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Contents

Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

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Introduction

A study item, “Study on NR-based Access to Unlicensed Spectrum”, was approved at 3GPP TSG RAN #77 [2]. This study is to determine a single global solution for NR-based access to unlicensed spectrum, to be compatible with the NR concepts.

The objectives of the study include:

- - Study NR-based operation in unlicensed spectrum (RAN1, RAN2, RAN4) including
    - Physical channels inheriting the choices of duplex mode, waveform, carrier bandwidth, subcarrier spacing, frame structure, and physical layer design made as part of the NR study and avoiding unnecessary divergence with decisions made in the NR WI
        - Consider unlicensed bands both below and above 6GHz, up to 52.6GHz
        - Consider unlicensed bands above 52.6GHz to the extent that waveform design principles remain unchanged with respect to below 52.6GHz bands
        - Consider similar forward compatibility principles made in the NR WI
    - Initial access, channel access. Scheduling/HARQ, and mobility including connected/inactive/idle mode operation and radio-link monitoring/failure
    - Coexistence methods within NR-based and between NR-based operation in unlicensed and LTE-based LAA and with other incumbent RATs in accordance with regulatory requirements in e.g., 5GHz , 37GHz, 60GHz bands
        - Coexistence methods already defined for 5GHz band in LTE-based LAA context should be assumed as the baseline for 5GHz operation. Enhancements in 5GHz over these methods should not be precluded. NR-based operation in unlicensed spectrum should not impact deployed Wi-Fi services (data, video and voice services) more than an additional Wi-Fi network on the same carrier;

The above study will address the following architectural scenarios (RAN2):

- An NR-based LAA cell(s) connects with an LTE or NR anchor cell operating in licensed spectrum

    - The study assumes the techniques for linking between Pcell (LTE or NR licensed CC) and Scell (NR unlicensed CCs) according to the NR WI

- An NR-based cell operating standalone in unlicensed spectrum, connected to a 5G-CN network with priority on frequency bands above 6GHz, e.g., for private network deployments;

- Study how to ensure from a RAN level that connection and security management can be integrated with the E-UTRAN, NG RAN and 5G CN architecture, including service continuity requirements for users moving between cells of licensed and unlicensed frequency bands, liaising with SA2 as required

The results and findings of the study are documented in this technical report.

1 Scope

The present document contains the results and findings from the study item, “Study on NR-based Access to Unlicensed Spectrum” [2]. The purpose of this TR is to document the identified NR enhancements and corresponding evaluations for a single global solution framework for NR based access to unlicensed spectrum.

This document addresses evaluation methodology and possible scenarios for NR based unlicensed deployments.

This technical report documents the existing regulatory requirements for unlicensed spectrum deployment in the 5GHz bands, [and other bands]

This document identifies and captures coexistence evaluations of physical layer options and enhancements to NR and, if necessary, NR RAN protocols to meet the requirements and targets for unlicensed spectrum deployments.

This document contains an assessment of the feasibility of base station and terminal operation of 5GHz band (based on regulatory limits) in conjunction with relevant licensed frequency bands.

This document is a ‘living’ document, i.e. it is permanently updated and presented to TSG-RAN meetings.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP RP-172021: “Revised SID on NR-based Access to Unlicensed Spectrum”.

[3] FCC Part 15 ruling, http://www.ecfr.gov/cgi-bin/text-idx?SID=3c5e2d1533490603e0131fcdc041030d&node=pt47.1.15&rgn=div5

[4] FCC 13-22, “Notice of proposed rulemaking” , Feb 20, 2013.

[5] ETSI EN 301 893, Harmonized European Standard, “Broadband Radio Access Networks (BRAN); 5 GHz high performance RLAN”

[6] ETSI EN 302 502, Harmonized European Standard, “Broadband Radio Access Networks (BRAN); 5,8 GHz fixed broadband data transmitting systems”

[7] ETSI EN 302 571, Harmonized European Standard, “Intelligent Transport Systems (ITS); Radio communications equipment operating in the 5 855 MHz to 5 925 MHz frequency band”

[8] “Commission decision of 11 July 2005 on the harmonised use of radio spectrum in the 5 GHz frequency band for the implementation of wireless access systems including radio local area networks (WAS/RLANs)” (2005/513/EC).

[9] “Commission decisions of 12 February 2007 amending Decision 2005/513/EC on the harmonised use of radio spectrum in the 5 GHz frequency band for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs)” (2007/90/EC).

[10] ECC/DEC (04)08, “ECC Decision of 09 July 2004 on the harmonised use of the 5 GHz frequency bands for the implementation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs)”

[11] KDB 443 999, FCC Office of Engineering and Technology – Laboratory Division: “Interim Plans to Approve UNII Devices Operating in the 5470-5725 MHz Band with Radar Detection and DFS Capabilities” (14th October 2010).

[12] FCC 12-148, “Notice of Proposed Rulemaking and Order: amendment of the Commission’s Rules with regard to Commercial Operations in the 3550-3650 MHz Band” (GN Docket No. 12-354), adopted and released December 12, 2012.

[13] FCC 13-154, “Public Notice. Commission Seeks Comment on Licensing Models and Technical Requirements in the 3550-3650 MHz Band”, released November 1, 2013

[14] ECC Recommendation ECC/REC (06)04: “Use of the band 5725- 5875 MHz for Broadband Fixed Wireless Access (BFWA)”

[15] Commission Decision 2008/671/EC of 5th August2008 on the harmonised use of radio spectrum in the 5875-5905 MHz frequency band for safety related application of Intelligent Transport Systems (IOTS)

[16] ECC Decision (08)01: "ECC Decision of 14 March 2008 on the harmonized use of the 5875-5925 frequency band for Intelligent Transport Systems (ITS)”

[17] ECC Recommendation (08)01:"Use of band 5855-5875 MHz for Intelligent Transport Systems (ITS)".

[18] ETSI EN 300 440-1 v1.6.1: “Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 1: Technical characteristics and test methods”

[19] Document RSCOM 13-32rev3: “Mandate to CEPT to study and identify harmonised compatibility and sharing conditions for Wireless Access Systems including Radio Local Area Networks in the bands 5350-5470 MHz and 5725-5925 MHz ('WAS/RLAN extension bands') for the provision of wireless broadband services”

[20] Group of Administrative Co-operation Under the R&TTE Directive (ADCO R&TTE): Report on the 5th joint cross-border R&TTE Market Surveillance Campaign on WLAN 5 GHz (2013)

[21] RSS-210 Issue 8 (December 2010): Licence-exempt Radio Apparatus (All Frequency Bands): Category I Equipment

[22] National Frequency Allocation Plan 2011 (In-Force): http://www.wpc.gov.in/WriteReadData/userfiles/file/National_Frequency_Allocation_Plan-2011.pdf

[23] http://legislacao.anatel.gov.br/resolucoes/2008/104-resolucao-506 , Resolução nº 506, de 1º de julho de 2008, Regulamento sobre Equipamentos de Radiocomunicação de Radiação Restrita.

[24] 3GPP TR 36.872: “Small cell enhancements for E-UTRA and E-UTRAN - Physical layer aspects”.

[25] **Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, IEEE Std 802.11-2012.**

[26] **https://mentor.ieee.org/802.11/dcn/14/11-14-0571-08-00ax-evaluation-methodology.docx**

[27] **3GPP TR 36.942 V11.0.0, “Radio Frequency (RF) system scenarios,” Sept. 2012.**

[28] 3GPP TR 38.802, "Study on new radio access technology Physical layer aspects"

[29] 3GPP TS 38.901, "Study on channel model for frequencies from 0.5 to 100 GHz"

[30]

[31]

[32]

[33]

[34]

[35] GSR No. 46(E) Dated: 28th Jan. 2005, Rule - Indoor Use of low power wireless equipment in the frequency band 5 GHz (Exemption from Licensing Requirement) Rules, 2005.

[36] GSR No. 37(E) Dated: 10th Jan. 2007, Rule - Indoor use of low power wireless equipment in the frequency band 5 GHz (Exemption from Licensing Requirement) Amendment Rules, 2006. (GSR No. 46(E) Ammendment).

[37] GSR No. 38(E) Dated: 19th Jan. 2007, Rule - the Outdoor Use of wireless Equipment (Exemption from Licensing Requirement) Rules, 2007.[38] RESOLUTION 229 (Rev. WRC-12), "Use of the bands 5 150-5 250, 5 250-5 350 MHz and 5 470-5 725 MHz by the mobile service for the implementation of wireless access systems including radio local area networks".

[39] Recommendation ITU-R M.1652-1 (05/2011) "Dynamic frequency selection in wireless access systems including radio local area networks for the purpose of protecting the radiodetermination service in the 5 GHz band".

[40] http://www.ncc.gov.tw/chinese/law_detail.aspx?site_content_sn=260&is_history=0&law_sn=1807&sn_f=1807, the regulations for low-power transmitters in Taiwan, June 28, 2011 (in Chinese).

[41] http://www.motc.gov.tw/post/home.jsp?id=369&parentpath=0,364, the frequency allocation in Taiwan (in Chinese)

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

3.2 Symbols

For the purposes of the present document, the following symbols apply:

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

4 Regulatory requirements

4.1 Regulatory requirements for 5GHz band

The range 5150-5925 MHz, or parts thereof, is potentially available for license-assisted access to unlicensed operation. This represents a significant amount of spectrum that can be used by operators to augment their service offerings in licensed bands. The range above can be operated under a license-exempt regime or ISM but must be shared with existing mobile services and other incumbent services. The quality of service offered by a licensed regime can therefore

not be matched. Hence, unlicensed access is viewed as complementary, and does not reduce the need for additional allocations for licensed operation in view of the increased demand for wireless broadband access.

It is relevant to consider the global (International) ITU-R allocations and technical provisions first. These could be basis for defining globally harmonised bands for LAA and starting points for requirements and limits before the local variations are considered.

5150-5350 and 5470-5725 MHz

WRC 2003 allocated the bands 5 150-5 350 MHz and 5 470-5 725 MHz on a co-primary basis to the mobile service for the implementation of "wireless access systems (WAS), including radio local area networks (RLANs)". This was subject to technical and regulatory provisions included in the radio regulations given in Resolution 229 (WRC-03), which was subsequently revised at WRC-12 to Resolution 229 (Rev. WRC-12) [38]. These provisions are followed by many Administrations and resolves:

1) that the use of these bands by the mobile service will be for the implementation of WAS, including RLANs, as described in the most recent version of Recommendation ITU-R M.1450;

2) that in the band 5 150-5 250 MHz, stations in the mobile service shall be restricted to indoor use with a maximum mean e.i.r.p. of 200 mW and a maximum mean e.i.r.p. density of 10 mW/MHz in any 1 MHz band or equivalently 0.25 mW/25 kHz in any 25 kHz band;

3) that administrations may monitor whether the aggregate pfd levels given in Recommendation ITU-R S.1426 have been, or will be exceeded in the future, in order to enable a future competent conference to take appropriate action;

4) that in the band 5 250-5 350 MHz, stations in the mobile service shall be limited to a maximum mean e.i.r.p. of 200 mW and a maximum mean e.i.r.p. density of 10 mW/MHz in any 1 MHz band. Administrations are requested to take appropriate measures that will result in the predominant number of stations in the mobile service being operated in an indoor environment. Furthermore, stations in the mobile service that are permitted to be used either indoors or outdoors may operate up to a maximum mean e.i.r.p. of 1 W and a maximum mean e.i.r.p. density of 50 mW/MHz in any 1 MHz band, and, when operating above a mean e.i.r.p. of 200 mW, these stations shall comply with the following e.i.r.p. elevation angle mask where θ is the angle above the local horizontal plane (of the Earth):

–13	dB(W/MHz)	for	$0^\circ \leq \theta < 8^\circ$
$-13 - 0.716(\theta-8)$	dB(W/MHz)	for	$8^\circ \leq \theta < 40^\circ$
$-35.9 - 1.22(\theta-40)$	dB(W/MHz)	for	$40^\circ \leq \theta \leq 45^\circ$
–42	dB(W/MHz)	for	$45^\circ < \theta$;

5) that administrations may exercise some flexibility in adopting other mitigation techniques, provided that they develop national regulations to meet their obligations to achieve an equivalent level of protection to the EESS (active) and the SRS (active) based on their system characteristics and interference criteria as stated in Recommendation ITU-R RS.1632;

6) that in the band 5 470-5 725 MHz, stations in the mobile service shall be restricted to a maximum transmitter power of 250 mW^3 (administrations with existing regulations prior to WRC 03 may exercise some flexibility in determining transmitter power limits) with a maximum mean e.i.r.p. of 1 W and a maximum mean e.i.r.p. density of 50 mW/MHz in any 1 MHz band;

7) that in the bands 5 250-5 350 MHz and 5 470-5 725 MHz, systems in the mobile service shall either employ transmitter power control to provide, on average, a mitigation factor of at least 3 dB on the maximum average output power of the systems, or, if transmitter power control is not in use, then the maximum mean e.i.r.p. shall be reduced by 3 dB;

8) that, in the bands 5 250-5 350 MHz and 5 470-5 725 MHz, the mitigation measures found in Annex 1 to Recommendation ITU-R M.1652-1 shall be implemented by systems in the mobile service to ensure compatible operation with radiodetermination systems,

This resolution makes DFS as described in the Annex 1 of ITU-R Recommendation M.1652-1 [39] mandatory, the basis for the DFS requirements developed e.g. in Europe and the US.

WAS is defined as end-user radio connections to public or private core networks, while primary allocation means that the services can claim protection from services of the secondary service. However, the WAS/RLAN services must protect the incumbent primary services.

Even if primary in the International table of allocations, this may not be the case in all countries. The bands are not allocated on a primary basis in the US allocation table, but to the Part 15 rules that provide for operation of low power radio transmitters without a license (secondary service operated on a non-interference basis).

5725-5850 MHz

The 5725-5875 MHz is allocated for ISM applications by means a footnote in the allocation table. Radiolocation is allocated on primary basis up to 5850 MHz so DFS is required up to this limit. Operation in 5725-5850 MHz is allowed in the US under the Part 15 rules (15.247 and 15.407).

5850-5925 MHz

The band is allocated to the mobile service on a primary basis in all regions. In Europe it has been decided (2008) to harmonise the use of the 5875-5925 MHz frequency band for Intelligent Transport Systems (ITS). Similarly, according to the US allocation table, the use of the non-Federal mobile service in the band 5850-5925 MHz is limited to Dedicated Short Range Communications operating in the Intelligent Transportation System radio service.

4.1.1 ITU Region 1

4.1.1.1 Europe

The European regulation is determined by the European Commission and the ECC. The relevant regulations for the 5 GHz bands are found in two Commission Decisions [8, 9] and one ECC Decision [10]. These are interpreted by ETSI and used as a basis for harmonized standards, which are used for conformance declaration when products are placed on the European market. Harmonized European standards have a higher regulatory relevance than other product standards, since they are produced based on a mandate from the Commission with reference to an EU directive. They also go through a public enquiry and voting process, and are cited by the Commission. The European requirements on 5 GHz unlicensed deployment are specified in three ETSI harmonized standards [5, 6, and 7]. Figure 4.1.1.1-1 summarizes the relevant parts of the 5 GHz band set aside for unlicensed spectrum usage. The 5150-5350 MHz and the 5470-5725 MHz bands are referred here as the broadband radio access networks (BRAN) bands where the wireless access systems (WAS) including RLAN equipment are operating in. Moreover, the 5725-5875 MHz band (in the BRAN domain) is used by the fixed wireless access (FWA) networks and finally the intelligent transport systems (ITS) utilize the 5855-5925 MHz band.

The BFWA and the ITS are designated by the ECC for use as parts of the 5 GHz band and the relevant regulations are found in:

- An ECC Recommendation for FBWA [14], and
- A Commission Decision [15], an ECC Decision [16] and an ECC Recommendation for ITS [17].

General purpose SRD devices can also operate in the band 5725-5875 MHz under the provisions of the ETSI harmonised standard EN 300 440 [18], but with reduced max EIRP of 25 mW.

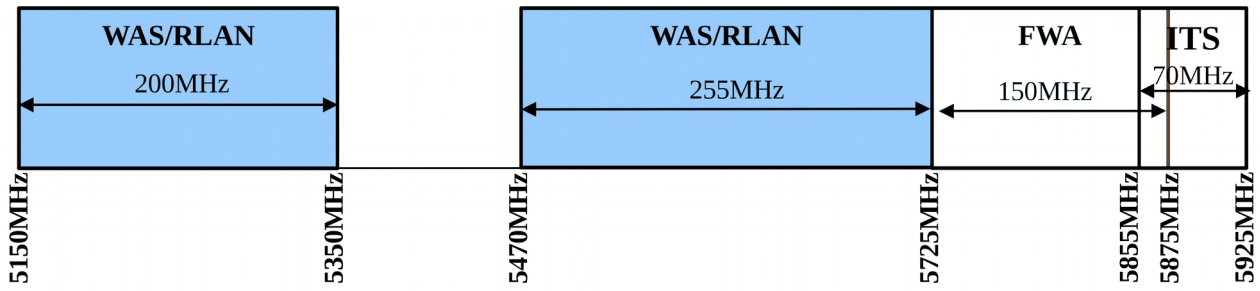


Figure 4.1.1.1-1: 5 GHz spectrum allocations in Europe.

The European Commission has recently submitted to CEPT a mandate to study the conditions for the extension of the 5 GHz range designated for WAS/RLANs [19] in order to allow the use by WAS/RLANs of the whole 5150-5925 MHz band.

ECC approved CEPT Report 57 in March 2015 in response to the mandate based on the results of the Public Consultation. CEPT has carried out a significant amount of work but studies on mitigation techniques have not been completed in the timeframe and there are still a number of open issues ongoing.

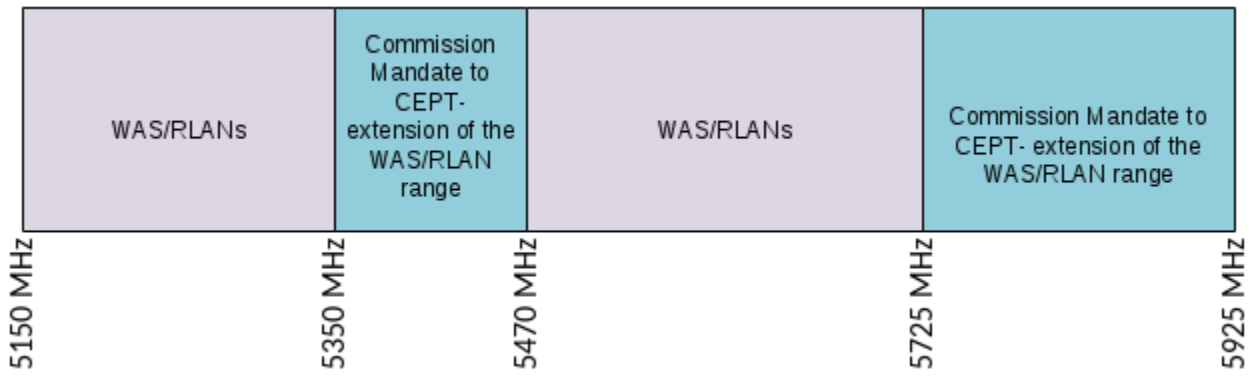


Figure 4.1.1.1-2: Summary of existing and proposed EU regulations for WAS/RLANs in the 5GHz band

In the rest of this section, the specified ETSI requirements for the WAS/RLAN and FWA bands are summarized. Table 4.1.1.1-1 provides the limits on the transmit power control (TPC), the RF output power and power density given by the mean EIRP and the mean EIRP density at the highest power level. Additionally the requirements on the transmitter out of band emissions are listed in Table 4.1.1.1-2, Figures 4.1.1.1-3a, and Figure 4.1.1.1-3b. Table 4.1.1.1-4 illustrates the DFS requirements for some of these bands in Europe. Moreover, the 5150-5350 MHz is restricted to indoor deployments.

Transmit Power Control (TPC) is a mechanism to be used by the RLAN device to ensure a mitigation factor of at least 3 dB on the aggregate power from a large number of devices. This requires the RLAN device with TPC to have a TPC range for which the lowest value is at least 6 dB below the values for mean EIRP given in Table 4.1.1.1-1.

In ETSI EN 301 893 [5], the requirements on the Nominal Channel Bandwidth and the Occupied Channel Bandwidth are defined for unlicensed spectrum in the 5 GHz region. The Nominal Channel Bandwidth, i.e., the widest band of frequencies inclusive of guard bands assigned to a single channel, shall be at least 5MHz at all times. The Occupied Channel Bandwidth, i.e., the bandwidth containing 99 % of the power of the signal, shall be between 80 % and 100 % of the declared Nominal Channel Bandwidth. During an established communication, a device is allowed to operate temporarily in a mode where its Occupied Channel Bandwidth may be reduced to as low as 40 % of its Nominal

Channel Bandwidth with a minimum of 4 MHz. The Occupied Channel Bandwidth is determined by the test procedure defined in Section 5.3.3.2 in [5].

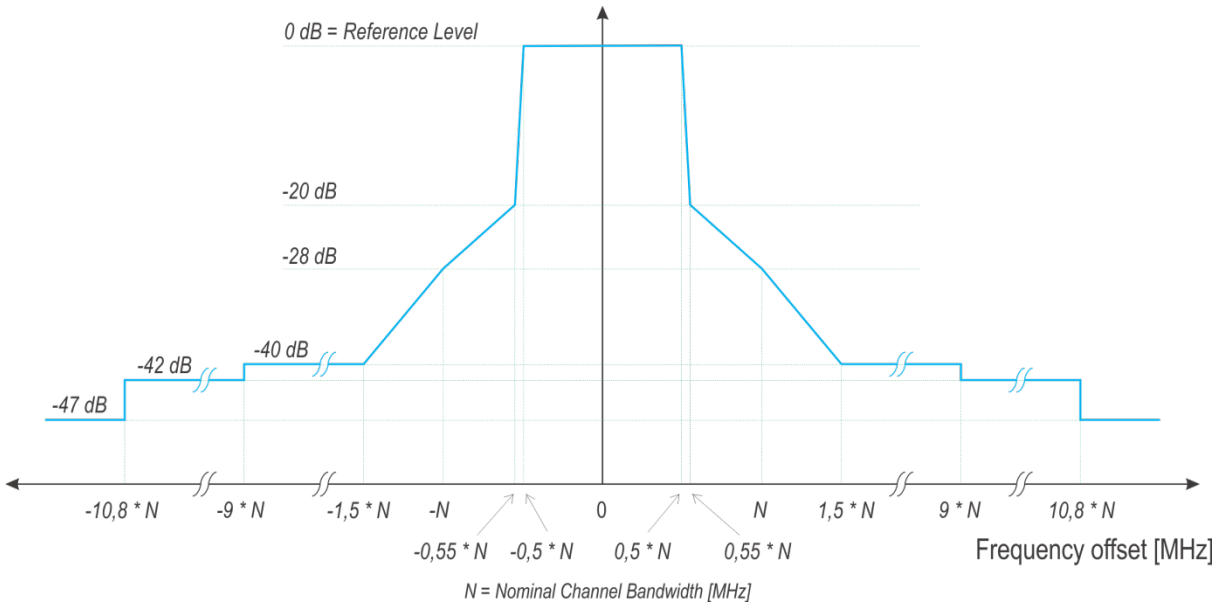
ETSI mandates the usage of DFS in some bands as shown in Table 4.1.1.1-4. Furthermore, a Listen-Before-Talk (LBT) mechanism is requested independently of whether the channel is occupied or not, the LBT parameters being given in Table 4.1.1.1-5a and 4.1.1-5b. Both the requirements on frame-based equipment and the requirements on load-based equipment are summarized in Table 4.1.1.1-5a and 4.1.1.1-5b, respectively. Note that no LBT requirement is requested in [6] for the FWA band.

Table 4.1.1.1-1: TPC, Transmit power and power spectral density requirements in Europe

	Freq. range (MHz)	Max Mean EIRP (dBm)	Max Mean EIRP density (dBm/MHz)	Comment
WAS/RLAN	5150-5350	23	10	20 MHz and 40 MHz channels
	5470-5725	30	17	
FWA	5725-5875	33	23	10 MHz channels
	5725-5875	36	23	20 MHz channels
Transmit Power Control (TPC): TPC ensures an average reduction in the aggregated transmission power by at least 3 dB (5 dB for FWA) compared with the maximum permitted transmission power. TCP is not required for channels within the band 5150-5250 MHz. Without TPC, the highest permissible average EIRP (density) are reduced by 3 dB.				

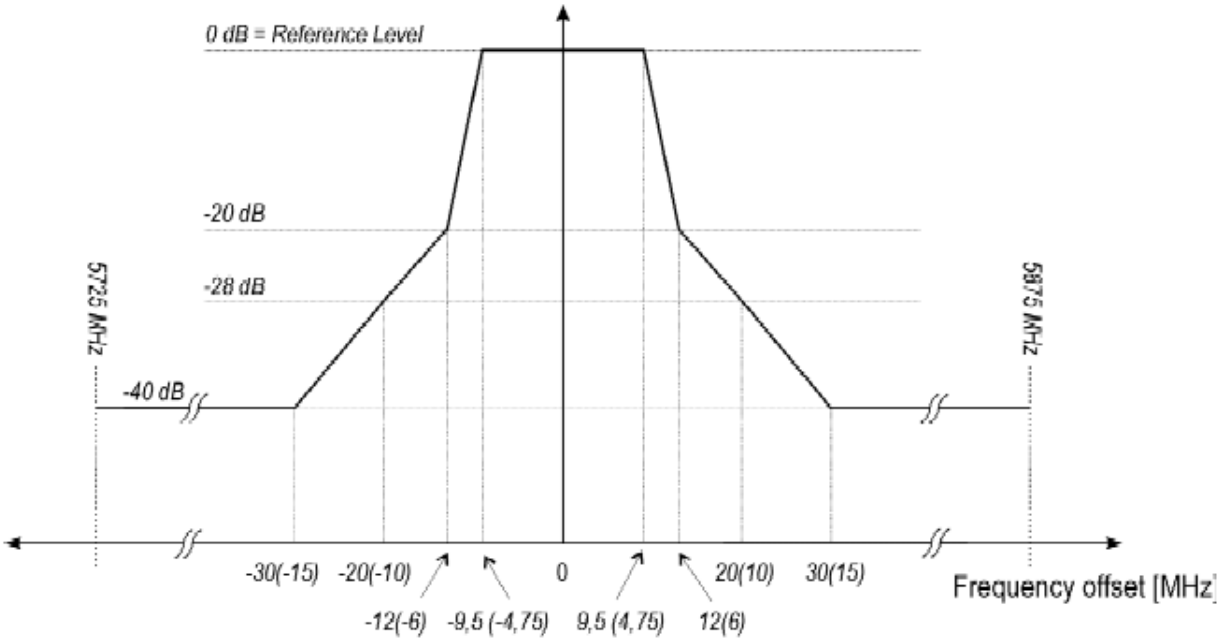
Table 4.1.1.1- 2: Requirements on out of band emissions in Europe

	Frequency range	Max. power	Bandwidth
WAS/RLAN, FWA	30-47 MHz	-36 dBm	100 kHz
	47-74 MHz	-54 dBm	100 kHz
	75-87.5 MHz	-36 dBm	100 kHz
	87.5-118 MHz	-54 dBm	100 kHz
	118-174 MHz	-36 dBm	100 kHz
	174-230 MHz	-54 dBm	100 kHz
	230-470 MHz	-36 dBm	100 kHz
	470-862 MHz	-54 dBm	100 kHz
	0.862-1 GHz	-36 dBm	100 kHz
	1-5.15 GHz	-30 dBm	1 MHz
	5.35-5.5.47 GHz	-30 dBm	1 MHz
	5.725-26 GHz	-30 dBm	1 MHz



NOTE: dBc is the spectral density relative to the maximum spectral power density of the transmitted signal.

Figure 4.1.1.1-3a: Transmit spectral power mask for RLAN equipment operating within the frequency bands 5150-5250 MHz; 5250-5350 MHz or 5470-5725 MHz



NOTE1: 0 dB Reference Level is the spectral density relative to the maximum spectral power density of the transmitted signal.

NOTE2: On the Frequency Offset axis, the figures apply to ChS = 20 MHz whereas the figures in parentheses apply to ChS = 10 MHz.

NOTE3: Emissions that fall outside the lower and upper band frequency limits of 5 725 MHz and 5 875 MHz, respectively shall instead meet the unwanted emission limits of clause 4.3.1 [6].

Figure 4.1.1.1-3b: Transmit spectral power mask for FBWA equipment operating within the frequency band 5725-5875 MHz

FWA devices in the 5.8 GHz range are also subject to an additional requirement of EIRP spectral density limit in the elevation plane, see Table 5.

Table 4.1.1.1-3: EIRP spectral density limits in the elevation plane (5.8 GHz frequency range)

EIRP spectral density	Elevation angle
For sectorised (e.g. P-MP Central or Base Station) and Omni-directional deployments:	
−7 dB(W/MHz)	0° ≤ θ <4°
−2.2 - (1.2*θ) dB(W/MHz)	4° ≤ θ ≤ 15°
−18.4 - (0.15*θ) dB(W/MHz)	θ > 15°
For P-MP Customer Terminal Station and P-P deployments:	
−7 dB(W/MHz)	for 0° ≤ θ <8°
−2.68 -(0.54*θ) dB(W/MHz)	8° ≤ θ < 32°
−20 dB(W/MHz)	32° ≤ θ ≤50°
−10 - (0.2*θ) dB(W/MHz)	θ > 50°

Table 4.1.1.1-4: DFS requirements in Europe

Parameter	Requirement	Comments
DFS Threshold (dBm) for WAS/RLAN	-62(dBm) + 10(dBm/MHz) - EIRP Spectral density (dBm/MHz) + G(dBi)	*No DFS requirements on 5150 MHz – 5250 MHz *G denotes antenna gain
DFS Threshold (dBm) for FWA	-69 (dBm) + 23(dBm/MHz) - EIRP Spectral density (dBm/MHz) + G(dBi)	*No DFS requirements on 5850 MHz – 5875 MHz *G denotes antenna gain
Channel Availability check	60 seconds outside 5600-5650 MHz 10 minutes inside 5600-5650 MHz	Master mode
Channel move time	10 seconds	Master and slave modes
Non-occupancy time	30 minutes	After radar detection in either channel availability check or in-service monitoring
Uniform Spreading is required across the frequency ranges 5150 -5350 MHz and 5470-5725 MHz. *Uniform Spreading* is not applicable for equipment that only operates in 5150-5250 MHz band.		

Table 4.1.1.1-5a: LBT requirements for Frame-Based-Equipment in Europe

Parameter	Requirement	Comment
Clear Channel Assessment (CCA) time	Minimum 20μs	
Channel Occupancy time	Minimum 1 ms, maximum10 ms	
Idle period	Minimum 5% of channel occupancy time	
Fixed frame period	Equals to Channel Occupancy time + Idle Period	
Short control signaling transmission time	Maximum duty cycle of 5% within an observation period of 50ms	Part of Channel occupancy time
CCA Energy detection threshold	Assuming receive antenna gain G=0dBi: If EIRP=23dBm at transmitter Threshold ≤ -73 dBm/MHz Otherwise (different transmit power levels, PH) Threshold = -73(dBm/MHz) + 23(dBm) – PH(dBm)	For WAS/RLAN

Table 4.1.1.1-5b: LBT requirements for Load-Based-Equipment in Europe

Parameter	Requirement	Comment
Clear Channel Assessment (CCA) time	Minimum 20μs	Also referred to as CCA time slot
N (number of clear idle slots) in extended CCA	N shall be randomly selected in the range 1..q every time, q=4…32	
Channel Occupancy time	<= (13/32) × q ms	
Idle period	At least the duration of a random factor N multiplied by the CCA time slot.	
Short control signaling transmission time	Maximum duty cycle of 5% within an observation period of 50ms	Part of Channel occupancy time
CCA Energy detection threshold	Assuming receive antenna gain G=0dBi: If EIRP=23dBm at transmitter Threshold ≤ -73 dBm/MHz Otherwise (different transmit power levels, PH) Threshold = -73(dBm/MHz) + 23(dBm) – PH(dBm)	For WAS/RLAN

Interference to Weather Radars

Interference to Weather Radars is also a hot topic in the EU. The two last versions of EN 301 893 (1.6.1 and 1.7.1) have included amendments to better protect these radars, like the prohibition to give the user access to the configuration control settings that would allow him to disconnect the DFS functionality.

The use of the band 5.60-5.65 GHz by WLANs is allowed in Europe, and a Market Surveillance campaign on WLANs 5 GHz has been led at EU level by the ADCO R&TTE Group. The report [20] of the campaign has proposed specific recommendations to improve the situation. These recommendations do not require amendments to the last version of EN 301 893.

4.1.1.2 Israel

In Israel the bands 5150-5250 MHz and 5250-5350 MHz are open to RLANs.

4.1.1.3 Russia

In the Russian Federation the bands 5150-5350 MHz, the band 5470-5725 MHz above 5650 MHz and the band 5725-5825 MHz [20] are allowed to RLANs. Use of DFS is not mandated.

4.1.1.4 South Africa

In South Africa the bands 5150-5250 MHz and 5250-5350 MHz are available to RLANs but restricted to indoor use. The band 5470-5725 MHz is also open to RLANs.

4.1.1.5 Turkey

In Turkey the bands 5150-5250 MHz and 5250-5350 MHz are restricted to indoor use. DFS and TPC are mandated in the band 5470-5725 MHz.

4.1.2 ITU Region 2

4.1.2.1 USA

The use of unlicensed 5 GHz spectrum in USA is governed by FCC part 15 regulations [3]. In Feb 2013, potential new rules were proposed in FCC 13-22 [4]. Figure 4.1.2.1-1 summarizes the relevant part 15 rules for 5GHz unlicensed spectrum usage:

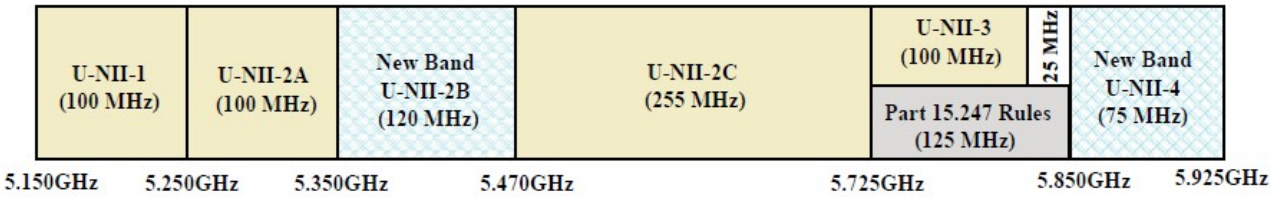


Figure 4.1.2.1-1 : Summary of existing and proposed new FCC part 15 rules for 5GHz unlicensed spectrum usage

In Figure 4.1.2.1-1, U-NII-x bands denote frequency bands for Unlicensed National Information Infrastructure devices usage that are governed by §15.407 [3]. As shown in the figure, there is also an overlapping ruling of §15.247 from 5.725 to 5.85 GHz. A device could choose to follow either U-NII rulings or §15.247 rulings when operating within the frequency range.

In the rest of this section, we summarize FCC paragraphs 15.407 and 15.247 rules. In general either frequency hopping or digital modulation techniques are permitted under part 15 rules. Since LTE is not designed as a frequency hopping system, the rest of the document will focus on regulations related to digital modulation.

Paragraph 15.247 rules relevant for LTE point to multi-point communications are summarized in 4 aspects:

- Transmission Bandwidth:
  - The minimum 6 dB bandwidth shall be at least 500 kHz.
- Maximum Transmit Power:
  - Peak conducted output power shall not exceed 1 W. An alternative to peak power measurements is maximum conducted output power, which is the total transmit power over all antennas and antenna elements when the transmitter is operating at its maximum power control level.
  - Note that, the conducted output power limit is based on the use of antennas with directional gains that do not exceed 6 dBi. If transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi.
- Out of Band Emission:
  - In any 100 kHz bandwidth outside the frequency band, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.
- Power Spectrum Density:
  - The power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. The same method of determining the conducted output power shall be used to determine the power spectral density.

Paragraph15.407 rules for UNII devices are summarized in following tables. In Table 4.1.2.1-1, the maximum transmit power, PSD and out of band emission requirements are listed for UNII-1/2/3 bands. In Table 4.1.2.1-2, the dynamic frequency selection requirements for radar detection are summarized for UNII-2 devices.

Table 4.1.2.1-1: Transmit power requirements for UNII devices

		UNII-1	UNII-2A	UNII-2C	UNII-3	Comments
Frequency Range (GHz)		5.15 – 5.25	5.25-5.35	5.47-5.725	5.725-5.85	
Max conducted output power < min(a, b) (dBm)	a	eNB: 30 UE: 24	24	24	30	
	b		11+10logB	11+10logB		B is the 26-dB emission bandwidth in MHz
Peak PSD (dBm/MHz)		eNB: 17 UE: 11	11	11	30dBm in 500kHz	
Assumed Antenna Gain (dBi)		6	6	6	6*	Peak power is reduced by G-6 dB for directional antennas with gain > 6 dBi; * UNII-3 fixed point to point operation power scaling threshold is 23 dBi
Out of band emission	Frequency Support (GHz)	Outside 5.15 – 5.35	Outside 5.15 – 5.35	Outside 5.47-5.725	Outside 5.715-5.865	
	EIRP (dBm/MHz)	-27	-27	-27	-27	Resolution bandwidth 1 MHz
	Frequency Support (GHz)				5.715-5.725 5.85-5.86	
	EIRP (dBm/MHz)				-17	Resolution bandwidth 1 MHz
Transmit Power Control		N/A	TPC to 6 dB below a mean EIRP of 30 dBm. No TPC for mean EIRP < 27 dBm		N/A	

Table 4.1.2.1-2: DFS requirements for UNII-2 devices

	Levels	Comments
Max EIRP (dBm)	23 to 30	* DFS power is averaged in 1 micro-second for 0 dBi antenna. * Uniform spread over available channels.
DFS Threshold (dBm)	-64	
Max EIRP (dBm)	<23	
DFS Threshold (dBm)	-62	
Channel Availability check	60 seconds	Master mode
Channel move time	10 seconds	Master and slave modes
	200 ms normal operation	
Non-occupancy time	30 minutes	After radar detection in either channel availability check or in-service monitoring

Interference to Weather Radars

In order to resolve interference to Terminal Doppler Weather Radar (TDWR) the FCC has defined interim plans to approve UNII devices operating in the 5470-5725 MHz band [11]. These interim plans provide specific actions for equipment authorization and installation, as detailed below. The main elements in the interim plan are:

- Master devices shall not transmit on channels overlapping with the range 5600-5650 MHz band used by TDWRs;
- Professional installation of equipment operating within the band 5470-5720 MHz;

- Prohibition to include configuration controls (like country code settings) that would allow to change the frequency of operations to any frequency other than those specified on the grant of certification for US operation.

In parallel FCC is continuing its work to develop long-term equipment authorization test procedures that will ensure that the devices comply with the rules that protect the TDWR operations.

4.1.2.2 Canada

In Canada, the use of RLANs is forbidden in the band 5600-5650 MHz in order to protect the meteorological radars from interference caused by RLANs. The regulations for RLANs in the 5 GHz range in Canada are defined in RSS-210 Annex 9 [21]. Table 4.1.2.2-1 presents the transmit power requirements for RLAN devices while Table 4.1.2.2-1 provides the EIRP spectral density limits in the elevation plane required from RLAN devices operating with an EIRP level higher than 200 mW in the frequency range 5250-5350 MHz.

Table 4.1.2.2-1: Transmit power requirements for RLAN devices in Canada

Frequency Range (GHz)		5.15 – 5.25	5.25-5.35	5.47-5.60 and 5.65-5.725	5.725-5.825	
Max conducted output power < min(a, b) (dBm)	a		24	24	30	
	b		11+10logB	11+10logB	17+10logB	B is the 26-dB emission bandwidth in MHz
Peak PSD (dBm/MHz)		4	11	11	17	Resolution bandwidth 1 MHz
Max e.i.r.p. < min(a, b) (dBm)	a	23	30	30	36	
	b	10+10logB	17+10logB	17+10logB	23+10logB	
Max e.i.r.p density (dBm/MHz)		10				Resolution bandwidth 1 MHz
Out of band emission	Frequency Support (GHz)	Outside 5.15 – 5.25	Outside 5.25 – 5.35	Outside 5.47-5.725	Outside 5.725-5.825	
	EIRP (dBm/MHz)	-27	-27	-27	-17 within 5.715-5.725 and 5.825-5.835; -27 outside	Resolution bandwidth 1 MHz
Transmit Power Control		N/A	TPC to 6 dB below a mean EIRP of 30 dBm. No TPC for mean EIRP < 27 dBm			
DFS		N/A	Required			
e.i.r.p. elevation mask		N/A	If e.i.r.p. > 23 dBm compliance with e.i.r.p. elevation mask required	N/A	N/A	

Table 4.1.2.2-1: EIRP spectral density limits in the elevation plane for devices with EIRP > 200 mW (5.25-5.35 GHz frequency range)

EIRP spectral density	Elevation angle
−13 dB(W/MHz)	0° ≤ θ <8°
–13 – 0.716(θ-8) dB(W/MHz)	8° ≤ θ < 40°
–35.9 – 1.22(θ-40) dB(W/MHz)	40° ≤ θ < 45°
–42 dB(W/MHz)	44° ≤ θ

4.1.2.3 Brazil

In Brazil, nearly all the 5 GHz spectrum is allocated for Restricted Radiation, which means low-power unlicensed bands (i.e. any low-power-device can use it on a secondary basis). The bands 5250-5350 MHz, 5470-5650 MHz, 5650-5725 MHz and 5725-5850 MHz are allowed to RLANs [22]. Bands 5150-5250 MHz and 5250-5350 MHz are restricted to indoor use, and DFS is mandated in the bands 5250-5350 MHz and 5470-5725 MHz.

The relevant restrictions by band are as follows [23]:

From (MHz)	To (MHz)	Service	Restriction [insert reference]
5150	5350	Restricted radiation	Indoor use only, EIRP limited to 200mW, EIRP spectral power density limited to 10mW/MHz. DFS mandated between 5250-5350MHz.
5350	5470	Unregulated	
5470	5650	Restricted radiation	DFS mandated. Max transmitter output power limited to 250mW, EIRP limited to 1W, EIRP spectral power density limited to 50mW/MHz
5650	5725	Restricted radiation or amateur radio	DFS mandated. Max transmitter output power limited to 250mW, EIRP limited to 1W, EIRP spectral power density limited to 50mW/MHz
5725	5875	Restricted radiation (ISM Band)	Max transmitter output power limited to 1W, max EIRP EMF density of 50,000 microvolt per meter (measured at 3 meter distance)

NOTE: Note that the 5350-5470MHz band is not regulated.

4.1.2.4 Mexico

In Mexico, the bands 5150-5250 MHz, 5250-5350 MHz, 5470-5600 MHz, 5650-5725 MHz and 5725-5875 MHz are open to RLANs [22].

4.1.3 ITU Region 3

4.1.3.1 China

The 5150-5350 MHz frequency band is open to unlicensed WAS/RLANs indoor deployment in China. Furthermore, mandatory DFS / TPC (no less than 6 dB) or DFS only with a 3 dB backoff of the max mean EIRP, Power spectrum density and max emission is required for 5250-5350 MHz.

The key regulatory restrictions include:

- EIRP: ≤200mW

- Power Spectrum Density: ≤10dBm/MHz (EIPR)
- Max Emission at edges of the used frequency: ≤-80dBm/Hz (EIRP)
- Spurious Emission (corresponding to frequency range outside 2.5*carrier bandwidth)
  - 30-1000MHz: -36dBm/100kHz
  - 48.5-72.5MHz, 76-118MHz, 167-223MHz, 470-798MHz: -54dBm/100kHz
  - 2400-2483.5MHz: -40dBm/1MHz
  - 5150-5350MHz: -33dBm/100kHz
  - 5470-5850MHz: -40dBm/1MHz
  - Other frequency in 1-40GHz: -30dBm/1MHz

The 5725-5850 MHz frequency band was assigned as light licensed in 2009, shared among operators and traffic control bureau, open for both WAS (wireless access system) and RLAN, for both indoor and outdoor deployment in China. The key regulatory restrictions as below:

- Transmit Power: ≤500mW and ≤27dBm;
- EIRP: ≤2W and ≤33dBm
- Power Spectrum Density: ≤13dBm/MHz and ≤19dBm/MHz(EIRP)
- Out of Band Emission: ≤-80dBm/Hz(≤5725MHz and ≥5850MHz)
- Spurious emission
  - 30-1000MHz: ≤-36dBm/100kHz
  - 2400-2483.5MHz: ≤-40dBm/1MHz
  - 3400-3530MHz: ≤-40dBm/1MHz
  - 5725-5850MHz: ≤-33dBm/100kHz
  - corresponding to frequency range outside 2.5*carrier bandwidth
  - Other frequency in 1-40 GHz: -30dBm/1MHz

In the end of 2014, the regulation requirements of this band were adjusted from light license to fully unlicensed. Meanwhile, some restrictions for equipment were proposed to be updated such as spurious emission etc., which was publicly inquired on the website of ministry of industry and information technology of China without formal issued so far. The proposed key regulation restrictions update in 5725-5850MHz can be found in the table below.

Table 4.1.3.1-1 Proposed key regulatory restrictions update in 5725-5850MHz

Parameter	Requirement
EIRP	≤25mW for Micro power(short range) station ≤2W for others
Power Spectrum Density(EIRP)	≤19dBm/MHz (other than ITS system)
Max Emission at edges of the used frequency	≤-80dBm/Hz (EIRP)
Spurious Emission (corresponding to frequency range outside 2.5*carrier bandwidth)	-36dBm/100kHz (30-1000MHz) -54dBm/100kHz (48.5-72.5MHz, 76-118MHz, 167-223MHz, 470-798MHz) -40dBm/1MHz (2400-2483.5MHz, 5150-5350MHz) -33dBm/100kHz (5470-5850MHz) -30dBm/1MHz(Other frequency in 1-40GHz)

The band 5470-5725 MHz has not yet been officially open for WAS/RLAN (is put on hold). However, this band as a potential WAS/RLAN frequency band has been widely discussed, while the related regulation restrictions are also

publicly inquired on the website of ministry of industry and information technology of China in the year of 2014. In order to protect the incumbent services (such as radio-determination service), DFS and TPC (no less than 6dB) are strictly required and DFS function can not be closed. The details of the proposed key regulation restrictions in 5470-5725MHz are listed as table below.

Table 4.1.3.1-2 Proposed key regulatory restrictions in 5470-5725MHz

Parameter	Requirement
EIRP	≤1W
Power Spectrum Density(EIRP)	≤50mW/MHz
Max Emission at edges of the used frequency	≤-80dBm/Hz (EIRP)
Spurious Emission (corresponding to frequency range outside 2.5*carrier bandwidth)	-36dBm/100kHz (30-1000MHz) -54dBm/100kHz (48.5-72.5MHz, 76-118MHz, 167-223MHz, 470-798MHz) -40dBm/1MHz (2400-2483.5MHz) -33dBm/100kHz (5470-5850MHz) -30dBm/1MHz (Other frequency in 1-40GHz)

4.1.3.2 Japan

With regard to the use of 5 GHz spectrum for RLAN in Japan, the following frequency bands are available:

- 5150-5250 MHz;
- 5250-5350 MHz;
- 5470-5725 MHz.

Table 4.1.3.2-1 summarizes overview of technical regulatory requirements in Japan based on those for IEEE 802.11a/n/ac. As shown in the table, it should be noted that “Max Burst Length” is specified as less than 4 msec for RLAN systems in Japan.

Table 4.1.3.2-1: Summary of basic regulatory requirements

Frequency		5.15-5.25 GHz	5.25-5.35 GHz	5.47~5.725 GHz
Location		Limited to indoor		Indoor and outdoor
Channel bandwidth		20/40/80/160 MHz		
Modulation	20/40/80/160 MHz	OFDM		
Maximum output power	20/40/80/160 MHz	10/5/2.5/1.25 mW/MHz		
Maximum antenna gain		Any		
Maximum e.i.r.p	20/40/80/160 MHz	10/5/2.5/1.25 mW/MHz		50/25/12.5/6.25 mW/MHz
Carrier sense	20/40/80/160 MHz	Required		
Max Burst Length		< 4 ms		
DFS, TPC (Note 1)		Not required	Required (only for master control station)	
Connection topology		Any	Any (connection between the stations not controlled by master control station is not allowed)	
NOTE 1: DFS (Dynamic Frequency Selection) , TPC (Transmitter Power Control)				

Figure 4.1.3.2-1 indicates the spectrum and channelling arrangements available for different channel bandwidth. This figure also provides information on incumbent systems to be coexisting with RLAN systems in Japan.

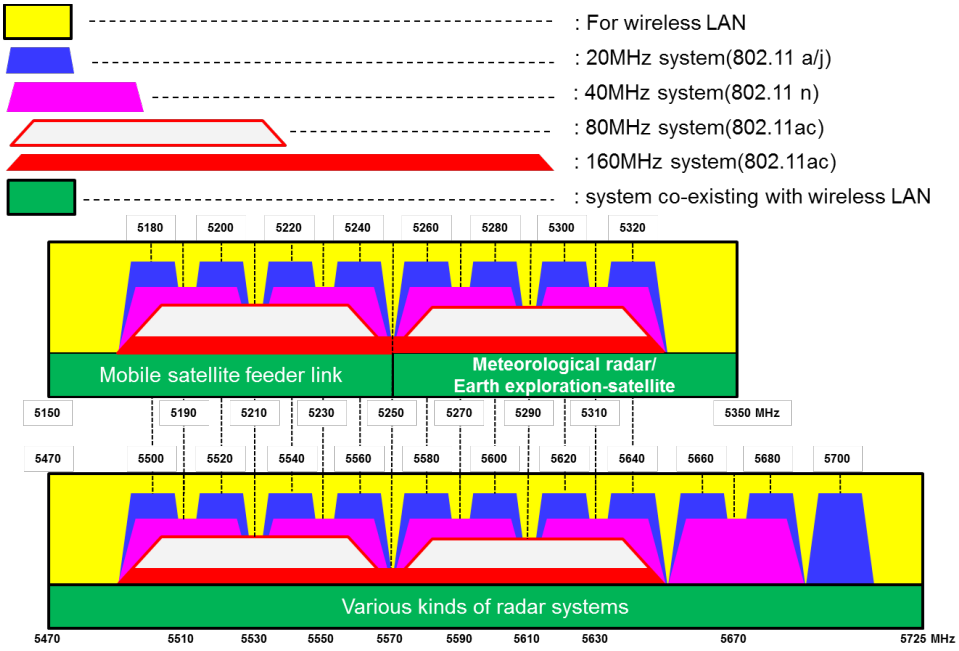


Figure 4.1.3.2-1: Spectrum and channel arrangement

Further detailed regulatory requirements, such as ACLR, SEM and peak data rate for the respective frequency bands are provided in the following sub-sections. Note that for "78 MHz < Occupied bandwidth ≤ 158 MHz" (covers the 160 MHz system), there are no ACLR1 and ACLR2 requirements specified.

4.1.3.2.1 5150-5250 and 5250-5350 MHz

Table 4.1.3.2.1-1: Adjacent Channel Leakage Ratio (ACLR) 1

Occupied bandwidth	≤ 18MHz	> 18MHz and ≤ 19MHz	> 19MHz and ≤ 38MHz	> 38MHz and ≤ 78MHz
ACLR 1	≥ 25 dB	≥ 25 dB	≥ 25 dB	≥ 25 dB
Measurement bandwidth	18 MHz	19 MHz	38 MHz	78 MHz
Adjacent channel centre frequency offset [MHz]	+20 / -20	+20 / -20	+40 / -40	+80 / -80

Table 4.1.3.2.1-2: Adjacent Channel Leakage Ratio (ACLR) 2

Occupied bandwidth	≤ 18MHz	> 18MHz and ≤ 19MHz	> 19MHz and ≤ 38MHz	> 38MHz and ≤ 78MHz
ACLR 2	≥ 40 dB	≥ 40 dB	≥ 40 dB	-
Measurement bandwidth	18 MHz	19 MHz	38 MHz	-
Adjacent channel centre frequency offset [MHz]	+40 / -40	+40 / -40	+80 / -80	-

Occupied bandwidth ≤ 18 MHz:

Table 4.1.3.2.1-3: SEM: Occupied bandwidth ≤ 18 MHz

Centre Frequency (MHz)	Frequency range(f) (MHz)	Frequency difference between centre frequency – the edges of frequency range(MHz)	e.i.r.p/MHz
5240	5140 ≤ f ≤ 5142	≥ 98 and ≤ 100	≤ 2.5 μW
	5142 < f ≤ 5150	≥ 90 and < 98	≤ 15 μW
	5250 ≤ f < 5251	≥ 10 and < 11	≤ $10^{1-(f-9)}$ mW
	5251 ≤ f < 5260	≥ 11 and < 20	≤ $10^{-1-(\frac{8}{90})(f-11)}$ mW
	5260 ≤ f < 5266.7	≥ 20 and < 26.7	≤ $10^{-1.8-(\frac{6}{50})(f-20)}$ mW
	5266.7 ≤ f ≤ 5360	≥ 26.7 and ≤ 120	≤ 2.5 μW
5260	5140 ≤ f ≤ 5233.3	≥ 26.7 and ≤ 120	≤ 2.5 μW
	5233.3 < f ≤ 5240	≥ 20 and < 26.7	≤ $10^{-1.8-(\frac{6}{50})(f-20)}$ mW
	5240 < f ≤ 5249	≥ 11 and < 20	≤ $10^{-1-(\frac{8}{90})(f-11)}$ mW
	5249 < f ≤ 5250	≥ 10 and < 11	≤ $10^{1-(f-9)}$ mW
	5350 ≤ f ≤ 5360	≥ 90 and ≤ 100	≤ 2.5 μW

18 MHz < Occupied bandwidth ≤ 19 MHz:

Table 4.1.3.2.1-4: SEM: 18 MHz < Occupied bandwidth ≤ 19 MHz

Centre Frequency (MHz)	Frequency range(f) (MHz)	Frequency difference between centre frequency – the edges of frequency range(MHz)	e.i.r.p/MHz
5180	5135 ≤ f ≤ 5142	≥ 38 and ≤ 45	≤ 2.5 μW
	5142 < f ≤ 5150	≥ 30 and < 38	≤ 15 μW
5240	5250 ≤ f < 5251	≥ 10 and < 11	≤ $10^{1-(f-9)}$ mW
	5251 ≤ f < 5260	≥ 11 and < 20	≤ $10^{-1-(\frac{8}{90})(f-11)}$ mW
	5260 ≤ f < 5266.7	≥ 20 and < 26.7	≤ $10^{-1.8-(\frac{6}{50})(f-20)}$ mW
	5266.7 ≤ f ≤ 5365	≥ 26.7 and ≤ 125	≤ 2.5 μW
5260	5135 ≤ f ≤ 5233.3	≥ 26.7 and ≤ 125	≤ 2.5 μW
	5233.3 < f ≤ 5240	≥ 20 and < 26.7	≤ $10^{-1.8-(\frac{6}{50})(f-20)}$ mW
	5240 < f ≤ 5249	≥ 11 and < 20	≤ $10^{-1-(\frac{8}{90})(f-11)}$ mW
	5249 < f ≤ 5250	≥ 10 and < 11	≤ $10^{1-(f-9)}$ mW
5320	5350 ≤ f ≤ 5365	≥ 30 and ≤ 45	≤ 2.5 μW

19 MHz < Occupied bandwidth ≤ 38 MHz:

Table 4.1.3.2.1-5: SEM: 19 MHz < Occupied bandwidth ≤ 38 MHz

Centre Frequency (MHz)	Frequency range(f) (MHz)	Frequency difference between centre frequency – the edges of frequency range(MHz)	e.i.r.p/MHz
5190	5100 ≤ f ≤ 5141.6	≥ 48.4 and ≤ 90	≤ 2.5 μW
	5141.6 < f ≤ 5150	≥ 40 and < 48.4	≤ 15 μW
5230	5250 ≤ f < 5251	≥ 20 and < 21	≤ $10^{-(f-20)+\log(1/2)}$ mW
	5251 ≤ f < 5270	≥ 21 and < 40	≤ $10^{-\left(\frac{8}{190}\right)(f-21)-1+\log(1/2)}$ mW
	5270 ≤ f < 5278.4	≥ 40 and < 48.4	≤ $10^{-\left(\frac{3}{50}\right)(f-40)-1.8+\log(1/2)}$ mW
	5278.4 ≤ f ≤ 5400	≥ 48.4 and ≤ 170	≤ 2.5 μW
5270	5100 ≤ f ≤ 5210	≥ 60 and ≤ 170	≤ 2.5 μW
	5210 < f ≤ 5221.6	≥ 48.4 and < 60	≤ 2.5 μW
	5221.6 < f ≤ 5230	≥ 40 and < 48.4	≤ $10^{-\left(\frac{3}{50}\right)(f-40)-1.8+\log(1/2)}$ mW
	5230 < f ≤ 5249	≥ 21 and < 40	≤ $10^{-\left(\frac{8}{190}\right)(f-21)-1+\log(1/2)}$ mW
	5249 < f ≤ 5250	≥ 20 and < 21	≤ $10^{-(f-20)+\log(1/2)}$ mW
5310	5350 ≤ f < 5358.4	≥ 40 and < 48.4	≤ 15 μW
	5358.4 ≤ f ≤ 5400	≥ 48.4 and ≤ 90	≤ 2.5 μW

38 MHz < Occupied bandwidth ≤ 78 MHz:

Table 4.1.3.2.1-6: SEM: 38 MHz < Occupied bandwidth ≤ 78 MHz

Centre Frequency (MHz)	Frequency range(f) (MHz)	Frequency difference between centre frequency – the edges of frequency range(MHz)	e.i.r.p/MHz
5210	5020 ≤ f ≤ 5123.2	≥ 86.8 and ≤ 190	≤ 2.5 μW
	5123.2 < f ≤ 5150	≥ 60 and < 86.8	≤ 15 μW
	5250 ≤ f < 5251	≥ 40 and < 41	≤ $10^{-(f-40)+\log(1/4)}$ mW
	5251 ≤ f < 5290	≥ 41 and < 80	≤ $10^{-\left(\frac{8}{390}\right)(f-41)-1+\log(1/4)}$ mW
	5290 ≤ f < 5296.7	≥ 80 and < 86.7	≤ $10^{-\left(\frac{3}{100}\right)(f-80)-1.8+\log(1/4)}$ mW
	5296.7 ≤ f ≤ 5480	≥ 86.7 and ≤ 270	≤ 2.5 μW
5290	5020 ≤ f ≤ 5203.3	≥ 86.7 and ≤ 270	≤ 2.5 μW
	5203.3 < f ≤ 5210	≥ 80 and < 86.7	≤ $10^{-\left(\frac{3}{100}\right)(f-80)-1.8+\log(1/4)}$ mW
	5210 < f ≤ 5249	≥ 41 and < 80	≤ $10^{-\left(\frac{8}{390}\right)(f-41)-1+\log(1/4)}$ mW
	5249 < f ≤ 5250	≥ 40 and < 41	≤ $10^{-(f-40)+\log(1/4)}$ mW
	5350 ≤ f < 5376.8	≥ 60 and < 86.8	≤ 15 μW
	5376.8 ≤ f ≤ 5480	≥ 86.8 and ≤ 190	≤ 2.5 μW

78 MHz < Occupied bandwidth ≤ 158 MHz:

Table 4.1.3.2.1-7: SEM: 78 MHz < Occupied bandwidth ≤ 158 MHz

Centre Frequency (MHz)	Frequency range(f) (MHz)	Frequency difference between centre frequency – the edges of frequency range(MHz)	e.i.r.p/MHz
5250	4916 ≤ f ≤ 5099.6	≥ 150.4 and ≤ 334	≤ 2.5 μW
	5099.6 < f ≤ 5150	≥ 100 and < 150.4	≤ 15 μW
	5350 ≤ f < 5400.4	≥ 100 and < 150.4	≤ 15 μW
	5400.4 ≤ f ≤ 5584	≥ 150.4 and ≤ 334	≤ 2.5 μW

Table 4.1.3.2.1-8: Peak data rate

Occupied bandwidth(MHz)	Peak data rate (Mbps)
≤ 19	≥ 20
> 19 and ≤ 38	≥ 40
> 38 and ≤ 78	≥ 80
> 78 and ≤ 158	≥ 160

4.1.3.2.2 5470-5725 MHz

Table 4.1.3.2.2-1: Adjacent Channel Leakage Ratio (ACLR) 1

Occupied bandwidth	≤ 19.7MHz	> 19.7MHz and ≤ 38MHz	> 38MHz and ≤ 78MHz
ACLR 1	≥ 25 dB	≥ 25 dB	≥ 25 dB
Measurement bandwidth	19 MHz	38 MHz	78 MHz
Adjacent channel centre frequency offset [MHz]	+20 / -20	+40 / -40	+80 / -80

Table 4.1.3.2.2-2: Adjacent Channel Leakage Ratio (ACLR) 2

Occupied bandwidth	≤19.7MHz	> 19.7MHz and ≤ 38MHz	> 38MHz and ≤ 78MHz
ACLR 2	≥ 40 dB	≥ 40 dB	-
Measurement bandwidth	19 MHz	38 MHz	-
Adjacent channel centre frequency offset [MHz]	+40 / -40	+80 / -80	-

Occupied bandwidth ≤ 19.7 MHz:

Table 4.1.3.2.2-3: SEM: Occupied bandwidth ≤ 19.7 MHz

Frequency range(f) (MHz)	e.i.r.p/MHz
5455 ≤ f ≤ 5460	≤ 2.5 μW
5460 < f ≤ 5470	≤ 12.5 μW
5725 ≤ f < 5740	≤ 12.5 μW
5740 ≤ f ≤ 5745	≤ 2.5 μW

19.7 MHz < Occupied bandwidth ≤ 38 MHz:

Table 4.1.3.2.2-4: SEM: 19.7 MHz < Occupied bandwidth ≤ 38 MHz

Frequency range(f) (MHz)	e.i.r.p/MHz
5420 ≤ f ≤ 5460	≤ 12.5 μW
5460 < f ≤ 5470	≤ 50 μW
5725 ≤ f ≤ 5760	≤ 12.5 μW

38 MHz < Occupied bandwidth ≤ 78 MHz:

Table 4.1.3.2.2-5: SEM: 38 MHz < Occupied bandwidth ≤ 78 MHz

Frequency range(f) (MHz)	e.i.r.p/MHz
5340 ≤ f ≤ 5460	≤ 12.5 μW
5460 < f ≤ 5469.5	≤ 50 μW
5469.5 < f ≤ 5470	≤ 51.2 μW
5725 ≤ f ≤ 5800	≤ 12.5 μW

78 MHz < Occupied bandwidth ≤ 158 MHz:

Table 4.1.3.2.2-6: SEM: 78 MHz < Occupied bandwidth ≤ 158 MHz

Frequency range(f) (MHz)	e.i.r.p/MHz
5236 ≤ f ≤ 5419.6	≤ 12.5 μW
5419.6 < f ≤ 5470	≤ 50 μW
5725 ≤ f ≤ 5904	≤ 12.5 μW

Table 4.1.3.2.2-7: Peak data rate

Occupied bandwidth(MHz)	Peak data rate (Mbps)
≤ 19.7	≥ 20
> 19.7 and ≤ 38	≥ 40
> 38 and ≤ 78	≥ 80
> 78 and ≤ 158	≥ 160

4.1.3.2.3 Simultaneous use of 5150-5250 and 5470-5725 MHz / 5250-5350 and 5470-5725 MHz

When simultaneous use of non-contiguous two channels in 5150-5250 and 5470-5725 MHz or that in 5250-5350 and 5470-5725MHz is employed, the following regulatory requirements are also applied. It should be note that total channel bandwidth is less and equal to 160 MHz in these usages.

Table 4.1.3.2.3-1: SEM: 78 MHz < Occupied bandwidth ≤ 158 MHz

Case	Combination of simultaneous transmission Centre Frequencies	
	Centre Frequency 1 (MHz)	Centre Frequency 2 (MHz)
1	5210	5530
2		5610
3	5290	5530
4		5610

Side conditions

- Occupied bandwidth for respective Carrier for Centre frequency is > 38 MHz and ≤ 78 MHz.
- Maximum Output power ≤ 1.25 mW
- e.i.r.p.≤ 1.25 mW

Table 4.1.3.2.3-2: Adjacent Channel Leakage Ratio (ACLR)

Occupied bandwidth	> 38MHz and ≤ 78MHz
ACLR	≥ 25 dB
Measurement bandwidth	78 MHz
Adjacent channel centre frequency offset [MHz]	+80 / -80
Note: Applicable to respective carrier	

Table 4.1.3.2.3-3: SEM: Case 1 and 2

Centre Frequency (MHz)	Frequency range(f) (MHz)	Frequency difference between centre frequency – the edges of frequency range(MHz)	e.i.r.p/MHz
5,210	5,020 ≤ f ≤ 5,134.8	≥ 75.2 and ≤ 190	≤ 2.5 μW
	5,134.8 < f ≤ 5,150	≥ 60 and < 75.2	≤ 12.5 μW
	5,250 ≤ f < 5,251	≥ 40 and < 41	$\leq 10^{-\lvert f-40\rvert+\log(1/8)}$ mW
	5,251 ≤ f < 5,285.2	≥ 41 and < 75.2	$\leq 10^{-\left(\frac{8}{390}\right)\lvert f-41\rvert-1+\log(1/8)}$ mW
	5,285.2 ≤ f < 5,370	≥ 75.2 and < 160	≤ 2.5 μW
5,530	5,370 ≤ f ≤ 5,454.8	≥ 75.2 and ≤ 160	≤ 2.5 μW
	5,454.8 < f ≤ 5,470	≥ 60 and < 75.2	≤ 15 μW
5,610	5,725 ≤ f ≤ 5,800	≥ 115 and ≤ 190	≤ 15 μW

Table 4.1.3.2.3-4: SEM: Case 3 and 4

Centre Frequency (MHz)	Frequency range(f) (MHz)	Frequency difference between centre frequency – the edges of frequency range(MHz)	e.i.r.p/MHz
5,290	5,020 ≤ f ≤ 5,214.8	≥ 75.2 and ≤ 270	≤ 2.5 μW
	5,214.8 < f ≤ 5,249	≥ 41 and < 75.2	$\leq 10^{-\left(\frac{8}{390}\right)\lvert f-41\rvert-1+\log(1/8)}$ mW
	5,249 < f ≤ 5,250	≥ 40 and < 41	$\leq 10^{-\lvert f-40\rvert+\log(1/8)}$ mW
	5,350 ≤ f < 5,365.2	≥ 60 and < 75.2	≤ 15 μW
	5,365.2 ≤ f < 5,410	≥ 75.2 and < 120	≤ 2.5 μW
5,530	5,410 ≤ f ≤ 5,454.8	≥ 75.2 and ≤ 120	≤ 2.5 μW
	5,454.8 < f ≤ 5,470	≥ 60 and < 75.2	≤ 15 μW
5,610	5,725 ≤ f ≤ 5,800	≥ 115 and ≤ 190	≤ 15 μW

Table 4.1.3.2.3-5: Peak data rate

Peak data rate (Mbps)
≥ 160

4.1.3.3 Korea

Table 4.1.3.3-1: Transmit power requirements for 5GHz Devices

Frequency Range(MHz)	5100-5250		5250-5350		5470-5650		5725-5825, 2400~2483.5 (Note 7)	
Average PSD requirement (mW/MHz)	BW(MHz)	PSD	BW(MHz)	PSD	BW(MHz)	PSD	BW(MHz)	PSD
	0.5-20	≤2.5	0.5-20	≤10	0.5-20	≤10	0.5-26	≤10
	20-40	≤1.25	20-40	≤5	20-40	≤5	26-40	≤5
	40-80	≤0.625	40-80	≤2.5	40-80	≤2.5	40-80	≤2.5
							40-60 (Note 1)	≤0.1 (Note 1)
Assumed antenna gain G (dBi) (Note 4)	6		7		7		6, 20 (PTP) (Notes 2, 3)	
Out of band emission, EIRP (dBm/MHz)	-27		-27		-27		For any 100kHz in outside band, less than -30dBm(2400-2483.5MHz) -27dBm/MHz (5725-5825MHz)	
DFS (Note 5)	No		Yes		Yes		No	
TPC (Note 6)	No		Yes		Yes		No	

NOTE 1: 2400-2483.5MHz devices
NOTE 2: Fixed point to point operation power scaling threshold is 20 dBi
NOTE 3: PTP: Point to Point communication
NOTE 4: Peak power is reduced by G-THR dB for directional antennas with gain > THR dBi (THR = 6 dBi for 51005250MHz and 5725-5825MHz or 7dBi for 5250-5350MHz and 5470-5650MHz)
NOTE 5: DFS: Dynamic Frequency Selection
NOTE 6: TPC: Transmit Power Control
NOTE 7: 5725-5825MHz, 2400-2483.5MHz are not allowed to be used for point-to-multipoint service for the same information and omni-directional electro-magnetic wave transmission

Table 4.1.3.3-2: DFS requirements for 5GHz Devices

	Levels	Comments
DFS Threshold (dBm) for interference detection	-62dBm	Average power considering antenna gain: <10mW/MHz
	-64dBm	Average power considering antenna gain: 10mW/MHz ~50mW/MHz
Channel availability check time	> 60 seconds	
Channel move time	< 10 seconds	
Non-occupancy time	> 30 minutes	After radar detection in either channel availability check or in-service monitoring

Korean regulatory requirements are summarized as follows:

- Average PSD requirement (mW/MHz)
  - It covers both power spectral density and Max transmission power
  - The maximum PSD is defined for a given spectrum range
  - Maximum transmission power :
    - 50mW, 200mW, 200mW and 200/260mW for 5150-5250, 5250-5350, 5470-5650, and 5725-5825 MHz band respectively
- Antenna gain assumed:
  - 6 dBi for 5150-5250 and 5725-5825MHz band

  - 7 dBi for 52505350 and 5470-5650MHz band
- Out of Band Emission (EIRP (dBm/MHz))
  - <-27 dBm/MHz
- DFS & TPC
  - DFS is defined for 5250-5350MHz and 5470-5650MHz
  - TPC is defined for 5250-5350MHz and 5470-5650MHz
    - TPC ensures wireless devices with average Tx power including antenna gain larger than 25mW/MHz can reduce its average Tx power by at least 3dB (below 12.5mW/MHz)
- Maximum bandwidth occupancy
  - < 80MHz for 5GHz
- Maximum power spectral density for bandwidth aggregation (contiguous or non-contiguous)
  - Among 5150-5250, 5250-5350, 5470-5650, and 5725-5825 MHz bands, multiple of 80MHz bandwidth can be aggregated in contiguous or non-contiguous manner to form 160MHz bandwidth
  - In this case, maximum power spectral density for 5150-5250MHz should be lower than 0.625mW/MHz while it should be lower than 1.25mW/Hz in the other bands
- Modulation scheme
  - Digital modulation for 5GHz
- Difference from FCC regulation
  - Maximum transmission power in case of 5725 to 5825MHz is still 200mW for 20MHz bandwidth (a bit lower compared to 1W power in UNII-3)
  - 5825-5850MHz is not for WAS (Wireless Access System)

4.1.3.4 India

In India the bands 5150-5250 MHz, 5250-5350 MHz, 5570-5725 MHz and 5725-5875 MHz are open to RLANs [22], [35], [36], [37]. Table 4.1.3.4-1 and Table 4.1.3.4-2 summarize regulatory requirements in India for indoor and outdoor deployments respectively. Some parts of the 5 GHz band shall follow usage “on non-interference, non-protection and shared (non-exclusive) basis”. These are the 5725-5825 MHz band open to licensed WAS including RLANs, and the 5150-5350 MHz and 5725-5875 MHz bands open for unlicensed WAS including RLANs for indoor deployment.

Table 4.1.3.4-1: Summary of regulatory requirements for indoor deployment in India

Regulation code	NFAP2011-IND 67, GSR No 46E, 37E	NFAP2011-IND 69
Band (MHz)	5150-5350, 5725-5875	5570-5725
License Type	Unlicensed	Licensed
Maximum mean EIRP	200mW (23dBm)	1W (30dBm)
Maximum mean EIRP density	10 mW/MHz	50 mW/MHz
Band usage	Low power WAS including RLAN	Low power WAS including RLAN

Table 4.1.3.4-2: Summary of regulatory requirements for outdoor deployment in India

Regulation code	NFAP2011-IND 68	NFAP2011-IND 69	NFAP2011-IND 71	NFAP2011-IND 72, GSR No 38E
Band (MHz)	5150-5250	5570-5725	5725-5825	5825-5875
License Type	Licensed	Licensed	Licensed	Unlicensed
Maximum transmitter output power			1 W (30dBm) in spread of 10 MHz or higher	1 W (30dBm) in spread of 10 MHz or higher
Maximum mean EIRP	200mW (23dBm)	1W (30dBm)	4W (36dBm)	4W (36dBm)
Maximum mean EIRP density	10 mW/MHz	50 mW/MHz		
Band usage	Low power WAS including RLAN	Low power WAS including RLAN	Low power WAS including RLAN and Dedicated Short Range Communications (DSRC) for Intelligent Transport Networks	Low power WAS including RLAN

.

4.1.3.5 Taiwan

In Taiwan the bands 5250-5350 MHz, 5470-5600 MHz, 5650-5725 MHz and 5725-5850 MHz are allocated to RLANs [22][40]. Table 4.1.3.5-1 and Table 4.1.3.5-2 summarize the current regulatory requirements for transmit power and DFS in Taiwan [40]. DFS is mandate for 5470-5725 MHz [41]. Recently, work for specifying requirements for allowing RLANs in 5150-5250 MHz and 5600-5650 MHz has started but the detailed regulatory requirements for this has not yet been specified. Additionally specification work for allowing 5250-5350 MHz outdoor has started, this assumes that DFS will be performed, but detailed requirements are not yet defined.

Table 4.1.3.5-1 Transmit power requirements for 5GHz band in Taiwan

Frequency Range (GHz)		5.25-5.35 *	5.47-5.60 and 5.65-5.725	5.725-5.825	*For indoor use only
Peak transmit power < min(a, b) (dBm)	A	17	24	30	
	B	4+10logB	11+10logB	17+10logB	B is the 26-dB emission bandwidth in MHz
Peak PSD (dBm/MHz)		4	11	17	Resolution bandwidth 1 MHz
Assumed Antenna Gain (dBi)		6	6	6**	Peak power is reduced by G-6 dB for directional antennas with gain > 6 dBi; ** Fixed point to point operation power scaling threshold is 23 dBi
Out of band emission	Frequency Support (GHz)	Outside 5.25 – 5.35	Outside 5.47-5.725	Outside 5.715-5.835	
	EIRP (dBm/MHz)	-27	-27	-27	Resolution bandwidth 1 MHz
	Frequency Support (GHz)			5.715-5.725 5.825-5.835	
	EIRP (dBm/MHz)			-17	Resolution bandwidth 1 MHz
Transmit Power Control		N/A	TPC to 6 dB below a mean EIRP of 30 dBm. No TPC for mean EIRP < 27 dBm	N/A	
DFS		Required	Required	N/A	

Table 4.1.3.5-2 DFS requirements for 5.470-5.725GHz band in Taiwan

	Levels	Comments
DFS Detection Threshold (dBm)	-64 for EIRP between 200mW and 1W	DFS power is averaged in 1 micro-second for 0 dBi antenna. Uniform spread over available channels.
	-62 for EIRP < 200mW	
Channel availability check time	60 seconds	Master mode
Channel move time	<10 seconds	Master and slave mode After detection of radar signal: at most 200ms for normal communication manage and control signals can be transmitted discontinuously in the remaining time within 10 seconds
Non-occupancy time	>30 minutes	After radar detection in either channel availability check or in-service monitoring

4.1.3.6 Singapore

In Singapore the bands 5150-5250 MHz, 5250-5350 MHz, 5470-5725MHz and 5725-5850 MHz are open to RLANs.

4.1.3.7 Australia

In Australia the band bands 5150-5250 MHz, 5250-5350 MHz and 5470-5725 MHz, except the sub-band 5600-5650 MHz, are open to RLANs. DFS and TPC are mandatory in the bands 5250-5350 MHz and 5470-5725 MHz.

4.1.4 Applicability of DFS requirements

The concept surfaced around 2001 in the ECC for handling uniform spread of WLAN interference into satellite and radar services, but was soon extended to include methods for discovery and avoidance of frequencies used by the radar service in the preparation work for WRC 2003.

Use of DFS in accordance with Annex 1 of ITU-R Recommendation M.1652 [39] is mandated as per Resolution 229 [38]. The 5 GHz Harmonized European Standard developed by ETSI TC BRAN was the first to include these DFS rules (EN 301 893 V1.2.3 in 2003), the DFS test specification included in this standard therefore became the basis for the development of the FCC DFS test specification and other test specifications in other countries.

For ~~LAA~~NR-U, it appears that conformance testing would only have to be performed for the BS. Already at the outset in ITU-R M.1652 it was made clear that full DFS functionality may not have to be implemented in all devices, only those controlling the transmission [39]:

2.1 Detection requirements

The DFS mechanism should be able to detect interference signals above a minimum DFS detection threshold of –62 dBm for devices with a maximum e.i.r.p. of < 200 mW and –64 dBm for devices with a maximum e.i.r.p. of 200 mW to 1 W[3] averaged over 1 μs.

This is defined as the received signal strength (RSS) (dBm), normalized to the output of a 0 dBi receive antenna, that is required to be detected within the WAS channel bandwidth.

2.2 Operational

with the footnote 3 stating:

In practice, it may not be necessary for each device to implement full DFS functionality, provided that such devices are only able to transmit under the control of a device that ensures that all DFS requirements are fulfilled.

This is reflected in both regulation for Europe and the Part 15 rules by the FCC. The harmonized ETSI BRAN standard cited in the EC commission rules is also followed by many other countries outside Europe.

4.1.4.1 DFS according to ECC

In accordance with the ECC Decision [10], “Every Master Device will use the Radar Interference Detection function in order to check for any co-channel radar signal prior to use a channel but also during normal operation. In addition to this Radar Interference Detection function, every Master Device shall also implement a channel selection mechanism to ensure a near uniform spread of the loading of available spectrum.” In the latest version of the EN 301 893 [5], the applicability of the DFS requirements is listed as follows:

Table 5 lists the DFS related technical requirements and their applicability for every operational mode. If the RLAN device is capable of operating in more than one operational mode then every operating mode shall be assessed separately.

Table 5 (from EN 301 893): Applicability of DFS requirements

Requirement	DFS Operational mode		
	Master	**Slave without radar detection** (see table D.2, note 2)	**Slave with radar detection** (see table D.2, note 2)
Channel Availability Check	□	Not required	□□(see note 2)
Off-Channel CAC (see note 1)	□	Not required	□□(see note 2)
In-Service Monitoring	□	Not required	□
Channel Shutdown	□	□	□
Non-Occupancy Period	□	Not required	□
Uniform Spreading	□	Not required	Not required
NOTE 1: Where implemented by the manufacturer. NOTE 2: A slave with radar detection is not required to perform a CAC or *Off-Channel CAC* at initial use of the channel but only after the slave has detected a radar signal on the *Operating Channel* by *In-Service Monitoring.*			

The radar detection requirements specified in clauses 4.7.2.2 to 4.7.2.4 assume that the centre frequencies of the radar signals fall within the central 80 % of the *Occupied Channel Bandwidth* of the RLAN channel (see clause 4.3).

Notice also the assumption that the radar signal falls within 80% of the occupied bandwidth, which is linked to the requirements on occupied emission bandwidth in EN 801 893 (clause 4.7).

4.1.4.2 DFS in the Part 15 rules

The rules with regard to implementation of DFS functionality are similar in the Part 15 rules [3]; the required functionality is limited for the slave,

> (2) Radar Detection Function of Dynamic Frequency Selection (DFS). U-NII devices operating with any part of its 26 dB emission bandwidth in the 5.25-5.35 GHz and 5.47-5.725 GHz bands shall employ a DFS radar detection mechanism to detect the presence of radar systems and to avoid co-channel operation with radar systems. Operators shall only use equipment with a DFS mechanism that is turned on when operating in these bands. The device must sense for radar signals at 100 percent of its emission bandwidth. The minimum DFS detection threshold for devices with a maximum e.i.r.p. […]
>
> (i) Operational Modes. The DFS requirement applies to the following operational modes:

(A) The requirement for channel availability check time applies in the master operational mode.

(B) The requirement for channel move time applies in both the master and slave operational modes.

(ii) Channel Availability Check Time. A U-NII device shall check if there is a radar system already operating on the channel before it can initiate a transmission on a channel and when it has to move to a new channel. The U-NII device may start using the channel if no radar signal with a power level greater than the interference threshold values listed in paragraph (h)(2) of this section, is detected within 60 seconds.

(iii) Channel Move Time. After a radar's presence is detected, all transmissions shall cease on the operating channel within 10 seconds. Transmissions during this period shall consist of normal traffic for a maximum of 200 ms after detection of the radar signal. In addition, intermittent management and control signals can be sent during the remaining time to facilitate vacating the operating channel.

Similar to the ETSI BRAN harmonized standard, there is also a requirement that “the device must sense for radar signals at 100 percent of its emission bandwidth”. In deriving the minimum DFS detection threshold for the WAS receiver, it was assumed that above this threshold the emissions within the RLAN bandwidth would desensitize the radar receiver. Reciprocity was thus assumed, the WAS should be able to detect a radar within its emission bandwidth. The bandwidth of the WAS affects the probability of detecting a radar signal and its side lobes and the probability of causing interference (the WAS emissions).

4.2 Regulatory requirements for [X]GHz band

5 Spectrum considerations

For the NR-U study item, different unlicensed bands or shared bands have been discussed, such as 2.4 GHz band, 3.5 GHz band, 5 GHz band, 6 GHz band, 37 GHz band, and 60 GHz band. Some bands are available globally and some bands are only available in some specific regions.

Follow the NR design principles, from RAN1 design perspective, this NR-U study is not limited to a particular unlicensed band. Instead, the target NR-U design is applicable to a set of frequency ranges to be further defined. There is no prioritization between unlicensed bands. On the other hand, the NR-U study does not target sub-1 GHz unlicensed bands, due to the lack of spectrum in the band to support efficient NR-U operation.

6 Deployment scenarios

This section describes possible deployment scenarios for NR-U.

Five deployment scenarios have been identified:

- Scenario A: Carrier aggregation between licensed band NR (PCell) and NR-U (SCell)
  - NR-U SCell may have both DL and UL, or DL-only.
- Scenario B: Dual connectivity between licensed band LTE (PCell) and NR-U (PSCell)
- Scenario C: Stand-alone NR-U
- Scenario D: An NR cell with DL in unlicensed band and UL in licensed band
- Scenario E: Dual connectivity between licensed band NR (PCell) and NR-U (PSCell)

7 Design targets, functionalities and solutions

In the discussions in the NR-U study item, references to sub-7 GHz are intended to include unlicensed bands in the 6 GHz region that are being discussed in regulatory discussions which may have some region exceeding 7 GHz (e.g., 7.125 GHz).

7.1 Design targets and functionalities

The NR-U study targets identification of additional functionality needed for a PHY layer design (except channel access procedures) for operation in unlicensed spectrum that may be applicable over a particular frequency range (e.g., sub-7 GHz, 7-52.6 GHz, > 52.6 GHz). The definition of the frequency ranges is to be further defined. On the other hand, the optimizations for a particular frequency band may be necessary due to different requirements, such as PSD limitation or OCB requirement, for each band. Channel bandwidths below 5 MHz are not targeted in this study.

The study targets the design of channel access procedures for frequency bands based on coexistence and regulatory considerations applicable to the band. The study includes identification of procedures for technology neutral channel access for frequency bands that may become available subject to regulations. The study assumes regulation will provide the framework concerning the protection for the technologies not using unlicensed access in those bands.

7.2 Solutions for operation in unlicensed spectrum

7.2.1 Physical layer aspects

7.2.1.1 Frame structure

- NR-U supports both Type-A and Type-B mapping already supported in NR
  - Additional starting positions and durations are not precluded
- For sub-7 GHz, NR-U study the SCSs, 15/30/60KHz
  - Study performance difference between different SCS
  - Study if changes to UL design are needed to meet the PSD and OCB requirements
  - Study if an SS block design/RMSI/OSI with 60KHz SCS is needed
  - Impact on MIB and SIB1 content
  - Need for use of ECP for 60KHz
  - RACH design with 60KHz SCS in addition to options currently part of NR
  - Other considerations are not precluded.
  - Impact on support of different BWs with different SCS
- Study supporting more than one switching points within a TxOP
  - FFS the LBT requirement for each DL/UL data/control burst in the TxOP

7.2.1.2 Physical layer channel designs

For physical layer channel design, NR design will be used as baseline, and the following potential design changes are to be studied to support the following channels/signals in NR-U.

- PDCCH/PDSCH
- PUCCH/PUSCH
- PSS/SSS/PBCH
- PRACH
- DL and UL reference signals applicable to the operational frequency range

7.2.1.3 Physical layer procedure designs

If absence of Wi-Fi cannot be guaranteed (e.g. by regulation) in the band (sub-7 GHz) where NR-U is operating, the baseline assumption is, the NR-U operating bandwidth is an integer multiple of 20MHz.

For physical layer procedures, the following areas has been identified as areas for further study for NR-U:

- Study possible enhancements for HARQ operation
- Study changes needed for Configured Grant support in NR-U
- Channel access mechanisms

For channel access mechanism, LTE-LAA LBT mechanism are assumed as baseline for evaluations for 5GHz. At least for band where absence of Wi-Fi cannot be guaranteed (e.g. by regulation), LBT can be performed in units of 20 MHz.

Study whether or not the following techniques enhance performance beyond the baseline LBT mechanisms

- Techniques to cope with directional antennas/transmissions
- Receiver assisted LBT : RTS/CTS type mechanism
  - On-demand receiver assisted LBT: For example receiver assisted LBT enabled only when needed
- Techniques to enhance spatial reuse
- Preamble detection
- Enhancements to baseline LBT mechanisms above 7 GHz

7.2.2 Higher layer aspects

8 Performance evaluations

For performance evaluation, coexistence with other networks will be evaluation, such as WiFi, LTE-LAA, or other NR-U network.

When coexistence with WiFi is evaluated, following the study item description [2], NR-based operation in unlicensed spectrum should not impact deployed Wi-Fi services (data, video and voice services) more than an additional Wi-Fi network on the same carrier, where the deployed Wi-Fi includes 11ac in 5GHz band and 11ad in 60GHz band. The fairness criterion for coexistence with 11ax can be further discussed.

For sub-7 GHz bands, coexistence simulations will be performed using technology neutral assumptions (eg. channel access mechanism) at an arbitrary carrier frequency in 5GHz band for application to bands other than 5GHz which may become available subject to regulations. The study assumes regulation will provide the framework concerning the protection for the technologies not using unlicensed access in those bands.

8.1 Scenarios and methodology

For the NR-U study evaluation, to reuse the simulation platform already developed for NR study, the 5GCM in [29] is used for NR-U simulation evaluation. The evaluation deployment scenarios are derived from NR evaluation deployment scenarios as defined in [28] with proper modifications to introduce the second operator.

NR-U simulation evaluation considers the following layout scenarios:

- Indoor sub-7GHz, 2 operators
- Outdoor Sub-7 GHz, 2 operators
- Indoor mmW, 2 Operators
- Outdoor mmW, 2 operators
- Stadium scenario for sub-7GHz, 2 operators, can be optionally considered by interested companies.

The following deployment scenarios for simulation are identified:

- CA between NR licensed cell and NR unlicensed cell
- DC (with LTE and with NR)
- SA
- An NR cell with DL in unlicensed band and UL in licensed band

In the simulations, only unlicensed cell(s) is to be simulated. The licensed cell may not be explicitly modelled in the simulation. Necessary assumptions regarding the presence of the licensed carriers can be made and provided.

It was also noted that a single set of evaluations may be applicable to multiple deployment scenarios. For example, DC and SA deployment scenarios can share the same set of simulations, possibly with some minor differences on how the overhead (say for system information delivery) is captured in the result.

8.1.1 Sub7 GHz indoor scenario

For sub7 GHz indoor simulation evaluation, two operators each with 3 gNBs are deployed in a room of size 120 meters by 80 meters as shown in Figure 1. In the figure, the gNB of the same color belongs to the same operator. The parameters are of value a=20 meters, b=40 meters, c=20 meters, and d=40 meters. The deployment scenario is selected to achieved a target serving link RSSI distribution with 10%-15% serving link below -72dBm.

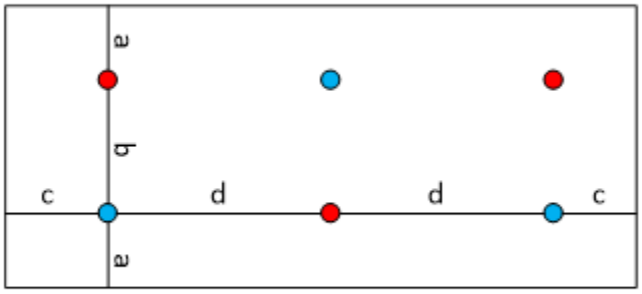


Figure 1. Indoor sub7 simulation office layout

Other parameters are as given in Table 1. Other parameters not explicitly included in the table will use values defined in [28] and [29]/

Table 1. Evaluation parameters for sub7 GHz indoor scenario

Parameter	Value
Carrier Frequency	5GHz
Carrier Channel Bandwidth	20MHz baseline , 80MHz optional
Number of carriers	1
Number of users per operator	5 per gNB per 20MHz
SCS	To be reported together simulation results
Channel Model	NR InH Mixed Office model
BS/AP Tx Power	23dBm (total across all TX antennas)
UE/STA Tx Power	18dBm (total across all TX antennas)
BS/AP Antenna gain	0dBi
UE/STA Antenna gain	0dBi
BS/AP Noise Figure	5dB
UE/STA Receiver Noise Figure	9dB
Minimum received power from serving cell for UE dropping	-82dBm
UE receiver	MMSE-IRC as the baseline receiver
BS/AP antenna Array configuration	(M, N, P, M_g, N_g) = (1, 2, 2, 1, 1), dH = dV = 0.5 λ
UE/STA antenna Array configuration	Baseline Tx/Rx: (M, N, P, Mg, Ng) = (1, 1, 2, 1, 1), dH = dV = 0.5 λ Optional Tx/Rx: (M, N, P, Mg, Ng) = (1, 2, 2, 1, 1), dH = dV = 0.5 λ
Traffic model	Use 36.889 Table A.1.1. Note: Results based on the mixed traffic models can be used to determine the design.
UE/STA to UE/STA link pathloss model	Directly use InH office pathloss model with proper d_3D with indoor mixed office LOS probability
gNB to gNB link pathloss model	Directly use InH office pathloss model with proper d_3D with indoor mixed office LOS probability

8.1.2 Sub7GHz outdoor scenario

8.1.3 mmW indoor scenario

8.1.4 mmW outdoor scenario

8.2 Channel access schemes

8.3 Evaluation results

9 Conclusions

Annex A: Evaluation methodology

A.1 General evaluation assumptions

Annex B: Evaluation results

Annex C:
Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2018-02-26	RAN1#92	R1-1803272			First version of TR		0.0.1
2018-05-21	RAN1#93	R1-180xxxx			Update to capture the agreements reached in RAN1 #92 and #92bis	0.0.1	0.0.2