 m in rural areas (1000 m if 10 MHz channel is used);
- lower than 1% when the UAS UE is between 300 and 500 m from the tracks (horizontal distance) in urban areas.”

ECC Report 332, section 5.2.2 says that, in order to further reduce interference from UAS GS or UE to RMR BS, further limitation of the UAS out-of-band and RMR blocking requirements could be implemented. In addition, some operational guidance could be defined to avoid UAS operations close to rail tracks.

A1.1 ANALYSIS ON THE REQUIREMENTS:

Looking at the results of the technical assessment made in ECC Report 332, annex 10, the following resume shows the probability of LTE induced interference for each scenario studied, considering the relevant UAS deployment range when separation distance between UAS and rail is between 100 m-300 m (related figures from ECC Report 332 are referenced in round brackets).

Rural/low-speed scenarios:

- UAS GS to RMR BS => all ranges, the probability is around 20% (100-300 m distance to the tracks) (Figures 88, 89 and 90);
- UAS UE to RMR BS => 5650 m range, the probability is around 50% (100-300 m distance to the tracks) (Figure 91);
- UAS UE to RMR BS => 1000 m range, the probability is <5% (100-300 m distance to the tracks) (Figure 92);
- UAS UE to RMR BS => 500 m range, the probability is <2% (100-300 m distance to the tracks) (Figure 93);
- UAS GS to RMR cab radio/UE => all ranges, the probability is < 0.1% (100-300 m distance to the tracks) (Figures 94, 95 and 96);
- UAS UE to RMR cab radio/UE => all ranges, the probability is < 0.1% (100-300 m distance to the tracks) (Figures 97, 98 and 99).

Rural/high-speed scenarios:

- UAS GS to RMR BS => all ranges, the probability is around/higher than 20% (100-300 m distance to the tracks) (Figures 100, 101 and 102);
- UAS UE to RMR BS => 5650 m range, the probability is around 50% (100-300 m distance to the tracks) (Figure 103);

- UAS UE to RMR BS => 1000 m range, the probability is <5% (100-300 m distance to the tracks) (Figure 104);
- UAS UE to RMR BS => 500 m range, the probability is <1.2% (100-300 m distance to the tracks) (Figure 105);
- UAS GS to RMR cab radio/UE => all ranges, the probability is <0.1% (100-300 m distance to the tracks) (Figures 106, 107 and 108);
- UAS UE to RMR cab radio/UE => all ranges, the probability is <0.1% (100-300 m distance to the tracks) (Figures 109, 110 and 111).

Urban/High-density scenario:

- UAS GS to RMR BS => all ranges (1000 m, 500 m, 300 m), the probability is < 1.8% (100-300 m distance to the tracks) (Figures 112, 113 and 114);
- UAS UE to RMR BS => 1000 m range, the probability is < 9% (100-300 m distance to the tracks) (Figure 115);
- UAS UE to RMR BS => 500 m range, the probability is < 4% (100-300 m distance to the tracks) (Figure 116);
- UAS UE to RMR BS => 300 m range, the probability is < 0.5% (100-300 m distance to the tracks) (Figure 117);
- UAS GS to RMR cab radio/UE => all ranges (1000 m, 500 m, 300 m), the probability is < 0.1% (100-300 m distance to the tracks) (Figures 118, 119 and 120);
- UAS UE to RMR cab radio/UE => all ranges (1000 m, 500 m, 300 m), the probability is < 0.1% (100-300 m distance to the tracks) (Figures 121, 122 and 123).

This resume of results shows that:

- Probability of interference from UAS GS to RMR BS is high in rural scenario independently of the deployment range of UAS;
- Probability of interference from UAS GS to RMR BS is negligible in urban scenario;
- Probability of interference from UAS UE to RMR BS decreases when the UAS deployment range decreases (e.g. interference is reduced to 5% when the UAS deployment range is 1000 m in both rural/low speed scenario and rural high-speed scenario. Probability of interference is reduced to around 4% when the UAS deployment range is 500 m in urban high/density scenario);
- Risk of interference from UAS UE to RMR BS can be decreased by limiting the UAS deployment range (e.g. 1000 m for rural scenarios and 500 m for urban scenario);
- Probability of interference from UAS UE or UAS GS to RMR cab radio/UE is lower than 0.1% in all scenarios.

A1.1.1 Conclusion on the UAS UE/GS requirements for the protection of RMR cab-radio/UE

Assuming separation distance between UAS and rail to 100 m - 300 m:

- There is no need for specific requirement on UAS UE/GS OOB limit for the protection of RMR cab-radio/UE considering that probability of interference from UAS UE/GS is negligible in all scenarios (rural and urban).

A1.1.2 Conclusion on the UAS UE requirements for the protection of RMR BS

Assuming separation distance between UAS and rail to 100 m - 300 m:

- There is no need for specific requirement on UAS UE OOB limits to mitigate the risk of interference from UAS UE to RMR BS considering the following reasons;
- As it was shown, the probability of interference from UAS UE to RMR BS decreases when the UAS deployment range decreases: i.e. the interference probability is reduced to less than 5% when the UAS deployment range is 1000 m in both rural/low speed scenario and rural high-speed scenario, and interference probability is reduced to around 4% when the UAS deployment range is 500 m in urban high/density scenario. Considering that the protection criterion is I/N, the probability of interference is

reasonable and can be reduced with other measures than OOB imposed to UAS UE (e.g. limiting the UAS range deployment, increase the separation distance between UAS and rail);

- The probability of interference is reduced by limiting the UAS deployment range, then this measure is possible considering that governmental UAS will be deployed in VLOS (Visual Line of Sight) in both scenarios rural and urban;
- UAS UE uses TPC function independently of the technology used (DECT-2020 NR or LTE), which reduces the transmit power of the UE considering the free space path loss between it and the UAS GS, thus reducing the risk of interference from UAS UE to RMR BS;
- Reducing the transmission power to 24 dBm which means using DECT-2020 NR technology for the UAS UE will also reduce the risk of interference, considering that 30 dBm for GS and 28 dBm for UE [LTE based UAS technology was the transmission power assumed in technical assessment made in ECC Report 332 [3];
- Extrapolating conclusions are obtained on MFCN UAS from ECC Report 309 [4], where no additional measure was required for UAS UE for the protection of RMR BS operating below 880 MHz. ECC Report 309 on the analysis of the usage of UE for communication in current MFCN harmonised bands, particularly in section 5.4.1.1 where the compatibility between RMR operating in (GSM-R and RMR BS UL) below 880 MHz and RMR cab-radio receiving above 919.4 MHz and MFCN UAS operating in 880-915 MHz band was assessed, concluded that for UE operating in a MFCN network at 880-915 MHz, no additional measures are required to protect RMR (GSM-R and RMR BS UL) below 880 MHz and RMR cab-radio receiving above 919.4 MHz.

ECC Report 309, section 5.4.1.1 "Impact of aerial UE on RMR BS below 880 MHz" states:

"Aerial UEs do modify the coexistence situation at 880 MHz because the aerial UEs minimum coupling loss with GSM-R/FRMCS base stations is slightly different to ground based UEs due to their physical operation location".

A Monte Carlo simulation of the interfering field strength generated by 5 UEs is compared with the interfering field strength generated by 15 ground UEs (see annex 2). The difference in UE density is justified by the LTE networks limited ability to handle airborne UEs due to self-interference issues. Monte Carlo simulations demonstrate that UEs create a lower interference field strength than ground based UEs but also that the variation of the interfering field strength is lower. This can be explained as follows:

- The antenna gain above the horizon from RMR and LTE base stations are similar;
- The propagation difference between the wanted link (UE to LTE BS) and the interfering link (UE to RMR BS) mostly differ due to free-space path loss;
- Free-space path loss varies less than more challenging propagation environment (e.g. Hata).

As a result, the power control of the wanted link ensures that the interfering field strength from UEs is lower than the interfering field strength generated by ground based UEs.

Further analysis concluded that, when considering coexistence issues with other systems, GSM-R base stations may accept at most 1 dB desensitisation. This value has been assumed in several former ECC reports, most notably ECC Report 96 [6], ECC Report 146 [7], ECC Report 162 [8] and ECC Report 200 [9] and is similar to the one used for MFCN base stations (see Report ITU-R M.2292 [10]). As a conclusion, RMR base stations, whether they use GSM-R, or RMR, or both systems in parallel, do not claim more protection than MFCN base stations, for which is commonly accepted that there is no significant performance degradation when the desensitisation is kept below 1 dB.

The situation between RMR base stations and UEs operating above 880 MHz is similar to the situation where two operators use adjacent FDD uplink frequency blocks, and where one of them operates UEs

ECC Report 309, section 4.2 [4] states:

"Studies in ANNEX 2 and ANNEX 16 show that the interference from aerial UEs in adjacent channel is negligible compared to the case of adjacent interference caused by ground UEs.

This trend can be explained by:

- comparing the distribution of transmission power for UEs and ground UEs: UEs operate with lower transmission power (than ground UEs) because of a lower coupling loss with their serving BS (due to no obstacles within the path);
- noticing the small effect of Adjacent Channel Interference Ratio (ACIR) in the aggregate interference thus making it negligible towards the noise level (i.e. $SNR \approx SNIR$).

A1.1.3 Conclusion on the UAS GS requirements for the protection of RMR BS

There is no need for a specific requirement on UAS GS OOB limits to mitigate the risk of interference from UAS GS to RMR BS considering that:

- The probability of interference from UAS GS to RMR BS is high only in rural scenarios, in urban scenarios the probability of interference is lower than 1.8% (negligible);
- Assuming TPC is implemented on the UAS GS, combined with the measure of reducing the UAS range deployment, the risk of interference in rural scenarios (e.g. 1000 m for rural scenario) is reduced. Limitation of the UAS range deployment is a possible measure to be adopted in order to reduce the risk of interference, considering that governmental UAS will be deployed in VLOS (Visual Line of Sight) in both scenarios, rural and urban;
- There is no such a limit requirement for current DECT devices operating in 1880-1900 MHz band.

ANNEX 2: ANALYSIS ON THE COMPATIBILITY BETWEEN GOVERNMENTAL UAS IN 1880-1900 MHZ AND MFCN DOWNLINK BELOW 1880 MHZ

ECC Report 332 [3] assessed the coexistence and compatibility between governmental UAS in 1880-1900 MHz and MFCN DL in 1805-1880 MHz.

The executive summary of ECC Report 332, section 0.3.1 concerning this topic concluded:

- 1 “SEAMCAT simulations ECC Report 332, annex 5 show that important levels of interference may happen from MFCN DL (1860-1880 MHz) to both UAS UE and GS 10 MHz channel operating in 1880-1890 MHz. Noting that these levels of interference translate to UE (drone) throughput loss between 87.7% and 99.5% and GS (controller) throughput loss between 50% and 88%, considering the UAS channel centred at 1885 MHz and a UAS in the range of 1000 m.
- 2 SEAMCAT simulations (ECC Report 332, Annex 5) show that the interference from MFCN DL (1860-1880 MHz) to both UAS UE and GS 10 MHz channel operating in 1890-1900 MHz is reduced. If the UAS UE/GS receiver selectivity can be improved with an additional filter (ACS_2 = 66 dB), the interference from MFCN1800 DL can be reduced, as shown in ECC Report 332, section 5.3.1.
- 3 Interference from UAS UE to MFCN1800 DL (UE reception) does not appear as a problem, including flying MFCN UE, as it translates to downlink throughput loss less than 0.1%.
- 4 Monte Carlo studies (ECC Report 332, annex 8) taking into account UAS protection criterions in-line with UAS bitrate requirements (300 kbps for controller to drone, 5 Mbps for drone to controller) show an interference probability of the UE and the GS by MFCN DL lower than 10% (but the range has to be limited to 1000 m in rural environments), assuming a GS transmit power of 30 dBm.
- 5 MCL computations ECC Report 332, section 5.3 has been performed to assess the interference from UAS GS to MFCN1800 DL (UE reception). For an UAS GS transmitting at 10 dBm, the I/N protection criterion of an MFCN UE is not exceeded at 50 m (urban environment) or 100 m (rural environment). For an UAS GS transmitting at 30 dBm however, the MFCN UE protection criterion can be exceeded even when the separation distance is above 100 m.

Considering that, for a governmental UAS, the highest data rate is transmitted from UAS UE to UAS GS, and in order to further protect the command and control signals received by UAS UE from MFCN interference, UAS command and control channel of a single UAS deployment could be placed in the frequency range 1890 - 1900 MHz.”

A2.1 CONCLUSION ON THE INTERFERENCE FROM LTE BASED MFCN DL BELOW 1880 MHZ TO UAS GS/UE

The results of the Monte Carlo simulations in ECC Report 332, annex 8 [3] show that:

UAS UE as a victim:

Rural scenario:

- MFCN DL to UAS UE => range of 5650 m, the probability of interference for UAS UE transmit power of 28 dBm is between 78.4% (5 MHz channel) and 47.36% (10 MHz channel) (Table 33);
- MFCN DL to UAS UE => range of 1000 m, the probability of interference for UAS GS transmit power of 28 dBm is between 6.21% (5 MHz channel) and 7.37% (10 MHz channel) (Table 33).

Urban scenario:

- MFCN DL to UAS UE => range of 1000 m, the probability of interference for UAS GS transmit power of 28 dBm is between 5.82% (5 MHz channel) and 3.78% (10 MHz channel) (Table 33);
- MFCN DL to UAS UE => range of 500 m, the probability of interference for UAS GS transmit power of 28 dBm is between 1.9% (5 MHz channel) and 2.48% (10 MHz channel) (Table 33).

UAS GS as a victim:

Rural scenario:

- MFCN DL to UAS GS => range of 5650 m, the highest probability of interference for both UAS GS transmit power values of 10 dBm and 30 dBm are 14.07% and 97.47% (Table 36);
- MFCN DL to UAS GS => range of 1000 m, the probability of interference for UAS GS transmit power of 10 dBm is between 14.75% (5 MHz channel) and 29.01% (10 MHz channel) and for UAS GS transmit power of 30 dBm is between 0.29% (5 MHz channel) and 0.54%(10 MHz channel) (Table 36).

Urban scenario:

- MFCN DL to UAS GS => range of 1000 m, the probability of interference for UAS GS transmit power of 10 dBm is between 90.49% (5 MHz channel) and 80.66% (10 MHz channel) and for UAS GS transmit power of 30 dBm is between 3.26% (5 MHz channel) and 1.25%(10 MHz channel) (Table 36);
- MFCN DL to UAS GS => range of 300 m, the probability of interference for UAS GS transmit power of 10 dBm is between 64.66% (5 MHz channel) and 36.73% (10 MHz channel) and for UAS GS transmit power of 30 dBm is between 0.28% (5 MHz channel) and 0.06%(10 MHz channel) (Table 36).

Therefore:

- Probability of interference from LTE based MFCN DL to UAS UE is high in rural scenario when the deployment range of UAS is at the maximum distance simulated (e.g. 5650 m);
- Probability of interference from LTE based MFCN DL to UAS UE decreases prominently in rural scenario when the deployment range of UAS decreases to 1000 m;
- Probability of interference from LTE based MFCN DL to UAS UE is low in rural scenario independently of the deployment range of UAS (1000 m or 500 m);
- Probability of interference from LTE based MFCN DL to UAS GS is high in rural scenario when the deployment range of UAS is at the maximum distance simulated (e.g. 5650 m);
- Probability of interference from LTE based MFCN DL to UAS GS decreases prominently in rural scenario when the deployment range of UAS decreases to 1000 m;
- Probability of interference from LTE based MFCN DL to UAS UE is very low in urban scenario independently of the deployment range of UAS (1000 m or 300 m);
- Monte Carlo simulations have shown that the probability of interference is low when the deployment range is limited. The highest probability in both studied scenarios, rural and urban, is achieved when the deployment range is the maximum simulated.

The following conditions are recommended to mitigate the risk of interference from LTE based MFCN DL below 1880 MHz to UAS GS/UE (1880-1900 MHz):

- Limitation of the deployment range of UAS in rural scenario avoiding worst-case distances (e.g. 5650 in rural scenario and 1000 m in urban scenario) where the probability of interference is the highest. VLOS operation of the governmental UAS.

It is recommended to adapt the video compression ratio to mitigate the possible impact on the quality of video flux on the link UAS UE to UAS GS (e.g. MPEG-DASH⁶ or RTSP along with RTP and RTCP):

- There are no specific reception parameters required in the current regulation for the compatibility between DECT in 1880-1900 MHz and MFCN DL below 1880 MHz. Therefore, using technology DECT-2020 NR, which is an advanced DECT, does not require specific reception parameters to be compatible with MFCN DL below 1880 MHz.

A2.2 CONCLUSION ON THE INTERFERENCE FROM UAS UE IN 1880-1900 MHZ TO MFCN DL BELOW 1880 MHZ

Interference from UAS UE to MFCN 1800 DL (UE reception) does not appear as a problem, including flying MFCN UE, as it translates to a downlink throughput loss less than 0.1%. Therefore, there is no technical or operational specific condition recommended.

⁶ MPEG Dynamic Adaptive Streaming over HTTP

A2.3 CONCLUSION ON THE INTERFERENCE FROM UAS GS IN 1880-1900 MHZ AND MFCN DL BELOW 1880 MHZ

Calculations (see ECC Report 332, section 5.3.1.5 [3]) has been performed to assess the interference from UAS GS to MFCN DL below 1880 MHz. Interference from LTE-based UAS GS to MFCN UE was calculated assuming distances of 50 m and 100 m and UAS GS transmit power of 10 dBm and 30 dBm. The performance degradation of the MFCN UE decreases when the transmit power of UAS GS is reduced.

Using DECT-2020 NR technology allows a transmit power of 24 dBm which is lower than the 30 dBm assumed on technical studies (see ECC Report 332, section 5.3.1.5).

Using DECT-2020 NR technology will add the TPC on the UAS GS to the UAS UE link, which will allow avoiding the transmissions at the highest transmission power.

Using DECT-2020 NR technology which allows the implementation of DCS (Dynamic Channel Selection) to enable the selection of time slots and frequency channels giving an efficient, dynamic and flexible use of channels and access to the spectrum.

Analysis on the compatibility between governmental UAS (1910-1920 MHz) and MFCN UL above 1920 MHz

ECC Report 332 assessed the coexistence and compatibility between governmental UAS in 1910-1920 MHz and MFCN UL in 1920-1980 MHz.

The executive summary of ECC Report 332 concerning this topic (Section 0.3.2) concluded:

- “SEAMCAT simulations (section 5.4) of interference from UAS UE to MFCN UL above 1920 MHz show a throughput loss between 8% and 25% for a UAS carrier frequency of 1917.5 MHz (5 MHz bandwidth).
- SEAMCAT simulation show that interference from MFCN UEs to UAS GS and UAS UE translate to throughput losses between 0.1% to 1.6%.
- Monte Carlo simulations (Annex 9) of interference from UAS UE show that the interference probability of the most impacted MFCN BS in the simulation area, considering a carrier frequency of 1915 MHz, can be limited to about 15% if the rural range is limited to 1000 m, and to 7% if the urban range is limited to 250 m.
- MCL computations (section 5.4.1.3) has been performed to assess the interference from UAS GS to MFCN UL. For an UAS GS with a maximum transmit power of 10 dBm and maximum antenna gain of 5 dBi, the I/N protection criterion is generally not exceeded for a separation distance of 100 m (criterion is exceeded in urban settings using propagation model of Recommendation ITU-R P.1546 [11]). The interference from a UAS GS with a transmit power of 30 dBm, however, is above the MFCN UL protection criterion at a separation distance of 100 m.

Monte Carlo simulations (ECC Report 332, annex 9 [3]) show that interference probability of the most impacted MFCN BS in the simulation area is around 0.4% for an UAS GS transmit power of 10 dBm⁷, and around 5% to 6% for an UAS transmit power of 30 dBm.”

A2.4 CONCLUSION ON THE INTERFERENCE FROM MFCN UL ABOVE 1920 MHZ TO UAS UE/GS IN 1910-1920 MHZ

Simulations performed in ECC Report 332, section 5.4.1.5 [3] concluded that the risk of interference from MFCN UE to LTE-based UAS UE is not a problem. Simulations performed in ECC Report 332, section 5.4.1.6 concluded that the risk of interference from MFCN UE to LTE-based UAS UE is not a problem. Therefore, any specific technical or operational condition is required for UAS UE/GS.

In the case of DECT-2020 NR, given the similarities between LTE and DECT-2020 NR waveforms, dynamic selection of time slots and frequency channels on both UAS GS and UAS UE, it is expected that the compatibility between MFCN UL above 1920 MHz and DECT-2020 NR based-UAS GS/UE in 1910-1920 MHz

⁷ Here, when the UAS GS transmit power is reduced from 30 dBm to 10 dBm, it is assumed that the out of band radiations are also attenuated by 20 dB.

is possible considering that MFCN DL (BS) below 1880 MHz is compatible with DECT in 1880-1900 MHz and that the transmit power of MFNC DL (BS) below 1880 MHz is much more higher than the transmit power of MFCN UL (UE) above 1920 MHz.

A2.5 CONCLUSION ON THE INTERFERENCE FROM UAS UE IN 1910-1920 MHZ TO MFCN UL ABOVE 1920 MHZ

ECC Report 332, section 5.4.1.1 [3] contains SEAMCAT simulations of interference from LTE-based UAS UE to MFCN UL, which show that the MFCN UL throughput loss caused by one LTE-based UAS UE is below 5% (protection criteria throughput loss < 5%) when the transmit power of the LTE-based UAS UE is reduced (e.g. 23 dBm). The use of the channel centred in 1912.5 MHz achieves easily the protection criteria (MFCN UL throughput loss).

ECC Report 332, section 5.4.1.1 and annex 9 contain Monte Carlo simulations of interference from LTE-based UAS UE in 1910-1920 MHz to MFCN UL above 1920 MHz. Thanks to UAS UE TPC, the worst-case interference happens when the LTE-based UAS UE is at its maximum deployment range simulated in both, rural scenario (e.g. 5650 m) and urban scenario (e.g. 1000 m). Hence, reducing the maximum range decreases the probability of interference, facilitating the compatibility between the UAS UE and the MFCN BS.

The following conditions are recommended to mitigate the risk of interference from UAS UE in 1910-1920 MHz to MFCN UL above 1920 MHz:

- Decrease the transmission power of the UAS UE in order to decrease the risk of performance degradation on MFCN UL above 1920 MHz;
- Avoid the deployment of the UAS to the maximum range of deployment in both scenarios rural (e.g. 5650 m) and urban (e.g. 1000 m).

Use DECT-2020 NR technology for the operation of the UAS UE which allows to reduce the power transmit (e.g. 24 dB) and the use of the DCS (Dynamic Channel Selection).

Conclusions on the interference from LTE-based UAS GS in 1910-1920 MHz to MFCN UL above 1920 MHz

ECC Report 332, section 5.4.1.3 shows calculation of interference from LTE-based UAS GS in 1910-1920 MHz to MFCN UL above 1920 MHz at a separation distance of 100 m. The outcomes show that the reduction of transmit power of the LTE-based UAS GS allows a better compatibility between LTE-based UAS GS in 1910-1920 MHz and MFCN UL above 1920 MHz.

ECC Report 332, section 5.4.1.4 and annex 9 contain Monte Carlo simulations of interference from LTE-based UAS GS in 1910-1920 MHz to MFCN UL above 1920 MHz. Outcomes show that the probability of interference remains limited, and it decreases when the power transfer is reduced. Therefore, the reduction of transmit power greatly relax the interference probability to MFCN BS. It is important to highlight that LTE technology does not implement TPC functionality in UAS GS, therefore this parameter was not included in this simulation.

The following conditions are recommended to mitigate the risk of interference from UAS GS in 1910-1920 MHz to MFCN UL above 1920 MHz:

- Decrease the transmission power of the UAS GS in order to decrease the risk of performance degradation on MFCN UL above 1920 MHz.

Use DECT-2020 NR technology for the operation of the UAS GS which allows to reduce the power transmit (e.g. 24 dB) and the implementation of TPC (Transmit Power Control) to moderate the transmit power of the UAS GS. Governmental UAS will operate in VLOS which enable advantages using TPC.

ANNEX 3: SPECIFIC CASE OF CROSS BORDER COORDINATION IN BASEL AREA

Governmental UAS may be used in any location in a country, so also very close to the country border. In the neighbouring country railway operation may be present, see for example the picture below for the Basel area with railway line, stations, and shunting areas.

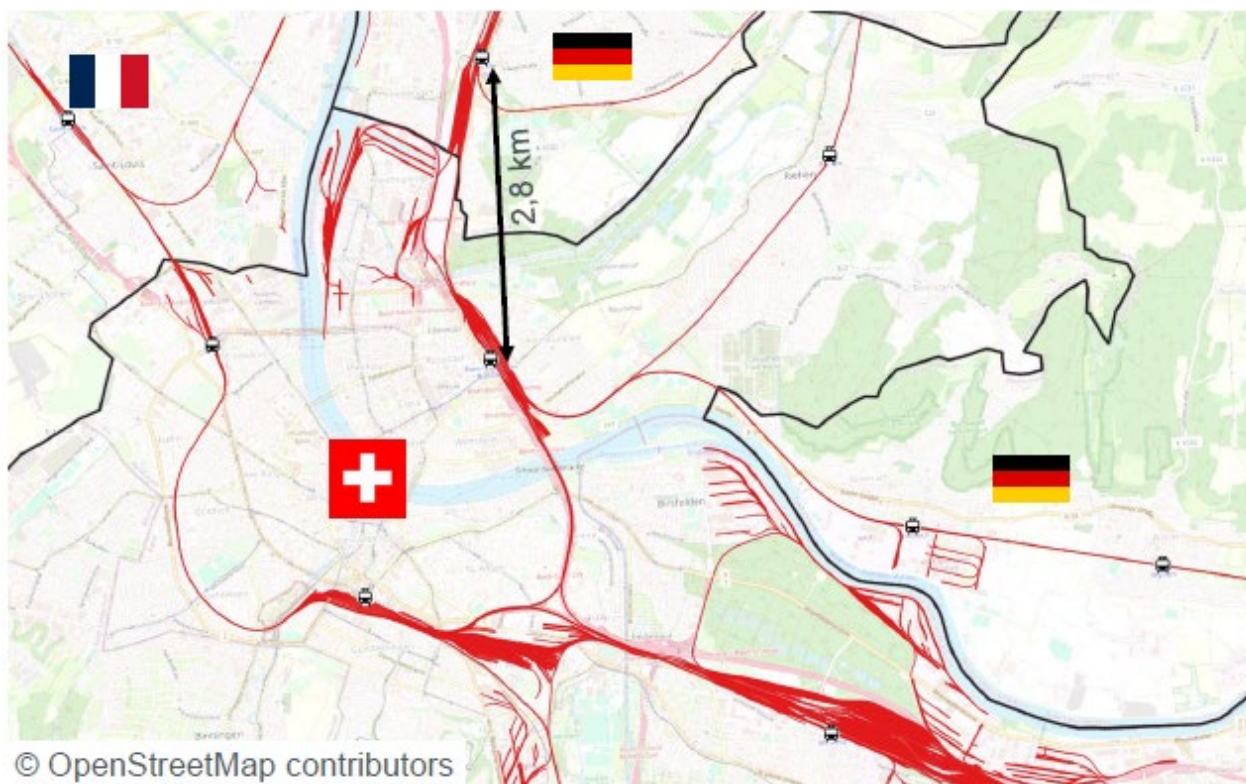


Figure 1: 3-country border area

Operating a governmental UAS in one country close to the border to a neighbouring country or countries as depicted in ECC Report 353 on cross-border coordination and synchronisation for RMR networks in the 1900-1910 MHz TDD band” [12] will lead to potential harmful interference towards RMR networks operating in the band 1900-1910 MHz.

To avoid or at least control such interferences affecting the operation and safety of the potentially interfered railway, there is a need to implement mechanisms that notify the railway operator involved of the possibility of interferences. This would enable him to put in place appropriate measures to ensure railway safety and operation.

The UAS operator(s) shall therefore be required to notify the involved railway operator(s) sufficiently far in advance of the intended UAS usage including all associated deployment and technical details. An efficient and effective process necessary to guarantee a smooth information flow shall be agreed by the administrations involved. This could be done either through a bilateral or multilateral cross-border administrations agreement or be part of a future European wide regulatory framework. The detailed technical conditions like separation distances and workflow requirements must be fixed as part of this regulatory framework.

ANNEX 4: FREQUENCY / CHANNEL MANAGEMENT USED IN DECT OPERATION (1880 -1900 MHZ)

A4.1 CONSIDERED SCENARIOS

This annex examines the channel management scenarios of DECT with various levels of user including with UAS UE sharing the band 1880-1900 MHz. Several frequency / time slots assignments are discussed and shown with the following scenarios:

- Scenario 1(a) - Example Quiet DECT spectrum (no active devices);
- Scenario 1(b) - Example Busy DECT system (many active devices);
- Scenario 2 - Example DECT spectrum with three DECT devices;
- Scenario 3 - Example DECT Spectrum with three legacy DECT devices and one DECT-2020 NR UAS UE in the same area;
- Scenario 4 - Example DECT Spectrum with three legacy DECT devices and one DECT-2020 NR UAS UE, with a distance of 100 m or more;
- Scenario 5 - Example DECT Spectrum with three legacy DECT devices and one DECT-2020 NR UAS UE in a distance of 100 m plus a second DECT-2020 NR UAS UE starting transmission;
- Scenario 6 - Example DECT Spectrum with three legacy DECT devices - Second DECT-2020 NR UAS UE flying 100-200 m from the legacy devices and third DECT-2020 NR UAS UE starts up in same location of legacy devices;
- Scenario 7 - Example DECT Spectrum with three legacy DECT devices + three DECT-2020 NR UAS UE in the same area;
- Scenario 8 - Example Busy DECT Spectrum (no UAS UE possible);
- Scenario 9 - Example UAS UE with 2x2 MIMO;
- Scenario 10 - Example UAS UE with 4x4 MIMO.

A4.2 PARAMETERS AND SPECIFICATIONS

Table 3: DECT parameter

Description of parameter	Typical value
Threshold for quiet slot / carrier	<= -80 dBm slots with weaker power level are instantly selectable
Selectable slot / carrier band	between -80 dBm and -62 dBm
Threshold for occupied slot / carrier	>= - 62 dBm
DECT frequency carriers	~ 1880 MHz = carrier 0 ; ~ 1900 MHz = carrier 9
DECT max RF power	24 dBm
Note: All DECT systems are timeslot synchronised. This is not always the case in real deployment, however assumed in all scenarios for easier illustration. Legacy DECT devices in the subsequent scenarios are assumed to be located outdoor.	

Table 4: Some DECT-2020 NR UAS parameter

Description of parameter	Typical value
Data rate	5 Mbps
Occupied DECT time slots	20 time slots out of 24 slots on two DECT carriers (note 1)
Threshold for occupied slot / carrier	>= - 62 dBm

Description of parameter	Typical value
DECT frequency carriers	~ 1880 MHz = carrier 0 ; ~ 1900 MHz = carrier 9
DECT max RF power	24 dBm
Note 1: Single spatial stream with 5 Mbps video signal requires 3 slots at MCS5 with 6 transmissions per 10 msec, which offers a data rate of 5.12 Mbps, Assuming a control data bit rate of 300 kbps that requires 2 slots at MCS 3 x 2 transmissions (bi-directional); which offers a data rate of 290 kbps. In summary 20 time slots are used out of 24 time slots per DECT carrier, two adjacent carriers are required.	

A4.2.1 Examining the DECT frequency management scenarios

A4.2.1.1 Scenario 1(a) - Example Quiet DECT spectrum (no active devices);

All grey coloured time slots in all 10 carriers are below the threshold of - 80 dBm and fully available.

Carrier	Time Slot	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
1	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
2	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
3	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
4	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
5	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
6	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
7	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
8	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
9	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<

Figure 2: Quiet DECT spectrum

A4.2.1.2 Scenario 1(b) - Example Busy DECT system (many active devices)

Red coloured time slots identify the slot as busy (in use by DECT devices, orange coloured time slots identify a value between busy and quite (caused by adjacent channel interference or by another DECT device far away) and grey coloured time slots identify that the time slot signal is below the threshold of -80 dBm and therefore considered to be fully available.

Carrier	Time Slot	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0		55	55	55	55	75	55	55	55	55	75	55	55	55	55	55	55	55	55	55	55	75	75	75	75
1		75	75	55	55	55	55	75	75	55	55	55	55	55	75	75	75	75	75	75	55	55	55	55	55
2		55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
3		55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
4		55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
5		75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
6		55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
7		55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
8		55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
9		55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55

Figure 3: Busy DECT spectrum

A4.2.1.3 Scenario 2 - Example DECT spectrum with four DECT devices

The example in the figure below shows the time slot occupancy by four DECT devices, e.g. two PPs (portable parts) and two FPs (fixed parts), operating outdoors, in a simple scenario.

Carrier	Time Slot	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
0	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
1	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
2	<	<	<	<	<	80	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
3	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
4	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
5	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
6	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
7	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
8	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<
9	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<	<

Figure 4: Four active DECT legacy devices

A4.2.1.4 Scenario 3 - Example DECT Spectrum with four legacy DECT devices and one DECT-2020 NR UAS UE in the same area

This scenario expands the scenario 2 with adding one DECT-2020 NR UAS UE on carriers 7 and 8.



Figure 5: Four active DECT legacy devices and one DECT-2020 NR UAS UE

Observations:

- UAS UE video / control bit rate requirements will occupy 40 time slots on two carriers (carrier 7 and 8). The two required DECT-2020 NR UAS UE carriers should be next to each other;
- Adjacent time slots (orange) can receive channel interference caused by RF leakage from active slots (red), this is dependent on the signal strength of the active slot;
- DECT legacy devices on carrier 2 and 4 make it difficult for the DECT-2020 NR UAS UE to pick other carriers than 7 and 8. Therefore, the DECT-2020 NR UAS UE cannot easily handover to another set of carriers if requested to e.g. interference reasons.

A4.2.1.5 Scenario 4 - Example DECT Spectrum with four legacy DECT devices and one DECT-2020 NR UAS UE, with a distance of 100 m or more

This scenario shows the same situation as considered in Scenario 3, however in this scenario the DECT-2020 NR UAS UE moved away, e.g. distance of 100 m to the DECT legacy devices.

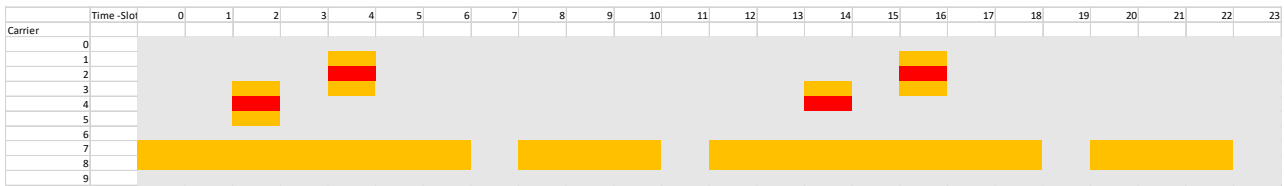


Figure 6: three active DECT legacy devices and one DECT-2020 NR UAS UE in distance

Observations:

- The DECT-2020 NR UAS UE using carrier 7 and 8 moved away. The time slot has changed from busy (red colour) to mid-level RF power (orange colour). No adjacent channel interference here as active slot has much weaker signal strength than previous scenario;
- If there is a requirement to increase the number of DECT legacy devices to 100 (a larger pro-audio installation) the grey bands will fill up and eventually the orange coloured DECT-2020 NR UAS UE time slots could be re-used causing interference, leading to broken video and control.

A4.2.1.6 Scenario 5 - Example DECT Spectrum with four legacy DECT devices and one DECT-2020 NR UAS UE in a distance of 100 m plus a second DECT-2020 NR UAS UE is starting transmission

This scenario, in addition to scenario 4, another DECT-2020 NR UAS UE starts to operate selecting carrier 0 and 1.

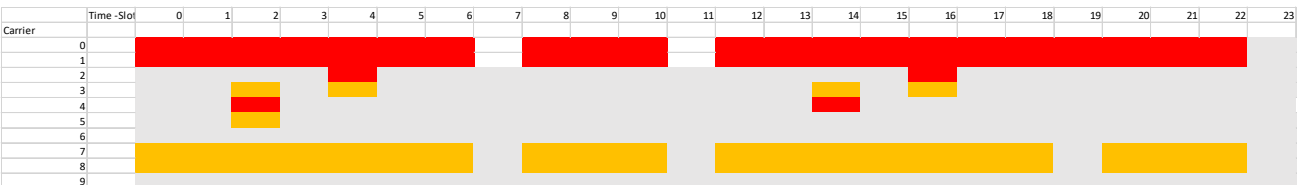


Figure 7: A second DECT-2020 NR UAS UE starts operating

Observations:

- A second DECT-2020 NR UAS UE started operation occupying carrier 0 and 1;
- The signal from the second DECT-2020 NR UAS UE is very strong identified by red colour;

- The two DECT-2020 NR UAS UEs should be able to coexist and allows spectrum to cope with a handover requirement;
- Interesting point to note on second DECT-2020 UAS UE allocation (carrier 0 and 1) is that on carrier 0, slot 4 and 16 has to re-use two slots suffering from adjacent channel interference from legacy devices, these slots could be noisy and as a result, UAS UE video/control could result in missing information.

A4.2.1.7 Scenario 6 - Example DECT Spectrum with four legacy DECT devices - Second DECT-2020 NR UAS UE flies 100 – 200 m away from the legacy devices and third DECT-2020 NR UAS UE starts up at where legacy devices are situated

This scenario shows three DECT-2020 NR UAS UE in operation. Two DECT-2020 NR UAS UE occupying carrier 0, 1, 7 and 8 and third one starting to use carriers 5 and 6.

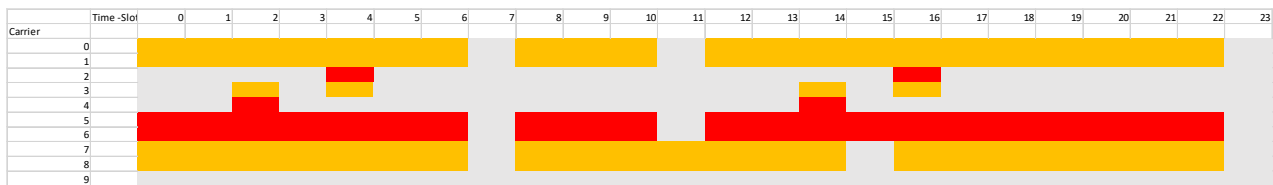


Figure 8: A third DECT-2020 NR UAS UE starts operating

Observations:

- Second DECT-2020 NR UAS UE allocated carriers 0 and 1 has moved away and signal levels detected around legacy devices for video are not so strong, hence highlighted in orange;
- The video signal from third DECT-2020 NR UAS UE is very strong (denoted by red marking on carriers 5 and 6). Note: carrier 5 slot 2 is re-using a time slot suffering from adjacent channel interference from legacy device, therefore it is noisy and liable to miss video/control information for this slot;
- Three DECT-2020 NR UAS UE almost use up all available spectrum, however since two of the DECT-2020 NR UAS UE are far away the DECT legacy devices do not detect strong interference and hence new DECT devices could try and re-use this spectrum once grey spectrum all used up.

A4.2.1.8 Scenario 7 - Example DECT Spectrum with four legacy DECT devices plus three DECT-2020 NR UAS UE in the same area

This scenario all three DECT-2020 NR UAS UE are flying back to the same location, all DECT devices, DECT legacy and DECT-2020 NR UAS UE are at the same area.

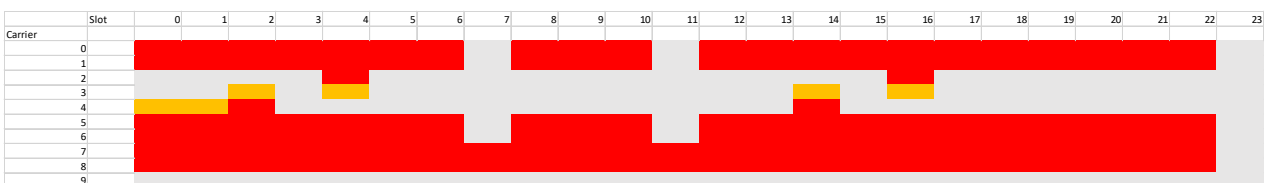


Figure 9: All DECT devices are at the same location

Observations:

- All DECT devices (four DECT legacy and three DECT-2020 NR UAS UE) are in the same area / location and therefore create high RF levels marked in red colour;
- This scenario shows that three DECT-2020 NR UE could work together in theory, however the following problems need to be considered;
- Problem 1: There is no space for handover for any of the DECT-2020 NR UAS UE in this situation (using carrier 2 and 3, or 3 and 4 can't be candidates as legacy devices already use carrier 2 slots 4 and 16), although carriers 3 could be a candidate;
- Problem 2: Further legacy devices and pro-audio enhanced devices will have little clean spectrum to work, indicated by grey bands only;

- Problem 3: A fourth UAS UE will see no space for accessing this spectrum as its needs 2 free adjacent carriers, but none are available. A scenario that could cause problems is if a fourth UAS UE is coming toward the legacy devices, but the spectrum at the legacy DECT devices appears weak or low RSSI, then this UAS UE could try to use it, thinking its free and therefore destroy the video and control link on both UAS UE;
- Maximum three DECT-2020 NR UE can use a completely empty 1880-1900 MHz DECT spectrum at the bit rates and bandwidth recommended above (see A4.2.1.7). Introducing a fourth DECT-2020 NR UAS UE leaves no spectrum for handover and as a result QoS on the current DECT-2020 NR UAS UE will be affected as adjacent channel RF leakage into the current DECT-2020 NR UAS UE will occur, causing degradation on the video and control signals;
- DECT-2020 NR UAS UE need two adjacent carriers to supply the bandwidth required, however looking at the above spectrum, carrier 9 cannot be used for DECT-2020 NR UAS UE, as not enough bandwidth is addressable. However, legacy devices could be a possible on carrier 9. This spectrum fragmentation caused by legacy devices, even if there are hardly any devices, can cause UAS UE spectrum usage problems i.e., reducing the number of possible UAS UE.

A4.2.1.9 Scenario 8 - Example busy DECT spectrum

Figure 10 shows a busy DECT spectrum. On that area / location, there is no space for an UAS UE to operate.



Figure 10: All DECT devices are at the same location

Observations:

- The spectrum / time slots are already in use. A UAS UE is not able to find two carriers for operation;
- An active UAS UE flying close to this DECT allocation will create interference into existing devices while the existing devices interfere into the UAS UE. If the UAS UE flies with some speed, it will fly into this area / location, interference zone, and will most likely stop operating;
- As shown and explained in earlier scenarios, this does not need to be such a busy environment for this to occur, even if just on every second carriers a single slot/carrier is occupied - it can cause this to occur (e.g. five active DECT legacy devices).

A4.2.1.10 Scenario 9 - Example UAS UE with 2x2 MIMO

With using 2x2 MIMO, the required timeslot allocation for an UAS UE is reduced to:

- 3 timeslots for control data, 344 kbps;
- 4 blocks with 5 timeslots each for video payload data, 5.19 Mbps.

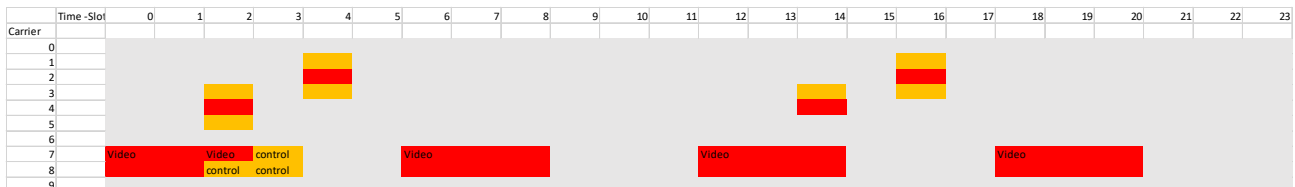


Figure 11: UAS UE time slot allocation with 2x2 MIMO

Observations:

- A 3.456 MHz channel could support two UAS UE, but this would demand slot coordination between the UAS UE (synchronisation).

A4.2.1.11 Scenario 10 - Example UAS UE with 4x4 MIMO

With using 4x4 MIMO, the required timeslot allocation for an UAS UE is reduced to:

- 2 timeslots for control data, 344 kbps;
- 2 blocks with 5 timeslots each for video payload data, 5.325 Mbps.

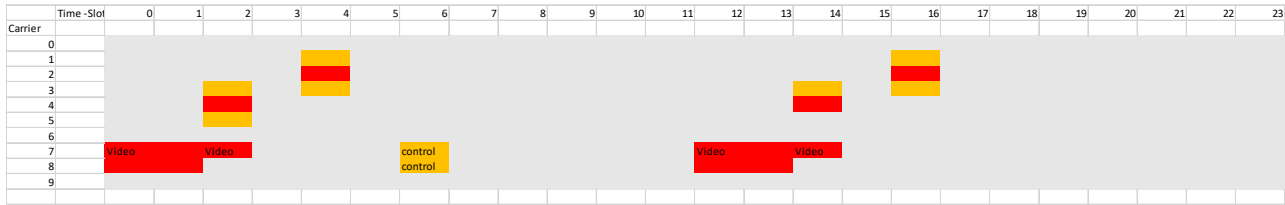


Figure 12: All DECT devices are on the same location

Observations:

- High gross bitrate devices should use the advanced modulation modes for better spectrum efficiency;
- In busy scenarios, the DECT-2020 NR allocation rules could support two (possibly three) UE on a single 3.456 MHz channel using the advanced modulation.

A4.3 CONCLUSIONS

- From the scenarios 1 to 9 it can be concluded that any more than a single UAS UE will impact the QoS of all users in the band 1880-1900 MHz including the UAS UE;
- If frequency resources are occupied at e.g. an outdoor event in a specific location, the deployment of additional DECT services could lead to significantly impacting the QoS of both the current and additional services;
- For critical UAS UE missions with up to three UAS UE the QoS of the DECT service will be significantly reduced, in this scenario UAS UE are unlikely to achieve the critical stable communication required;
- Legacy device spectrum fragmentation (example being 3-4 slot utilization space out on every second carrier, leading to less than 10% spectrum utilization) could lead to no UAS at all being able to use the spectrum, even though the spectrum is almost empty;
- The effects of DECT handover (detecting a bad channel and moving to a good one seamlessly) in fast moving UE, when there is space to handover, is unknown (traditional DECT system are either stationary or slow moving “walking pace”);
- Fragmented spectrum will lead to limited opportunities for handover (moving to less interfered channels);
- Scenarios 10 and 11 show the advantages of using advanced technologies including MIMO, time slot synchronisation and advanced modulation modes of DECT-2020 NR.

ANNEX 5: DECT-2020 NR COEXISTENCE AND RADIO LINK CAPABILITIES

A5.1 DECT-2020 NR AND CLASSICAL DECT COEXISTENCE IN THE 1880-1900 MHZ FREQUENCY BAND

A5.1.1 DECT-2020 NR physical layer technology introduction

DECT-2020 NR applies similar design principles as in classic DECT and DECT ULE (Ultra-low Energy). The smallest radio transmission bandwidth, radio frame and transmission slot lengths are aligned with classic DECT to ensure efficient spectrum use and minimize interference. Especially the inherent feature of automatic interference management allows deployments without extensive frequency planning.

The DECT-2020 NR physical layer employs Cyclic Prefix Orthogonal Frequency Division Multiplexing (CP-OFDM) combined with Time Division Multiple Access (TDMA) and Frequency Division Multiple Access (FDMA) in a Time Division Duplex (TDD) communication manner. The physical layer can support multiple numerologies, with different subcarrier spacings and corresponding Cyclic Prefix lengths and FFT sizes, allowing operation with different channel bandwidths.

The physical layer supports advanced channel coding (Turbo coding) for both control and physical channels and Hybrid ARQ with incremental redundancy, enabling fast re-transmission schemes. Advanced channel coding together with Hybrid ARQ ensures very reliable communication for URLLC use cases. The physical layer supports transmit and receiver diversity and MIMO operations up to 8 streams.

Subcarrier spacing is defined by the subcarrier scaling factor μ , resulting in either 27 kHz, 54 kHz, 108 kHz or 216 kHz OFDM subcarrier spacing. The Fourier transform scaling factor β can be set to allow different transmission bandwidths for each configuration of the subcarrier spacing.

The DECT-2020 NR release 1 standard supports RF bandwidth from 1.728 MHz, 3.456 MHz, 6.912 MHz and in later releases up to 221.184 MHz could be supported.

Supported modulation schemes are BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, and 1024-QAM. The channel coding scheme is Turbo Coding which combines error detection, error correction, rate matching and interleaving. Coding rates are 1/2, 2/3, 3/4, and 5/6 depending on the used modulation scheme. Error detection is supported using 16 or 24-bit CRC.

The data available to the MAC layer increases when the number of subslots is increased. A single slot length of 416.666 μ s is divided to 2, 4, 8 or 16 subslots depending on subcarrier scaling factor μ . A single subslot has always 5 OFDM symbols. The current specification allows up to 16 slots (6.6 ms) for a single transmission.

The radio channel-numbering scheme enables to assign of transmission frequencies from 450 MHz up to 5875 MHz.

The transmitter maximum allowed output power is +23 dBm and it can be adapted to support use cases like battery-powered, lower output power levels for industrial applications, enabling the support for high equipment densities. Standard supports three RD power classes with +23 dBm, 19 dBm and 10 dBm maximum TX powers respectively. Due to transmission power control, single transmission may use as low as -40 dBm Tx power.

The RX to TX transition time is performed within the Guard Interval (GI), enabling a very competitive low latency operation even with hybrid ARQ.

The receiver requirement defines the minimum performance for the radio device with hybrid ARQ support. The reference sensitivity levels for single RX devices scale depending on the operating bandwidths from -99.9 dBm@1.728 MHz, -96.9 dBm@3.456 MHz, and -93.9 dBm@6.912 MHz. With the use of more advanced receiver structures such as RX diversity, the receiver sensitivity can be further improved when needed. The applied design of demodulated reference symbols has been demonstrated to support operation close, a margin of 3dB, to perfect channel knowledge (ETSI Evaluation Group (EG) to the IMT-2020 process). The design supports further beamforming and different TX diversity and MIMO transmissions.

Radio device measurement requirements are defined for channel access purposes and to support radio environment quality reporting for mobility and mesh routing purposes. The requirements are defined keeping in mind the state of art performance, low power consumption and enabling affordable implementations.

DECT-2020 NR (i.e. physical layer numerology and MAC algorithms) is designed to enable coexistence with classic DECT and DECT evolution in current frequency bands allocated to DECT. For coexistence between DECT-2020 NR systems, the standard supports advanced features enabling autonomous, time-accurate interference avoidance schemes between DECT-2020 NR systems and over-the-air synchronisation of different parts of the network.

A5.1.2 Dynamic frequency selection

Extensive coexisting analysis between the DECT-2020 NR and legacy DECT system sharing the 1.9 GHz band have been carried out in ETSI TC DECT. Results are showing that coexisting between legacy and DECT-2020 NR shown a very little interference even with the worst-case assumptions made in these studies. However, if the load is high and all frequency resources are in use, the interference will increase due to lack of the available spectrum. The same applies to UAS operation in case when all frequencies are used locally.

With DECT-2020 NR and legacy DECT, the channel sensing can detect power that is allocated to the 1.728 MHz channel (in DECT-2020 case also wider channels). However, actual procedure how this is done is different between legacy DECT and DECT-2020 NR.

A5.1.2.1 DECT-2020 NR frequency selection

In DECT-2020 NR spectrum access, the first phase is the dynamic channel selection where the Fixed Termination point (FT), which is an access point (or router in mesh case) scans over the available frequencies to see which frequencies have the lowest interference. After frequency scanning, it selects free or the lowest interfered channel(s). The frequency scan procedure is also performing time domain analysis on frequencies and operating frequency selection is prioritising channels, which has the highest amount of subslots with low interference level. If all available frequencies are in use, then the FT selects frequency channel(s) for operation that has the lowest amount of highly interfered subslots.

After selection, the FT initiates its operation by sending broadcast beacon messages in selected frequency and announces the random-access resources (RACH) for the other devices operating in a portable device (PT) role. These random-access resources can be used to establish connection and association to the FT as well as transfer application data between Radio Devices (RD).

Random access transmission always uses a Listen Before Talk (LBT) functionality with exponential back-off (time the transmitter defers transmission). LBT time is minimum of 2 symbols (approx. 40 μ s) prior the random-access transmission for sensing whether the channel is free for use.

Random access can be used for establishing connection as well as sending any application data that is not periodical, or the periodicity is rather long. Few times a second to once per day for example.

For the scheduled services, such as voice or video, transmission is not based on random access and LBT use as the service assumes periodic transmissions with short or relative short, fixed intervals, 2.5 to 10 ms up to 40 to 80 ms for example. In this case, the FT side of the connection assigns dedicated resources (frequency(s) and time slot(s)) which the connection is using in both directions; the amount of resources does not need to be equally sized to UL and DL direction, rather resources can be adjusted independently. A new resource selection and assignment may happen based on FT device monitoring interference and reconfiguring the connection on a need basis. The FT (sink or cluster head) is controlling the resource utilization and concentrates operation to a single frequency channel instead of distributing transmission to the whole available band. In case a FT has multiple RX/TX receiver chains, it may utilize multiple channels.

The type of interference can be anything, which duration occurs into LBT measurement period (40 μ s) and is within the detection range of, -90 to -20 dBm/1.728 MHz.

It should be noted that if all frequencies are interfered, FT device is selecting one frequency to maintain the service.

A5.1.2.2 Legacy DECT channel selection

Legacy DECT channel selection is a bit different as there the PT (portable device) selects the least interfered channel. In this case, the channel means a single time slot (416 us) and a 1.728 MHz carrier frequency combination forming a time and frequency pair. Before initiating the call, the PT side measures all possible timeslot and frequency pairs (24 slot on each 10 frequency channels) and selects timeslot/frequency pair where the interference is the lowest one. Once the call is initiated, the call is maintained on this timeslot/frequency pair resources. If either side of the connection detect interference on used resources, devices may initiate handover to new time/frequency pair resources. The system broadcast (beaconing) works very similar manner. FT side measures frequency and timeslots, selects one timeslot on one frequency channel and start-sending beacon on that resource with 10 ms period.

A5.1.2.3 Dynamic frequency selection considering the adjacent band services RMR or MFCN

MFCN services, which in this case are operating on the 1820-1880 MHz frequencies, are cellular base stations having a high power and almost constant transmission will cause a wideband noise floor due to transmitter nonlinearities to the 1880-1900 MHz band, which will be detected as interference by both the DECT-2020 NR and legacy DECT devices. This interference may block DECT channels in close vicinity of the base station. When the distance to the base station increases, this interference will become less of an issue. See ECC Report 332.

Rules explained in the above chapters will cause the concentration of DECT-2020 NR and DECT traffic to channel(s) which are least interfered by the base station. However, if load is high on DECT band, also interfered channels are selected, especially by the DECT-2020 NR, which is more robust against interference due to channel coding and hybrid ARQ support. In this case, the FT will select lowest interfered channel based on measured power.

RMR in 1900-1910 MHz is causing similar interference as MFCN in terms of wideband interference. However, the difference will be that in this case the interference is time division multiplexed as downlink and uplink transmission are sharing the same channel over 10 ms LTE TDD radio frame time. This interference is detected by the DECT-2020 NR and legacy DECT devices during their frequency-scanning phase. It should be noted that all mobile users operating in the RMR band would also be a potential interferer and this interference is more challenging to mitigate as there may be a higher number of mobile users. The mobile RMR users will not perform any channel sensing in advance.

If MFCN and RMR base stations would be co-located on the same site tower, their combined interference to the 1880-1900 MHz band could cause an effect that DECT operation is concentrating first into middle channels of DECT band.

Both DECT-2020 NR and legacy DECT systems can detect interference from RMR and MFCN systems, causing the use of the DECT spectrum in the middle of the DECT band. RMR mobiles will also cause interference, but the area of interference is smaller due to lower transmission power.

A5.1.3 Out of band emissions from DECT-2020 NR

Tables 5 to 12 provide the out of band emission requirement for DECT-2020 NR operating with 3.456 MHz channel bandwidth, and the conversion of emission levels for 1.728 MHz adjacent channels.

Table 5: 3.456 MHz channel spectrum emission limits

3.456 MHz channel spectrum emission limits			
$\Delta f_{OOB}/\text{MHz}$	Limit(dBm)	Measurement bandwidth	Emission in 1.728 MHz channel
± 0 to 0.2025	-10	30 kHz	
± 0.2025 to 3.2535	-10	1 MHz	-7.6 dBm

3.456 MHz channel spectrum emission limits			
±3.2535 to 3.6585	-13	1 MHz	
±3.6585 to 6.7095	-20	1 MHz	-17.6 dBm
±6.7095 to 6.912	-23	1 MHz	

The coupling loss or attenuation required for -85 dBm “free channel” or legacy or DECT-2020 NR is approx. 77 dB when the UAS would be operating with maximum power level. The reduction of transmission power is improving the transmitter linearity and reducing interference. The out of band emissions with lower transmission levels e.g. at 10 dBm is estimated to be below -30 dBm, which is reducing the coupling loss to approx. 50 dB to the adjacent system. Therefore, it is important to consider using transmitter power control to mitigate interference.

A5.1.3.1 DECT-2020 NR Radio configuration for UAS use

DECT-2020 NR supports advanced receiver technologies from single stream transmission up to 8 multiple input multiple output (MIMO) streams to improve spectrum efficiency. The use of MIMO and transmitter beamforming technologies provide clear benefits for the operation in the field in terms of reliability, bitrate and spectrum efficiency. The UAS service requirements are shown in the table below, which is the basis for the radio configuration analysis done.

Table 6: DECT-2020 NR UAS typical parameter

Description of parameter	Typical value
Data rate video (from UAS to ground station)	Up to 5 Mbps
Data rate UAS control (from ground station to UAS)	Up to 300 kbps
DECT-2020 NR frequency carriers with 3.456 MHz operation	1880-1900 MHz band: 1882.656, 1886.112, 1889.568, 1893.024 and 1896.48 MHz or alternatively 1884.384, 1887.84, 1891.296, 1894.752, 1898.208 MHz 1910-1920 MHz band: 1912.032 and 1915.488 MHz pair or alternatively 1914.624 and 1918.08 MHz
DECT-2020 NR RF power	-40 to 24 dBm

DECT-2020 NR physical layer supports the advanced technologies increasing the spectrum efficiency. For UAS operation, these technologies are significantly improving the efficient spectrum utilization.

A5.1.3.2 Single stream operation reference case

Link conditions "A" using more robust modulation.

Table 7: link "A" conditions

Parameter	Modulation class	# Subslots	transmission time in 10 ms;	bitrate
Control BS -> UE	MCS2 (QPSK 1/2)	5	1.04 ms	388 kbps

Parameter	Modulation class	# Subslots	transmission time in 10 ms;	bitrate
Video UE -> BS	MCS4 (16 QAM 3/4)	36	7.49 ms	5.06 Mbps
Total		41	8.53 ms	

Link conditions "B" using more efficient modulation.

Table 8: link "B" conditions

Parameter	Modulation class	# Subslots	transmission time in 10 ms;	bitrate
Control BS -> UE	MCS3 (QPSK 3/4)	4	0.83 ms	388 kbps
Video UE -> BS	MCS5 (64 QAM 2/3)	27	5.62 ms	5.01 Mbps
Total		31	6.45 ms	

A5.1.3.3 2x2 MIMO stream transmission

Link conditions "A" using more robust modulation.

Table 9: link "A" conditions

Parameter	Modulation class	# Subslots	transmission time in 10 ms;	bitrate
Control BS -> UE	MCS2 (QPSK 1/2)	3	0.62 ms	344 kbps
Video UE -> BS	MCS4 (16 QAM 3/4)	20	4.16 ms	5.19 Mbps
Total		41	4.78 ms	

Link conditions "B" using more efficient modulation.

Table 10: link "B" conditions

Parameter	Modulation class	# Subslots	transmission time in 10 ms;	bitrate
Control BS -> UE	MCS4 (16 QAM 3/4)	2	0,42 ms	402 kbps
Video UE -> BS	MCS5 (64 QAM 2/3)	16	3.33 ms	5.33 Mbps
Total		18	3.75 ms	

With 2x2 MIMO operation, two UAS connections can be time multiplexed on a single 3.456 MHz frequency channel.

A5.1.3.4 4x4 MIMO stream transmission

Link conditions "A" using more robust modulation.

Table 11: link "A" conditions

Parameter	Modulation class	# Subslots	transmission time in 10 ms;	bitrate
Control BS -> UE	MCS2 (QPSK 1/2)	2	0.42 ms	402 kbps
Video UE -> BS	MCS4 (16 QAM 3/4)	10	2.08 ms	5.2 Mbps
Total		12	2.5 ms	

Link conditions "B" using more efficient modulation.

Table 12: link "B" conditions

Parameter	Modulation class	# Subslots	transmission time in 10 ms;	bitrate
Control BS -> UE	MCS2 (QPSK 1/2)	2	0.42 ms	402 kbps
Video UE -> BS	MCS5 (64 QAM 2/3)	8	1.66 ms	5.33 Mbps
Total		18	2.08 ms	

With 4x4 MIMO, four UAS connections can be time multiplexed on a single 3.456 MHz frequency channel. Supporting different MIMO modes for UAS devices is highly beneficial for improving spectrum efficiency.

A time multiplexing single 3.456 MHz channel enables very good interference coordination between different UAS UE as it is locally possible to time synchronize them, even in the case they are not operated by same authority. This is enabled by the physical layer control information signalling, which contains information on next transmit time information.

The time-synchronised operation eliminates UAS-to-UAS interference.

A5.2 SUMMARY

The spectrum access in DECT-2020 NR is designed to support shared spectrum operation. It selects the least interfered frequency for operation based on spectrum scanning and performs listen before talk monitoring for infrequent transmissions on random access channel.

The frequency use behaves differently between legacy DECT and DECT-2020 NR. The DECT-2020 NR spectrum use strategy limits the use of multiple frequencies in the same local area to enable efficient tracking of the connections towards gateway FT and allows the frequency re-use for wider area deployments.

Radio operation is controlled by the radio device operating in FT role, which can be selected based on use case needs. In UAS case, it can be either the UAS or the ground station.

For scheduled services, the FT assigns the resources and the device in PT mode uses them without performing Listen Before Talk before transmission. The FT device may modify connection during active communication.

A DECT-2020 NR device can monitor other systems transmission timing and perform local interference management.

The transmitter output power should be adaptive as it impacts the out of band emissions on adjacent frequencies and hence reduces interference.

It is recommended to use 2x2 MIMO or 4x4 MIMO for physical layer configuration due to higher spectrum efficiency and connection reliability.

With 2x2 MIMO, 2 UAS can time-share the same 3.456 MHz frequency channel. This also removes the UAS-to-UAS interference.

With 4x4 MIMO, one can time multiplex 4 UAS into the same 3.456 MHz frequency channel. This also removes the UAS-to UAS interference.

ANNEX 6: EXTRACT FROM ECC REPORT 332, ANNEX 13

ECC Report 332 contained some conclusions of coexistence of UAS based on DECT 2020 NR (in Annex 13: MCL Study of the possible impact of DECT-2020-Based UAS Deployment in 1880-1900 MHz and 1910-1920 MHz to adjacent services).

See below, an extract of this Annex 13 (in the section A13.3.3 summary / page 224):

“Co-existence between FRMCS in 1900-1910 MHz band UAS using DECT-2020 in 1880-1900 MHz and 1910-1920 MHz shows that the UAS UE (drone) has higher impact on the co-existence as it is more susceptible to interfere (in particular, the FRMCS BS), and more susceptible from interference (in particular, from FRMCS BS).

In urban areas, separation distances between UAS GS and FRMCS BS/UE are always lower than 200 m.

Regarding UAS UE in urban areas, and both UAS GS and UE in rural areas, the following applies:

- On DECT-2020 carriers between 1896.46 MHz and 1914.624 MHz, the interference received by either UAS GS or UAS UE (or both) is high enough that they are unlikely to be selected by DECT-2020 dynamic channel selection (DCS), unless the UAS operates very far away from the railways (up to 10 km).
- Using channels at 1893.024 MHz, 1894.752 MHz, and above 1915.488 MHz (included) leads to a MCL separation distance lower than 3 km to protect the FRMCS BS (it also protects FRMCS UE, and UAS GS/UE).
- Using channels between 1882.656 MHz and 1891.296 MHz (included), separation distance of 500 m protects the FRMCS BS and UE. However, MCL computations in a rural context suggest that a range 5650 m cannot be attained when the UAS GS/UE are 1000 m or closer from an FRMCS BS. A range of 1000 m in rural areas allows for separation distances less than 500 m.”

It should also be noted that the considered scenarios in ECC Report 332, annex 13.3 are different from the updated ones (i.e. 500 m in urban scenario and 3.5 km in rural scenario used in this Report).

ANNEX 7: LIST OF REFERENCES

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- [14] ERC Decision (98)02: “exemption from individual licensing and free circulation and use of DECT equipment”, approved November 1998, latest amended November 2021
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- [16] Commission implementing Decision (EU) 2021/1730 of 28 September 2021 on the harmonised use of the paired frequency bands 874.4-880.0 MHz and 919.4-925.0 MHz and of the unpaired frequency band 1900-1910 MHz for Railway Mobile Radio