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| 3GPP TR 38.844 V18.0.0 (2023-03) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Radio Access Network;  NR;  Study on Efficient utilization of licensed spectrum that is not aligned with existing NR channel bandwidths  (Release 18) | |
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# Foreword

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

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

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In the present document, modal verbs have the following meanings:

**shall** indicates a mandatory requirement to do something

**shall not** indicates an interdiction (prohibition) to do something

The constructions "shall" and "shall not" are confined to the context of normative provisions, and do not appear in Technical Reports.

The constructions "must" and "must not" are not used as substitutes for "shall" and "shall not". Their use is avoided insofar as possible, and they are not used in a normative context except in a direct citation from an external, referenced, non-3GPP document, or so as to maintain continuity of style when extending or modifying the provisions of such a referenced document.

**should** indicates a recommendation to do something

**should not** indicates a recommendation not to do something

**may** indicates permission to do something

**need not** indicates permission not to do something

The construction "may not" is ambiguous and is not used in normative elements. The unambiguous constructions "might not" or "shall not" are used instead, depending upon the meaning intended.

**can** indicates that something is possible

**cannot** indicates that something is impossible

The constructions "can" and "cannot" are not substitutes for "may" and "need not".

**will** indicates that something is certain or expected to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**will not** indicates that something is certain or expected not to happen as a result of action taken by an agency the behaviour of which is outside the scope of the present document

**might** indicates a likelihood that something will happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

**might not** indicates a likelihood that something will not happen as a result of action taken by some agency the behaviour of which is outside the scope of the present document

In addition:

**is** (or any other verb in the indicative mood) indicates a statement of fact

**is not** (or any other negative verb in the indicative mood) indicates a statement of fact

The constructions "is" and "is not" do not indicate requirements.

# Introduction

One of the aims of 5G is providing bandwidth flexibility. Although this is achieved in general, but for some spectrum allocations the ability to achieve such flexibility needs further study.

# 1 Scope

The present document is the Technical Report of the Study Item on Efficient utilization of licensed spectrum that is not aligned with existing NR channel bandwidths, approved at TSG RAN #89-e [2]. The purpose of this document is to capture and document the outcome of the objectives stated in the SID.

# 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] RP-202103: SID “Study on Efficient utilization of licensed spectrum that is not aligned with existing NR channel bandwidths”

[3] R4-2200031: Reply LS on specification impact for methods on efficient utilization of licensed spectrum that is not aligned with existing NR channel bandwidths, RAN2

[4] R4-2119411: Reply LS on specification impact for methods on efficient utilization of licensed spectrum that is not aligned with existing NR channel bandwidths, RAN1

[5] R2-1902778, “Clarification to channel bandwidth signalling”, Nokia, Nokia Shanghai Bell, Qualcomm

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

For the purposes of the present document, the terms given in 3GPP 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 3GPP TR 21.905 [1].

**Larger Channel BW than licensed BW:** Uses the closest NR channel bandwidth defined in Rel-17 which is larger/wider than the irregular bandwidth. Also referred to as Next Wider CBW.

**Irregular bandwidth**: an NR bandwidth that is not defined in Rel-17

**Overlapping UE channel BW from network perspective:** network supports the irregular bandwidth (either by a single carrier or by two overlapping carriers) while each UE operates in an existing lowerregular NR channel bandwidth

**Combined UE channel BW (one cell):** network supports the irregular bandwidth as well as some new UEs with support of two overlapping (RF) carriers. Also referred to as Overlapping UE channel BW from UE perspective.

**Overlapping CA:** the irregular bandwidth is handled by two overlapping component carriers (CCs) with NR channel bandwidth defined in Rel-17. It is network responsibility to prevent collisions between the different component carriers.

**Single BB carrier:** means that from baseband (RAN1) perspective, there is a single cell with a waveform according to a single carrier

## 3.2 Symbols

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

<symbol> <Explanation>

## 3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP 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 3GPP TR 21.905 [1].

ACLR Adjacent Channel Leakage Ratio

ACS Adjacent Channel Selectivity

BS Base Station

BW Bandwidth

CBW Channel Bandwidth

FR1 Frequency Range 1

OBUE Operating Band Unwanted Emissions

RF Radio Frequency

SCBW Smaller Channel Bandwidth (Existing immediate lower channel bandwidth)

UE User Equipment

WCBW Wider Channel Bandwidth (Existing immediate wider channel bandwidth)

# 4 Background

One of the aims of 5G is providing bandwidth flexibility. Although this is achieved in general, for some spectrum allocations the ability to achieve such flexibility needs further study.

Solutions for the following spectrum allocations have been requested so far:

Table 4-1: Summary of operators’ input for irregular channel bandwidth

|  |  |
| --- | --- |
| Band (s) | Channel Bandwidth(s) |
| n5 | 7, 11 MHz |
| n12, n85 | 6, 12 MHz |
| n26 | 7 MHz |
| n28 | 13 MHz |
| n29 | 6, 11 MHz |

Some techniques have been suggested for re-using existing channel bandwidths which can include but are not limited to overlapping UE channel bandwidths, and/or using larger bandwidths than operator licensed bandwidth. This Study Item is needed to evaluate where existing techniques can be used to efficiently utilize operator spectrum allocations, and whether and how new channel bandwidths should be created. The Study shall also analyse if a proprietary solution(s) is sufficient.

## 4.1 Objectives

The following objectives are listed in the SID [2]

1) Identify operator licensed channel bandwidths in FR1 that do not align with existing NR channel bandwidths.

- Only licensed spectrum wider than 5 MHz to be considered in this SID.

- Spectrum block of 33MHz in n28 require further investigation since there is dual duplexer assumption (2x30MHz) for this band.

2) Evaluate the potential use of larger channel bandwidths than operator licensed bandwidth, including the impacts on regulatory emission requirements/UE output power implications and UE ACS/blocking impacts depending on the guard band and the SCS.

3) Study the use of overlapping UE channel bandwidths (from both UE and network perspective) to cover operator’s license spectrum for both UL and DL, and if new gNB channel bandwidths are needed.

NOTE: For all considered solutions, new (dedicated) channel filters (e.g. non-integer-multiples of 5MHz) are not considered for the UE and not prioritized for the gNB.

4) Identify operator licensed bandwidths that are not compatible with the use of techniques like overlapping UE channel bandwidths. Every proposed method shall be summarized with respect to whether all considered spectrum scenarios are supported or whether there are specific limitations. Some limitations for a specific method shall not disqualify such method if there is a trade-off between flexibility and implementation challenges.

5) Study the complexity and efficiency of adding new channel bandwidths vs. using other including testing aspects.

6) Generic solution(s) should be intended as much as possible, with priority should be given to approaches that avoid the introduction of new channel BWs on the UE side. Proprietary solutions if proven relevant should not be precluded. Spectrally efficient methods providing a fine channel bandwidth granularity as well as low to moderate guard band width and signalling overhead should be preferred

7) Impact on RAN1 and RAN2 should be considered and minimized

8) For any considered solution, Ues not supporting such solution (both legacy and new Ues) should be able to use the next lower supported channel bandwidth in the UL and DL without implications.

9) Impact (if any) on RAN4 requirements should be identified for the preferred solutions.

# 5 General

## 5.1 UE channel bandwidth

The following text is copied from TS38.101-1 for information:

The UE channel bandwidth supports a single NR RF carrier in the uplink or downlink at the UE. From a BS perspective, different UE channel bandwidths may be supported within the same spectrum for transmitting to and receiving from Ues connected to the BS. Transmission of multiple carriers to the same UE (CA) or multiple carriers to different Ues within the BS channel bandwidth can be supported.

From a UE perspective, the UE is configured with one or more BWP / carriers, each with its own UE channel bandwidth. The UE does not need to be aware of the BS channel bandwidth or how the BS allocates bandwidth to different Ues.

The placement of the UE channel bandwidth for each UE carrier is flexible but can only be completely within the BS channel bandwidth.

# 6 Result, Analysis outcome

## 6.1 Study of larger Channel BW than licensed BW

### 6.1.1 General Aspects

This clause describes, in general terms, how to utilize an irregular Channel Bandwidth by deploying the “larger channel Bandwidth” method.

The premise idea is that the system is configured with the larger channel bandwidth, as indicated in the broadcast System Information (SIB1) as described in 6.1.2.1, or UE is reconfigured to the larger channel bandwidth in connected mode than SIB1 as described in 6.1.2.2, but the actual number of scheduled RBs is restricted so that it matches actual spectrum allocation ensuring sufficiently large guard bands.



Figure 6.1.1-1: Using the next larger channel bandwidth (example for 7MHz).

NOTE: It should be checked further whether it is possible to configure the next larger channel so that it goes over the band edge and which implications it has.

NOTE: The UE UL channel bandwidth is assumed to be the next-smaller regular channel bandwidth (in MHz) in this study.

One of the first aspects for this approach is the size of guard bands and the anticipated number of schedulable RBs. For the standard channel bandwidths, both values are captured in the corresponding specification to avoid any misinterpretation on how many RBs can be configured and scheduled. Following the same principle for every irregular channel bandwidth would be feasible, but would create the same amount of technical specification work as if the corresponding irregular channel bandwidth were explicitly added to the specifications. Thus, the number of "available" RBs can be calculated based on certain assumptions.

The maximum number of "available" or "schedulable" RBs for a particular irregular channel bandwidth can be calculated based on the assumption of using larger guard bands from a *larger* channel bandwidth. As an example, while considering the 7MHz channel bandwidth, the assumption is to consider next larger 10MHz channel guard bands at both ends, from which number of available RBs can be calculated.

NOTE: Since a UE will be configured with the channel bandwidth, which is larger than the actual allocation, and it is not expected to provide the usual stop-band attenuation at the edges of the irregular channel bandwidth, it is necessary to verify the level of potential degradation of ACS/blocking. Sub-clause 6.1.3 provides further information on UE filters and potential performance.

NOTE: Similarly, the gNB operating with wider channel filters cannot be expected to provide stop-band attenuation at the edges of the irregular channel bandwidth to guarantee the co-existence. It is assumed that the gNB channel filters are implemented such that regulatory unwanted emissions requirements are met outside any operator spectrum block of irregular bandwidth (this is a common case also in existing deployments).

Table 6.1.1-1 below presents example maximum number of available RBs for different irregular channel bandwidths considered in this study item.

NOTE: Number of available RBs and spectral utilisation are taken from R4-2112365. The gNB transmitter filter assumption used to derive the RB numbers is FFS.

Table 6.1.1-1: Exemplary number of RBs based on the next larger channel guard bands (15kHz SCS).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Channel (MHz) | Next larger channel (MHz) | Next larger channel guard band (kHz) | Next larger channel  Nrb | Channel Nrb | Utilisation (%) |
| 6 | 10 | 312,5 | 52 | 29 | 87 |
| 7 | 10 | 312,5 | 52 | 35 | 90 |
| 11 | 15 | 382,5 | 79 | 56 | 91,6 |
| 12 | 15 | 382,5 | 79 | 62 | 93 |
| 13 | 15 | 382,5 | 79 | 67 | 92,8 |

Table 6.1.1-2 below presents similar calculations for 30kHz SCS, from which one can see that combination of 30kHz SCS and the next larger channel is not generally a good approach for small channel bandwidths. The main reason is that 30kHz SCS has much larger guard bands, which immediately impacts number of available RBs. As a small summary, assuming using guard band from the next larger channel the resulting spectrum Utilization would range from 87 to 92.8% for an SCS of 15kHz and 72 to 88.6% for an SCS of 30kHz.

NOTE: Number of available RBs and spectral utilisation are taken from R4-2112365. The gNB transmitter filter assumption used to derive the RB numbers is FFS.

Table 6.1.1-2: Exemplary number of RBs based on the next larger channel guard bands (30kHz SCS).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Channel (MHz) | Next larger channel (MHz) | Next larger channel guard band (kHz) | Next larger channel Nrb | Channel Nrb | Utilisation (%) |
| 6 | 10 | 665 | 24 | 12 | 72 |
| 7 | 10 | 665 | 24 | 15 | 77,1 |
| 11 | 15 | 645 | 38 | 26 | 85,1 |
| 12 | 15 | 645 | 38 | 29 | 87 |
| 13 | 15 | 645 | 38 | 32 | 88,6 |

### 6.1.2 Signalling and configuration aspects

In this section we provide further signaling details on how to support irregular channels in the DL. Two signaling methods are described. In 6.1.2.1 the next larger or next-after-next CBW is used for an FDD case with a 7 MHz allocation as an example. The use of the method for a TDD case with a larger irregular block size is also illustrated. In 6.1.2.2, the next smaller CBW is used during initial access, and then once RRC connection is established, the next larger CBW is used.

#### 6.1.2.1 Method using a larger channel bandwidth is broadcast in SIB1

##### 6.1.2.1.1 General

The gNB broadcasts the DL carrier bandwidth and the bandwidth of the initial BWP (BWP#0) in SIB1. For the 7MHz allocation, SIB1 can indicate DL next larger standard channel bandwidth, i.e. 10 MHz, and that the initial DL BWP can be set to 5 MHz:

- SIB1-> servingCellConfigCommon-> downlinkConfigCommon-> frequencyInfoDL-> scs-SpecificCarrierList-> carrierBandwidth = 52 PRBs / subcarrierSpacing = 15 kHz

- SIB1-> servingCellConfigCommon-> downlinkConfigCommon-> initialDownlinkBWP-> genericParameters-> locationAndBandwidth = 25 PRBs

Once the UE established the RRC connection, the gNB can account for the UE capabilities and configure the UE accordingly. At this point the gNB can configure the UE with the larger channel bandwidth (that used by the UE for initial access is not known to the gNB) and with an additional BWP with a bandwidth that differs from the bandwidth of BWP#0. gNB may configure a larger bandwidth part that will cover the whole 7MHz allocation.

- ServingCellConfig-> downlinkChannelBW-PerSCS-List-> carrierBandwidth = 52 PRBs, subcarrierSpacing = 15 kHz

- ServingCellConfig-> downlinkBWP-ToAddModList-> bwp-Common-> genericParameters-> locationAndBandwidth = 35 PRBs

with the BWP size taken from Table 6.1.1-1. The PRBs within this BWP can be scheduled. the remaining PRBs in the downlink channel bandwidth are blanked. Alternatively, the BWP size is set to 52 PRB with 35 PRBs scheduled.

NOTE: BWPs of sizes different from the already defined channel bandwidths are not currently tested within the RAN4 defined requirements. As such, UE behaviour under such configuration is not verified by RAN4 requirements. Furthermore, the above configuration does not consider the PRB grid alignment between SIB1 channel bandwidth and UE configured channel bandwidth based on the 100 kHz channel raster.

For the UL the UE is configured with a UE channel bandwidth smaller than the irregular block or equal to the UL BWP#0 size such that this is the only possible channel bandwidth and location during initial access. For *uplinkChannelBW-PerSCS-List* and *scs-SpecificCarrierList* symmetric operation bands with fixed duplex distance and asymmetric UL/DL channel bandwidth is band specific aspect which is defined in TS 38.101-1 and TS 38.101-2. Bands which utilize the wider channel bandwidth approach for the irregular bandwidths may need to be adopted for this aspect.

Another example of interest to some operators is 5 MHz at the bottom of n12 being shared with 6 MHz at the bottom of n85. The details can be found in Annex A.

##### 6.1.2.1.2 FDD

We begin by listing the prerequisites and assumptions for the method of using a larger channel bandwidth as described in this subclause to verify that these are consistent with existing specifications and features.

There is one carrier of carrier bandwidth for subcarrier spacing configuration *m* per serving cell and transmission direction (UL or DL), with as defined in [38.211]. The carrier bandwidth is indicated in SIB1 by the *carrierBandwidth* for subcarrier spacing configuration *m* in the *scs-SpecificCarrierList* and is thus cell specific. Furthermore

- the carrier bandwidth is the BS transmission bandwidth configuration for subcarrier spacing configuration *m* (not necessarily the same as a BS maximum transmission configuration for a channel bandwidth specified in 38.104)

- the gNB configures all UEs in a cell with an initial BWP (denoted BWP#0) and additional BWPs contained within the said carrier bandwidth indicated in SIB1 for the DL and UL

- the fields *downlinkChannelBW-PerSCS-List* and *uplinkChannelBW-PerSCS-List* in dedicated signalling are only used for the purpose of configuring the UE with a size and location of a UE *regular* channel bandwidth in MHz to ensure compliance with regulatory requirements consistent with the clarification of the use of UE dedicated channel bandwidths (MHz) agreed in [5].

The UE channel bandwidth must be located within the BS channel bandwidth as per the existing clause 5.3.1 or 38.104,

- The *BS channel bandwidth* supports a single NR RF carrier in the uplink or downlink at the Base Station. Different *UE channel bandwidths* may be supported within the same spectrum for transmitting to and receiving from UEs connected to the BS. The placement of the *UE channel bandwidth* is flexible but can only be completely within the *BS channel bandwidth*.

and its corresponding maximum bandwidth configuration must fall within the within the *BS transmission bandwidth configuration* of the BS channel bandwidth as per clause 5.3.4 of 38.104

- For each numerology, all *UE transmission bandwidth configurations* indicated to UEs served by the BS by higher layer parameter *carrierBandwidth* defined in TS 38.331 [11] shall fall within the *BS transmission bandwidth configuration*.

For irregular bandwidths implemented with larger bandwidths we assume that similar rules apply:

- the transmission bandwidth configuration (PRB) corresponding to the irregular bandwidth is within the carrier bandwidths of the DL and UL carriers indicated to the UE by SIB1, that is, the BS transmission bandwidth configuration of the BS DL that also contain blanked PRBs if larger than the irregular block size

- the BS does not configure a UE with any dedicated channel bandwidth (MHz) outside the carrier resource grid indicated in SIB1.

- the *BS channel bandwidth* supports a single NR RF carrier in the uplink or downlink as specified in 38.104.

The UE need not be aware of the actual BS channel bandwidth, the carrier location and bandwidth are indicated to the UE in SIB1:

- From a UE perspective, the UE is configured with one or more BWP / carriers, each with its own UE channel bandwidth. The UE does not need to be aware of the BS channel bandwidth or how the BS allocates bandwidth to different UEs.

The channel raster defines a subset of RF reference frequencies that can be used to identify the RF channel position in the uplink and downlink. The mapping between the channel raster and the corresponding resource element within a resource grid of a carrier within the RF channel is specified in the same way in 38.104 and 38.101-1:

- The mapping between the *RF reference frequency* on the channel raster and the corresponding resource element is given in table 5.4.2.2-1 and can be used to identify the RF channel position. The mapping depends on the total number of RBs that are allocated in the channel and applies to both UL and DL. The mapping must apply to at least one numerology supported by the BS.

Table 5.4.2.2-1: Channel Raster to Resource Element Mapping

|  |  |  |
| --- | --- | --- |
|  |  |  |
| Resource element index | 0 | 6 |
| Physical resource block number |  |  |

k, and NRB are as defined in TS 38.211 […]



We assume that the corresponding notions in 38.211 are NRB = and that is relative to a BWP starting at the start of the carrier resource grid indicated by the common resource block, =, is thus the index of the centre PRB within the resource grid of a numerology.



For the configuration examples below, we make the assumption that the NRB can only take values corresponding to the maximum transmission bandwidth configurations corresponding to channel bandwidths in the respective conformance specifications for the BS and the UE. For an operating band with a 100kHz channel raster this implies that any regular BS and UE channel bandwidth are always mapped to the channel raster. For operations in the field this also means that a configured UE-specific bandwidth within a larger BS channel bandwidth must be on the channel raster just like the BS channel bandwidth.

The assumption that UE performance can only be ensured for RRC configurations according to the conformance test specification implies restrictions on the location and bandwidth of UE specific CHBW in operating bands with a 100 kHz channel raster. If the *carrierBandwith* of the carrier resource grid is an odd/even number of PRBs and the maximum transmission bandwidth configuration for the UE CHBW is even/odd for SCS = 15k, then the corresponding UE-specific CHBW cannot be located anywhere within a wider BS carrier resource grid: the said transmission bandwidth configuration cannot both be PRB aligned and separated by a multiple of 100 kHz to the center SC of the resource grid on the channel raster for m\*180 + 90 = n\*100 has no solution for any integers. If, on the other hand, the *carrierBandwidth* of the carrier resource grid is an odd/even number and the maximum transmission bandwidth configuration for the UE CHBW is odd/even for SCS = 15k, then the UE-specific CHBW can only be located with 5 PRB granularity, solutions to m\*180 = n\*100.

Notwithstanding the above we assume that symmetric UE-specific channel bandwidths (MHz) can be set at the default duplex spacing: the centre frequencies of the UL and DL channel bandwidths as set by the parameters of the *downlinkChannelBW-PerSCS-List* and *uplinkChannelBW-PerSCS-List* should be at default duplex spacing that is, the default TX-RX *carrier* centre frequency separation as specified in clause 5.4.4 of 38.101-1. We also assume that the BWP#0 are configured such that the UE can locate symmetric CHBW at default duplex spacing during initial access.

Next, we illustrate the method for a 7 MHz block within an operating band with a 100k channel raster and assuming the restrictions that

- the SIB1 *carrierBandwidth* and any UE specific channel bandwidth on the 100k channel raster, carrier bandwidths and maximum transmission bandwidth configurations for UL and DL either all odd or all even, otherwise impossible to put a narrower channel inside a wider BS/cell bandwidth

- the *BS channel bandwidth* supports a single NR RF carrier in the uplink or downlink as specified in 38.104. UL/DL *carrierBandwidth* in SIB1 only to a UE channel bandwidth (Rel-15)

We also note that these restrictions may impact the number of PRB that can be scheduled within the irregular spectrum block (the number of blanked PRB within the carrier resource grid) or the actual irregular spectrum block size that can be supported.

Figure 6.1.2.1.2-1 shows the configuration, the next-after-next larger bandwidth is used in this case such that the resource grid size of this and the smaller bandwidth used for the UL are both an odd number of PRBs. The size of the BWP#0 is 25 PRB in both the UL and DL, located at duplex spacing such that a UE only capable at locating its CHBW at the 100k channel raster can attach. UEs supporting the asymmetric channel bandwidth combination 5 MHz and 15 MHz can utilize the irregular block (the cell bandwidth) and legacy UEs not supporting this bandwidth combination can also be supported in the cell. UEs not supporting the 5 MHz channel bandwidth will not attach to the cell thus ensuring that unwanted emissions requirements in the UL are met by all capable UEs.

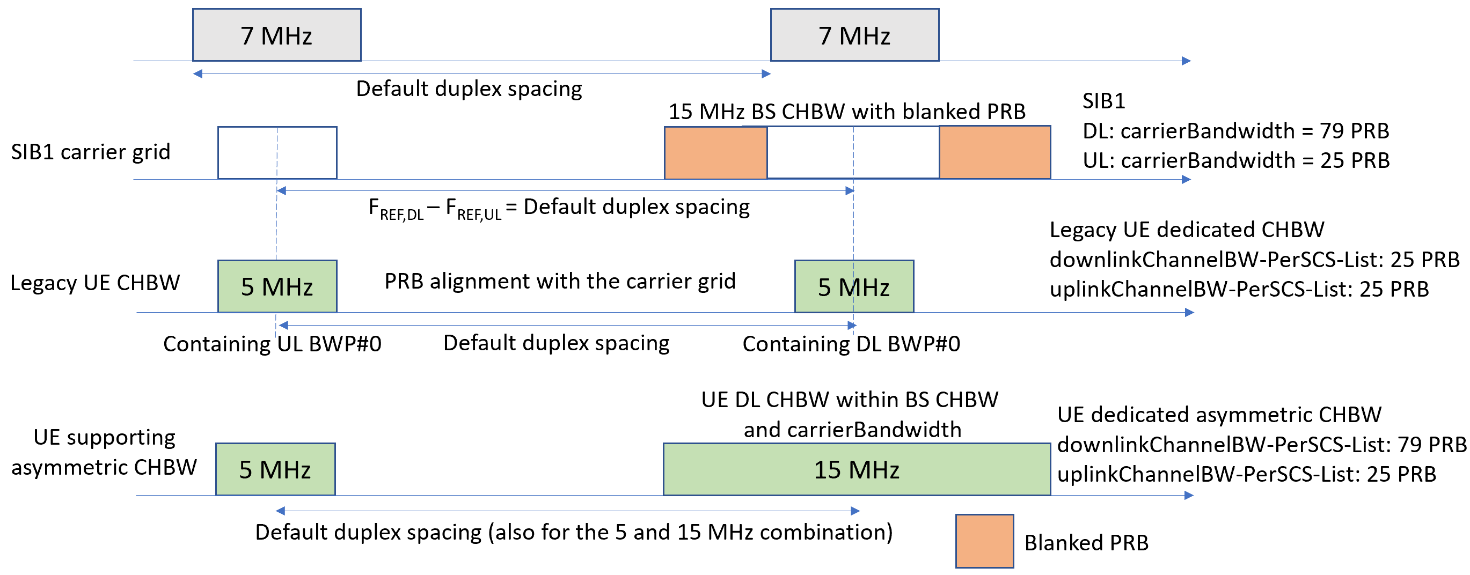


Figure 6.1.2.1.2-1: a 7 MHz irregular block within an FDD band.

The SIB1 procedure for initial attach is separate for the UL and DL. In case some UE implementations do not allow different carrier grid for the UL and DL (while still corresponding to UE CHBWs) then the next-after-next larger BW and PRB blanking can be used both in the UL and DL. The downside of this arrangement is that unwanted emissions are not ensure in case the UE uses a bandwidth wider than the BWP#0 (25 PRB) during initial access. The Point A of the UL and DL can be located with 5 kHz granularity.

The arrangement in Figure 6.1.2.1.2-1 would not support the case of an irregular block 817-824/862-869 MHz at the lower part of n26. However, the DL carrier grid corresponding to the 15 MHz CHBW can be shifted upwards by n\*900 MHz (5 PRB) such that the 15 MHz CHBW is within the band range (above 814 MHz) thus increasing the BS duplex spacing between the UL and DL carriers while maintaining PRB alignment and the default duplex spacing for the 2 x 5 MHz UE-specific bandwidths and the BWP#0. The default duplex spacing is not specified for the BS (cell) bandwidth and the SIB1 procedure for initial attach is separate for the UL and DL.

The methods only require one specification change: the UE must support the asymmetric channel bandwidth pair 5/10 MHz or 5/15 MHz for Band n26. Regular CHBW bandwidths are used for UE conformance tests, while the BS must meet the unwanted emissions limits and other regulatory requirements also for the irregular spectrum block.

##### 6.1.2.1.3 TDD

The method can readily be applied to the TDD case. Most TDD bands have an SCS-based raster rather than a 100k raster for alignment with LTE and therefore not subject to any potential restrictions that UE-specific CHBW cannot be configured with PRB granularity within a carrier resource grid. However, TDD is subject to restrictions on the center frequency of BWPs and the location of the Point A. Asymmetric bandwidths are also supported for TDD in existing specification with restrictions.

For the TDD case and bands we make the following additional assumptions:

- the carrier resource grids indicated in SIB1 for the UL and DL, the BWPs configured and UE-specific CHBW are all PRB aligned and use the same center frequency

- the carrier bandwidths for UL and DL (PRB) advertised in SIB1 are either both even or odd, the same applies for the transmission bandwidth configuration of the UE-specific CHBW are both either even or oddfor PRB alignment

- the UE dedicated regular channel bandwidths (MHz) with their corresponding maximum transmission bandwidth configurations (including the larger) are located within the DL and UL carrier bandwidths that may also include blanked PRBs

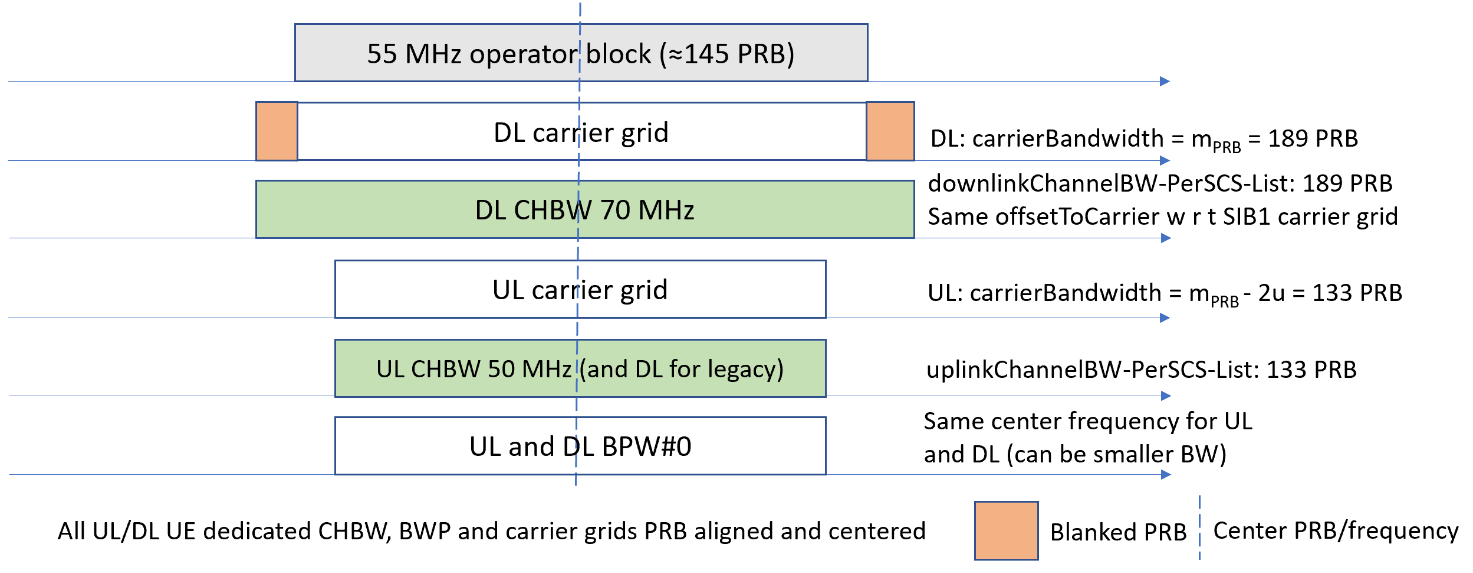
This would also ensure that the UE-specific CHBW meet the existing conditions for asymmetric bandwidths (Rel-16):

- both center frequency and BWP-ID shall match between DL and UL carriers as defined in 38.331

- in a case a UE is configured with a full width of BWP within both UL/ DL channels, the center frequency of UL/ DL channels shall be same

- a position of Point A is common between UL and DL carriers as defined in 38.331

Figure 6.1.2.1.3-1 shows an example of a 55 MHz spectrum block with DL and UL carrier grids of different sizes for SCS = 30k, about 145 PRBs used (not blanked) in the DL. The DL carrier resource grid size of mPRB = 189 PRB corresponds to the next-after-next larger DL bandwidth of 70 MHz, while the UL carrier bandwidth indicated in SIB1 is mPRB - 2u = 133 PRB corresponds to the next smaller bandwidth of 50 MHz with 2u the symmetric DL extension (both the UL and DL carrier grids are thus either odd or even sized) also covering blanked PRB. The bandwidth of BWP#0 is equal for the DL and UL and sized 133 PRBs or smaller. Thus legacy UEs only supporting symmetric CHBW can also attach to the cell.

Figure 6.1.2.1.3-1: support of a 55 MHz irregular channel block for TDD.

It is recognised that the restrictions above can imply limitations on the transmission bandwidth configuration of an irregular block (PRBs not blanked) or the irregular spectrum block size supported. However, it suffices that UEs support asymmetric bandwidths for the TDD band, a 50/70 MHz combination for the case above.

The method above also works for TDD bands with a 100k channel raster. The case of an irregular spectrum block at the band edge is described in section 6.1.2.4.

#### 6.1.2.2 Method using Next smaller channel bandwidth is broadcast in SIB1

The gNB broadcasts the DL carrier bandwidth and the bandwidth of the initial BWP (BWP#0) in SIB1. For the 7MHz allocation, SIB1 can indicate DL next smaller standard channel bandwidth, i.e., 5 MHz, and that the initial DL BWP can be set to 25PRBs:

- SIB1-> servingCellConfigCommon-> downlinkConfigCommon-> frequencyInfoDL-> scs-SpecificCarrierList-> carrierBandwidth = 25 PRBs / subcarrierSpacing = 15 kHz

- SIB1-> servingCellConfigCommon-> downlinkConfigCommon-> initialDownlinkBWP-> genericParameters-> locationAndBandwidth = 25 PRBs

Once the UE established the RRC connection, the gNB can account for the UE capabilities and re-configure the UE accordingly. At this point the gNB will override the carrier bandwidth value that the UE obtained from SIB1 and configure a dedicated BWP with a bandwidth that differs from the bandwidth of BWP#0. For the 7MHz allocation, gNB will override the SIB1 channel bandwidth by 10MHz and configure a larger BWP that will cover the whole 7MHz irregular channel.

- ServingCellConfig-> downlinkChannelBW-PerSCS-List-> carrierBandwidth = 52 PRBs, subcarrierSpacing = 15 kHz

- ServingCellConfig-> downlinkBWP-ToAddModList-> bwp-Common-> genericParameters->locationAndBandwidth = 35 PRBs

While not ruled out by the RRC specification, configuration of a UE-specific CHBW wider than the carrier bandwidth indicated by SIB1 and BWPs wider than this resource grid require further consideration and may be subject to UE capability.

It should be noted that BWPs of sizes different from the already defined channel bandwidths are not currently tested within the RAN4 defined requirements. As such, UE behaviour under such configuration is not verified by RAN4 requirements.

The above configuration doesn’t consider the PRB grid alignment between SIB1 channel bandwidth and UE configured channel bandwidth based on the 100 kHz channel raster.

#### 6.1.2.3 Further Signalling and configuration aspects: Band Edge

The network only configures channel bandwidth according to UE capabilities. RAN4 requirements do not cover the case when a UE is configured with a channel that is not contained within a specified band. Thus, if the network were to configure the UE channel bandwidth beyond the band edge, then the UE behavior would be unknown.

However, one approach to avoid the unexpected UE behavior is for the NW to ensure that the UE CBW filter will not exceed the NR band edges. This can be achieved as long as the wider CBW is not wider than the NR band. The NW can control the UE CBW filter location near band edges by setting the CRB0 location (within RIV *locationAndBandwidth*) and *carrierBandwidth.* Then the NW can set BWP to utilize the RBs aligned to the left or right edge of the UE carrier bandwidth using , etc. In this manner there is no need or the NW to schedule the UE CBW filter outside the NR band edge, potentially leading to unknown UE behaviour. Further channel filter configuration examples can be seen in Section 6.1.3 which show how the NW can avoid setting the UE CBW filter outside the band edge.

For the FDD case with a 7 MHz irregular block at the band edge, the arrangement in Figure 6.1.2.1.2-1 can be modified by shifting the DL carrier grid corresponding to the 15 MHz CHBW upwards by n\*900 MHz (5 PRB) as shown in Figure 6.1.2.3-1 such that the 15 MHz CHBW is within the band range thus increasing the BS duplex spacing between the UL and DL carriers while maintaining PRB alignment and the default duplex spacing for the 2 x 5 MHz UE-specific bandwidths and the BWP#0. The default duplex spacing is not specified for the BS (cell) bandwidth and the SIB1 procedure for initial attach is separate for the UL and DL.

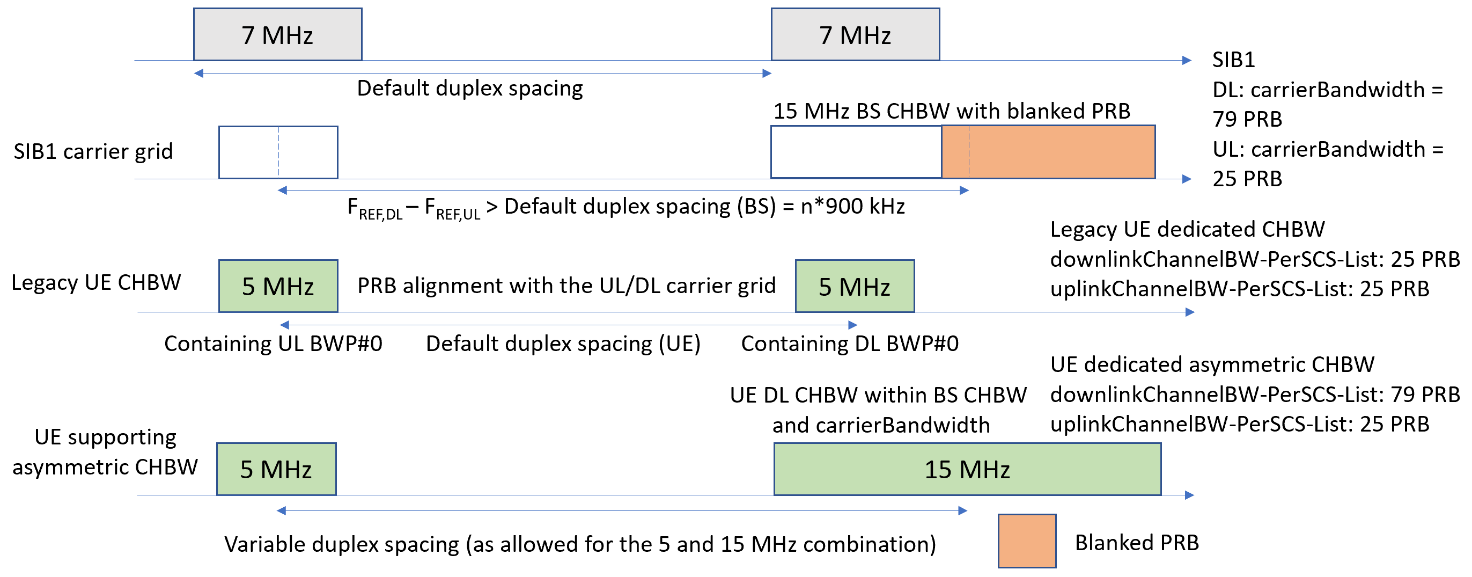


Figure 6.1.2.3-1: the FDD case with the irregular spectrum block at the band edge.

For the TDD case illustrated in Figure 6.1.2.1.3-2 with a 55 MHz irregular block at the band edge, a common center frequency for all CHBW and BWP can be maintained but with the bandwidths adjusted to optimize the transmission bandwidth configuration of the irregular block (PRBs not blanked) as shown in Figure 6.1.2.3-2. The additional BWP#1 configured for UEs supporting asymmetric bandwidth and the irregular channel bandwidth is also centred with the PRBs at the upper edge blanked. Legacy UEs are configured with the BWP#0 or any other BWP within the 40 MHz block, each additional BWP with common center frequency.

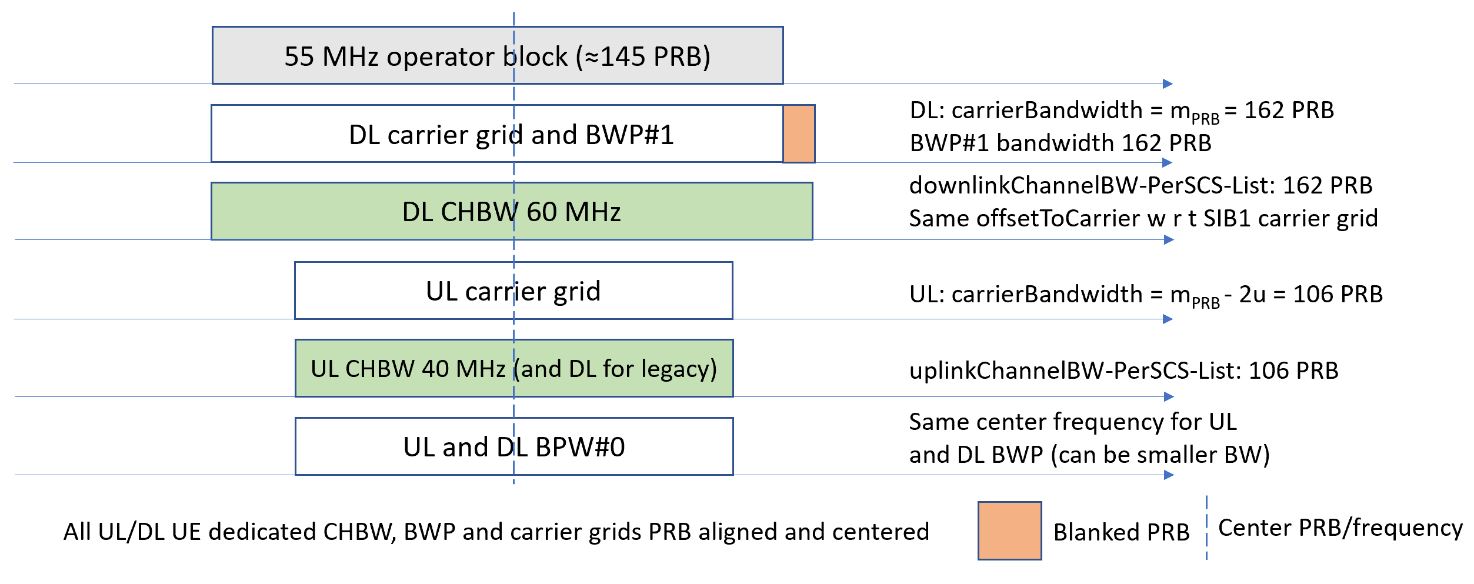


Figure 6.1.2.3-2: the TDD case with the irregular spectrum block at the band edge.

#### 6.1.2.4 Configuring a UE with a Channel not Fully Contained within the Operating Band

The possibility of configuring a UE with a channel that is not fully contained within the operating band supported by the UE was investigated in the context of using some spectrum allocation in n12 and n85(See Annex <A>, the case of n12 and n85).

RAN1 and RAN2 specifications are written agnostic to the operating bands and channel placements, hence, the current signaling supports configuring a channel that is not fully contained within the operating band. However, RAN1 and RAN2 clarified during the study that such a configuration was never discussed or analyzed, hence, the UE behavior under such a configuration is unknown.

Current RAN4 requirements are defined under the assumption that the BS and UE channel bandwidths are fully contained within one of the operating bands defined in the specifications. For example, Table 5.4.2.3-1 which defines the channel raster for each band contains NOTE 1 which states that “The channel numbers that designate carrier frequencies so close to the operating band edges that the carrier extends beyond the operating band edge shall not be used.”

In order to support such a configuration, at least a new UE capability would be needed. Also, in order to ensure that the UEs still meet the necessary requirements (including regulatory) the network would have to limit the RBs used by the UE to those that are confined within the operating band supported by the UE(see also Section 6.1.2.3). The note pointed out in the paragraph above would also have to be updated and any impact to legacy UEs should be avoided.

### 6.1.3 UE channel filters

A typical UE architecture utilises a number of filters of two major types – analogue and digital – and it is generally up to the UE implementation how they are combined. Nevertheless, it is often the case that a UE uses first the wideband analogue filter which typically covers a whole band. In addition to that, a UE may use another NR channel bandwidth specific analogue filter, premise function on which is to filter our non-adjacent blockers. However, since even the NR channel bandwidth specific analogue filter cannot ensure "brick-wall" like filtering, a UE also applies digital filter after ADC to eliminate adjacent interferer. Depending on the UE implementation, the digital filter is a combination of the hardware and software components that allow the UE to apply the corresponding filter coefficients to support a wide range of standard channels, e.g. from 5MHz to 100MHz in case of FR1.

As an example, consider Figure 6.1.3-1. In this example, RBs are scheduled close to the NR band edge. The potential adjacent interferer below the band edge will be removed by the CBW filter with no degradation of ACS at the lower side of the irregular BW since the filters have the same capability as the regular CBW operation.



Figure 6.1.3-1: Example of the NW utilizing the lower RBs near the NR band edge with BWP

However, for the scenario in the Figure 6.1.3-2 the wider channel filter cannot protect against adjacent interferer(s) when the irregular spectrum block is narrower than the channel filter and/or there are adjacent interferers on both sides.

NOTE: for the text above multi-operator scenario can be considered further in this example.

Current specifications do not define how a UE configures its digital filter within the configured channel bandwidth. So, in the provided example below, a UE implementation may configure the digital filter in accordance with the carrier bandwidth "ignoring" the actual smaller bandwidth part size. This is illustrated further in Figure 6.1.3-2. The wanted signal is smaller than 10MHz, but the UE filter is always set to 10MHz as signalled by the network. As can be seen, if there is an adjacent interferer, then it can "leak" into the wanted signal region.

Figure 6.1.3-2: Possible scenarios for the 10MHz channel filter.

To estimate anticipated performance described in Figure 6.1.3-2 when a UE configures its digital filter according to the channel bandwidth potentially allowing the adjacent interferer to "leak" into the wanted signal area, a series of measurements were conducted using the same testbed and setup as used for the commercial device conformance testing. The adjacent interfering signal is always set in such a way that it is right next to the wanted irregular channel bandwidth signal. Table 6.1.3-1 below summarises adjacent interfering channel parameters used in measurements, where adjacent interferer offset is the offset from the wanted signal center to the adjacent interfering signal center.

Table 6.1.3-1: Summary of adjacent interfering signal parameters.

|  |  |  |  |
| --- | --- | --- | --- |
| Irregular channel (MHz) | Effective bandwidth (MHz) | Adjacent interferer offset (MHz) | Adjacent interferer bandwidth (MHz) |
| 9 | 8.28 | 7 | 5 |
| 8 | 7.2 | 6.5 |
| 7 | 6.3 | 6 |
| 6 | 5.22 | 5.5 |

The following common parameters were applied:

- Center frequency: 1850MHz

- UE channel: 10MHz

- Wanted signal level at UE antenna: -82dBm

- Adjacent interferer level at UE antenna: from -120dBm to -50dBm in step of 1dB

- Adjacent interferer: 5MHz, 16QAM, SCS 15kHz (3GPP standard ACS test)

Intermediate irregular channel bandwidths are considered – from 9MHz to 6MHz – and the adjacent interferer offset is set accordingly. As the main performance indicator, the resulting SNR is estimated over the whole 10MHz region irrespective of the actual irregular channel size. This approach provides the worst-case estimation of the resulting SNR because in the real life a UE will most likely estimate SNR over the configured bandwidth part corresponding to the irregular channel size or its sub-part.

As can be seen from Figure 6.1.3-3 below, when the adjacent interferer level is low then the estimated SNR is around 39dB for all irregular channels (if the wanted signal is -82dBm and the adjacent interferer is -120dBm, then the theoretical SNR would be around 38dB, but in our case the adjacent interferer is not even fully inside the wanted signal bandwidth). The 9MHz irregular channel bandwidth has same SNR of 39dB even when the adjacent interferer level is same as the wanted signal. SNR degradation starts at the adjacent interferer level of approximately -72dBm, i.e. 10dB higher than the wanted signal. When the adjacent interferer level is 32dB higher than the wanted signal, i.e. -50dBm, the estimated SNR is around 27dB for the 9MHz irregular channel.

As for the opposite extreme case of the 6MHz irregular channel, SNR degradation can be already observed at the adjacent interferer level of around -100dBm, i.e. 18dB lower than the wanted signal. When the adjacent interferer level becomes as high as the wanted signal, the estimated SNR drops down to 27dB. Finally, when the adjacent interferer is 32dB higher than the wanted signal, the SNR becomes -5dB.

These results show the relative degradation in SNR that can occur due to adjacent channel interferers leaking through the next larger BW filter, and the actual performance degradation will depend on a particular scenario, especially ACI strength and the UE channel filter overlap with the interfering signal. Typical 3GPP ACS requirements are conducted so that a UE should be able to meet 95% of the target throughput of the reference QPSK level when the adjacent interferer is 32dB higher than the wanted signal (and which corresponds to approximately -1.5dB SNR). Referring to the right-most point on the X-axis of Figure 6.1.3-3, it can be seen that 9MHz and 8MHz irregular channel SNR is above -1.5dB, while the 6MHz channel SNR is clearly below -1.5dB.

NOTE: The corresponding throughput measurements should be also provided to assess throughput degradation, if any, in the QPSK reference channel.

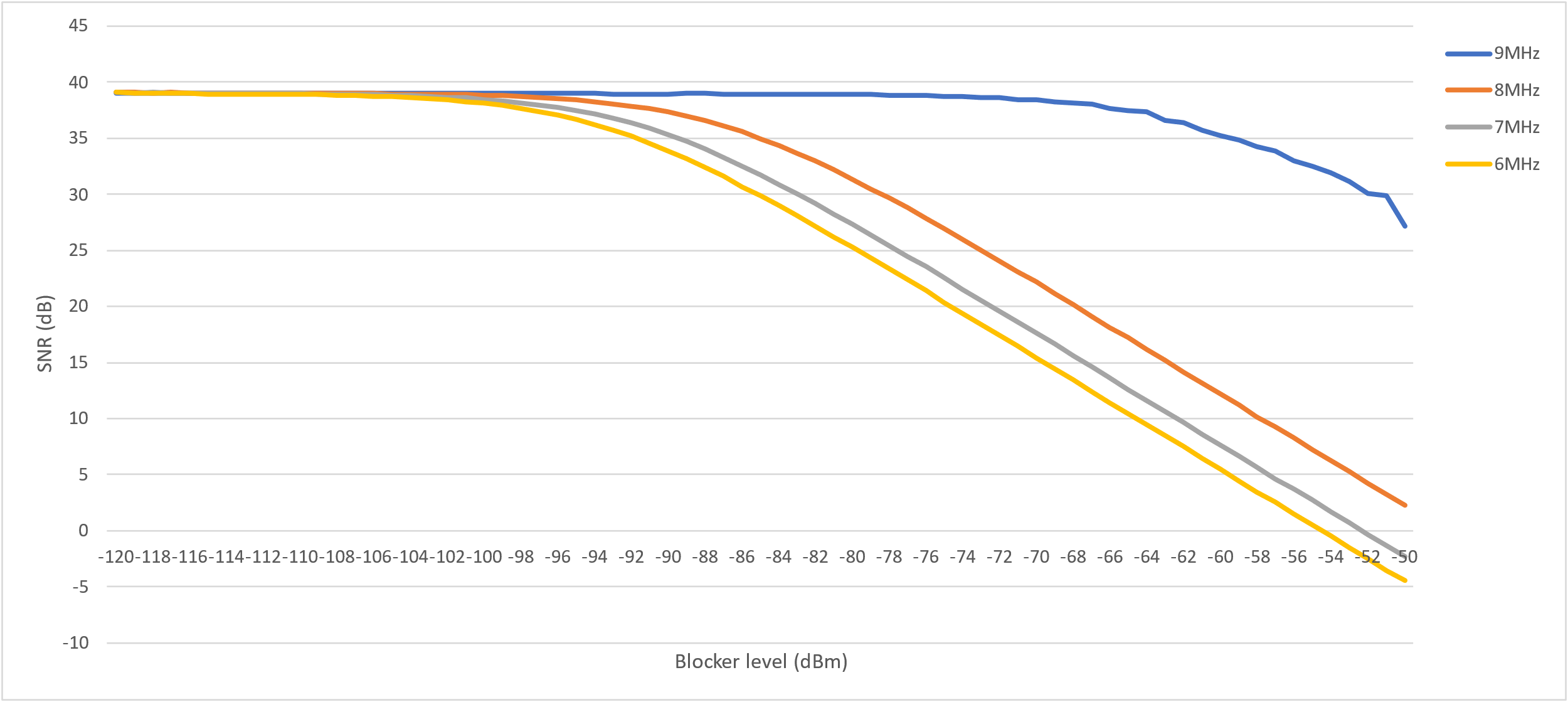


Figure 6.1.3-3: Estimated SNR depending on the adjacent interferer level.

To further reduce the risk of ACS reduction, as shown in this second example in Figure 6.1.3-2 and Figure 6.1.3-3, it is possible for new UEs to align their digital filter to the actual smaller bandwidth part within the wider analogue CBW filter bandwidth.

NOTE: It is FFS whether it will require new UE capability and/or configuration signalling for the NW to indicate the adjacent interferer location, left, right of the BWP.

## 6.2 Study of overlapping UE channel bandwidths

### 6.2.1 Overlapping UE CBWs from Network Perspective

#### 6.2.1.1 General

One way to utilise the whole chunk of irregular spectrum of a particular size is to combine several overlapping channels of next lower standard channel bandwidth. As an example, Figure 6.2.1.1-1 shows a case when two overlapping 10MHz carriers cover 13MHz channel bandwidth. From an individual UE perspective, each UE is configured with existing immediately lower channel bandwidth following legacy procedures and signalling: one UE can use the first 10MHz carrier, while another UE can use another carrier. In fact, both UEs can use overlapping part of the spectrum provided that the BS takes care that the overlapping region is allocated to one particular carrier at a time. It should be also noted that from the UE perspective, an existing immediately lower channel bandwidth will be always used, either for initial access (as the channel bandwidth advertised by the network) or as a dedicated channel bandwidth configured by RRC. From the network perspective, the BS will/can use the whole irregular channel bandwidth.



Figure 6.2.1.1-1: Using overlapping carriers (example for 13MHz).

It is worth noting that overall capacity of the cell will be according to the irregular channel bandwidth because the BS can use the full bandwidth. However, since a particular UE will use only one carrier of a smaller bandwidth within the irregular channel bandwidth, the maximum throughput for a single UE will be less than the theoretically possible within the spectrum in case there is only a single UE in the cell. Nevertheless, since there will be multiple UEs in the cell the overall system throughput will not decrease.

#### 6.2.1.2 Detailed description

One of the challenges associated with configuring overlapping carriers for the same frequency allocation is that both carriers should have aligned grid so that the BS can perform same FFT and schedule resources in the overlapping region.

While aligning RB grids is not an issue for bands above 3GHz that have the SCS based raster, it becomes more challenging for the sub-3GHz band that have 100kHz raster. As a result, carriers can be configured on raster points that correspond to the least common multiple of the channel raster and the RB size. As an example, the least common multiple will be 900kHz in case of the 15kHz SCS, which corresponds to 5RBs. It effectively means that overlapping carriers will not be able to address efficiently any irregular spectrum size and in some case maybe will not be applicable at all. Of course one way to improve spectrum utilisation is to allow shifting carriers in multiples of 1RB, but that will require introduction of new raster points, which will not be supported by legacy UEs.

Figure 6.2.1.2-1 presents an example for the 6MHz channel comprising two 5MHz channels. As can be seen from the figure, centre frequency distance between carriers is 900kHz, which is a multiple of 100kHz channel raster and 180kHz RB size. From an individual UE perspective, it is just a normal 5MHz carrier comprising 25RBs and having the 5MHz channel guard bands. From the BS perspective, it is a 6MHz channel with 30RBs. Figure 6.2.1.2-2 exemplifies how this approach can be used to support the 7MHz irregular channel bandwidth, in which the distance between the carriers is 1800kHz. Finally, Figure 6.2.1.2-3 shows the 11MHz channel that is supported with two 10MHz channels. Referring to Figure 6.2.1.2-1, 6.2.1.2-2 and 6.2.1.2-3, it should be noted that guard bands will not necessarily be symmetrical and the exact guard band size will depend on a particular spectrum allocation, its size, and how the overlapping channels are placed.



Figure 6.2.1.2-1: Detailed overview of overlapping carriers (6MHz channel with 5MHz carriers).



Figure 6.2.1.2-2: Detailed overview of overlapping carriers (7MHz channel with 5MHz carriers).

Figure 6.2.1.2-3: Detailed overview of overlapping carriers (11MHz channel with 10MHz carriers).

Table 6.2.1.2-1 below summarises potential number of schedulable RBs for a scenario when the next smaller overlapping channels are used. To calculate them, it is assumed that distance between individual carriers is a multiple of 900kHz and that the resulting guard bands must meet at least next smaller channel requirements. So, "Channel Nrb", and "Utilisation" represent the network view, while from the UE perspective all the parameters are the same as for the next smaller channel.

Table 6.2.1.2-1: Exemplary number of RBs based on the next smaller overlapping channel (15kHz SCS).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Channel (MHz) | Next smaller channel (MHz) | Next smaller channel guard band (kHz) | Next smaller channel Nrb | Channel Nrb | Utilisation (%) |
| 6 | 5 | 242,5 | 25 | 30 | 90 |
| 7 | 5 | 242,5 | 25 | 35 | 90 |
| 11 | 10 | 312,5 | 52 | 57 | 93,3 |
| 12 | 10 | 312,5 | 52 | 62 | 93 |
| 13 | 10 | 312,5 | 52 | 67 | 92,8 |

Table 6.2.1.2-2 presents similar calculations for the number of available RBs with overlapping carriers, but for the 30kHz SCS. As can be seen from the table, a solution based on the 30kHz SCS overlapping carriers does not provide a good spectral utilisation for certain non-standard channel bandwidths due to the reason that the "distance" between carriers raster points must be a multiple of 1800kHz. Because of that, channel bandwidths such as 7 and 12MHz have more or less good utilisation, whereas 6 and 11MHz do not provide any benefit at all.

Table 6.2.1.2-2: Exemplary number of RBs based on the next smaller overlapping channel (30kHz SCS).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Channel (MHz) | Next smaller channel (MHz) | Next smaller channel guard band (kHz) | Next smaller channel Nrb | Channel Nrb | Utilisation (%) |
| 6 | 5 | 505 | 11 | 11 | 66 |
| 7 | 5 | 505 | 11 | 16 | 82,3 |
| 11 | 10 | 665 | 24 | 24 | 78,5 |
| 12 | 10 | 665 | 24 | 29 | 87 |
| 13 | 10 | 665 | 24 | 29 | 80,3 |

To suppport two overlapping carriers, the network can consider using one or two SSBs. To be more precise, since the the SSB bandwidth is 3.6MHz and the CORESET#0 bandwidth is 4.32MHz, a single SSB/CORESET#0 can be placed into a common part between two overlapping channels. However, this approach works only if the overlapping part is at least 4.32MHz, e.g. it is not applicable to irregular channels smaller than 10MHz. So, some irregular channel bandwidth will need two SSB/CORESET#0. In this case, at least for irregular channel bandwidths smaller than 10MHz the network broadcasts two separate SSBs, one for each overlapping regular carrier. If a particular irregular channel bandwidth does not allow for placing two SSBs in the same time slots, then the network will have to ensure that they are "multiplexed" accordingly in the time domain.

NOTE: It may create the challenge of aligning SSBs in the time and frequency domain so that they do not overlap thus complicating the gNB scheduling, i.e. for this approach complexity increases to coordinate the overlapping SSBs for different UEs.

From the RAN2 specifications perspective, a single cell has a single cell-defining SSB, the channel bandwidth configuration broadcast in SIB1, CORESET#0, and the initial BWP. Thus, a single "common" SSB for two overlapping channels will effectively define only one of the overlapping channels as perceived by the UE (refer to sub-clause 6.2.1.3 for more information on configuration and signalling aspects with one and two SSBs).

NOTE: It is up to the network implementation whether to configure two SSBs for overlapping channels or one "common" SSB if the overlapping part is large enough (refer to Table 6.2.1.2-3).

Table 6.2.1.2-3: Summary of how many SSB/CORESET#0 needed for different channel bandwidths.

|  |  |  |
| --- | --- | --- |
| Channel (MHz) | Number of SSB/CORESET#0 | Time multiplexing for 2 SSBs is needed |
| 6 | 2 | yes |
| 7 | 2 | yes |
| 11 | 1 or 2 | no |
| 12 | 1 or 2 | no |
| 13 | 1 or 2 | no |

Figure 6.2.1.2-5 shows an example for the 13MHz irregular channel with a single/common SSB configured in the overlapping part of two 10MHz carriers.

Graphical user interface, text, application, email

Description automatically generated

Figure 6.2.1.2-4: Using overlapping carriers with single overlapping SSB (example for 13MHz).

#### 6.2.1.3 Configuration and signalling aspects

Since from an individual UE perspective each overlapping carrier is just a legacy channel bandwidth, the existing signalling applies. As an example, for the 7MHz allocation the UE can be configured with the 5MHz channel bandwidth, and the initial bandwidth part can be also 5MHz.

- SIB1-> servingCellConfigCommon-> downlinkConfigCommon-> frequencyInfoDL-> scs-SpecificCarrierList-> carrierBandwidth = 25 PRBs / subcarrierSpacing = 15 kHz

- SIB1-> servingCellConfigCommon-> downlinkConfigCommon-> initialDownlinkBWP-> genericParameters-> locationAndBandwidth = 25 PRBs

If the network configures two SSBs for an overlapping channel, then from the UE perspective each overlapping channel is perceived as an independent cell and a UE can camp on each cell following the existing cell (re-)selection procedures. If the network configures one "common" SSB, then from the UE perspective only one of the overlapping channels is perceived as a cell and some UEs will be re-configured with a dedicated channel bandwidth to another overlapping channel.

NOTE: From the signalling perspective, it is possible to override the SIB1 channel bandwidth by the dedicated channel bandwidth signalling in the RRC\_CONNECTED state.

#### 6.2.1.4 Channel raster handling

The UE channel BWs have to be backwards compatible such that this scheme works for existing UEs, hence, they would have to be deployed on the 100kHz raster used in the low FR1 bands. As such, the UE channels have to be deployed at a distance which is a multiple of 900kHz (common denominator between the RB size of 180kHz and 100kHz channel raster granularity).

The base station channel encompasses the overlapping UE channels. In the case that the distance between the UE channel centers is an even multiple of 900kHz, the center of the base station channel will also fall on a 100kHz multiple. In the case of an odd 900kHz multiple, the center of the base station transmission bandwidth configuration would fall in the middle of the 900kHz interval between the overlapping UE channel centers. This might require some additional specification work for BS.

### 6.2.2 Combined UE CBW (one cell)

#### 6.2.2.1 General Aspects

- Studied spectrum blocks covered by “main RF carrier” and “additional RF carrier”

- The “main RF carrier” is Rel-15 compatible and contains the SSB as well as all necessary broadcast information, legacy UEs and UEs which do not support this solution are able to camp on it and be connected without being aware of the “additional RF carrier”

- The “additional RF carrier” , which is partially overlapping with the “main RF carrier”, is aligned to the “main RF carrier” PRB grid and utilizes further PRBs that fit in relevant spectrum block. UEs which support this solution would be reconfigured (once UE capabilities are known) in RRC\_CONNECTED to use wider CBW and BWP than used for initial access.

- The “main RF carrier” and the “additional RF carrier” are treated as single cell (one carrier from baseband perspective) to allow for a single BWP to cover studied spectrum block in RRC\_CONNECTED

- Both the “main RF carrier” and the “additional RF carrier” would clearly define the size and position of the guard band which allows for an unambiguous placement of the overlapping channel filters and thus prevents problems with OBUE, ACS or in-band blocking

- From UE perspective, supported in downlink only

#### 6.2.2.2 Signalling and configuration aspects

In this section we provide further signaling details on how to support irregular channels given the 7MHz allocation as an example.

The gNB broadcasts the DL carrier bandwidth and the bandwidth of the initial BWP (BWP#0) in SIB1. For the 7MHz allocation, SIB1 would indicate DL standard channel bandwidth (i.e. 5 MHz), the initial DL BWP would be set to 5 MHz to accommodate legacy and new UEs:

- SIB1-> servingCellConfigCommon-> downlinkConfigCommon-> frequencyInfoDL-> scs-SpecificCarrierList-> carrierBandwidth = 25 PRBs / subcarrierSpacing = 15 kHz

- SIB1-> servingCellConfigCommon-> downlinkConfigCommon-> initialDownlinkBWP-> genericParameters-> locationAndBandwidth = 25 PRBs

Once the UE established the RRC connection, the gNB can account for the UE capabilities and re-configure the UE accordingly. At this point the gNB may override the carrier bandwidth value that the UE obtained from SIB1 and configure a dedicated BWP with a bandwidth that differs from the bandwidth of BWP#0. gNB may configure a larger bandwidth part that will cover the whole 7MHz allocation.

- ServingCellConfig-> downlinkChannelBW-PerSCS-List-> carrierBandwidth = 36 PRBs, subcarrierSpacing = 15 kHz

- ServingCellConfig-> downlinkBWP-ToAddModList-> bwp-Common-> genericParameters-> locationAndBandwidth = 36 PRBs

It should be noted that 36 PRBs do not correspond to any channel bandwidth currently defined in TS 38.101-1.

It is possible from signalling point of view to override the SIB1 channel bandwidth by the dedicated channel bandwidth signalling in RRC\_CONNECTED if the UE is capable of the dedicated channel bandwidth, and if the network ensures the SIB1 channel bandwidth and dedicated channel bandwidth use the same PRB grid. New capability might be needed to support such configuration [3].

#### 6.2.2.3 UE architecture aspects

With respect to the UE architecture, the following assumptions are made (according to SID objectives):

- New (dedicated) channel filters (e.g. non-integer-multiples of 5 MHz) are not considered

- UEs not supporting this solution (both legacy and new UEs) should be able to use the next lower supported channel bandwidth in the UL and DL without implications

Two different UE architecture scenarios are explained (legacy UEs using next smaller bandwidth in section 6.6.2 and UEs supporting two receive chains for reception described below):

This option is for new UEs that contain transceiver architectures and configurations that have flexibility in local oscillator and receive chain assignments. The flexibility in the configuration allows the UEs to configure their receive paths (Antenna to FFT) similarly to non-contiguous carrier aggregation, allowing the two LO and receive chains to down-convert the spectrum of the irregular bandwidth as if it consisted of two separate carriers on the UE side. Based on the channel center of the main RF carrier and the configured irregular bandwidth, the UE would know where to place the center frequency of the additional RF carrier that follows the PRB grid (which overlaps with the main RF carrier and includes the remaining agreed PRBs for the irregular BW). The UE down-converts two different sets of PRBs, with an overlapping segment and may use for irregular bandwidth below 15MHz the next smaller bandwidth channel filtering on both of the receive chains as shown in Figure 6.2.2.3-1 (“DigRF” serves as an example only and corresponds to the interface between RF and baseband chipset). This allows the UE to benefit from channel filtering designed for the specific bandwidth. Using the next smaller bandwidth channel filtering on both of the two carrier parts, the baseband signal processing following the FFTs must be modified such that the signals from these two carrier parts are combined and processed as a single codeword instead of being process separately. Since the LOs on the UE will operate at different frequencies, there will be a phase difference of the two signals contained in the two receive chains for the separate carriers.

In order to prevent problems in the channel estimation if there is an averaging or interpolation across reference signals at different subcarriers, the phases of the symbols in the frequency domain from both RF receive chains caused by the UE’s use of separate LOs should be aligned. This can be achieved by a new function comparing the overlapping symbols from both FFT outputs and phase shifting one FFT output accordingly before the FFT outputs are merged.

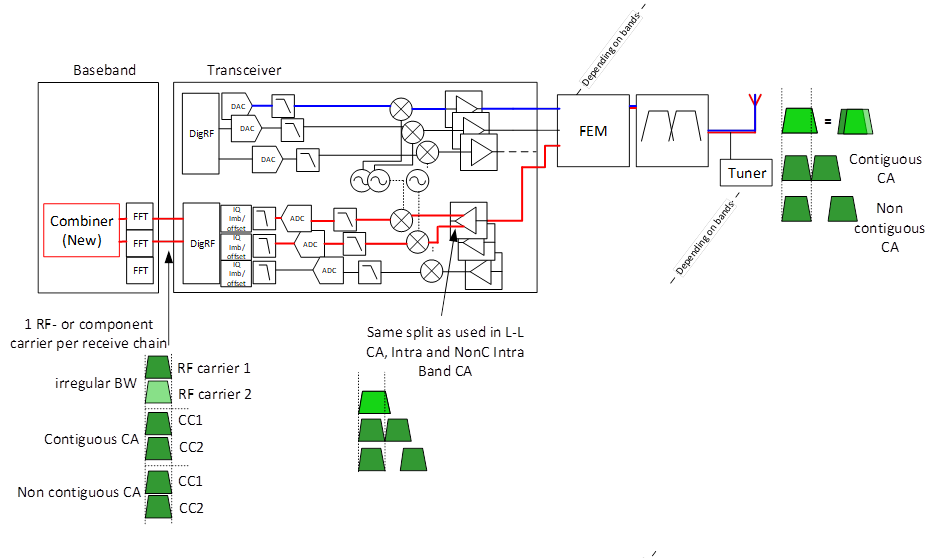


Figure 6.2.2.3-1: UE architecture for full BW support showing split by the use of two LOs

Depending on the receiver architecture and the distribution of the channel filtering between the analogue and the digital domain, it is also possible to A/D convert a frequency range that accommodates the entire irregular BW and to split the signal afterwards by means of NCOs (instead of LOs) into the 2 RF carriers with their individual channel filter positions as shown in Figure 6.2.2.3-2.

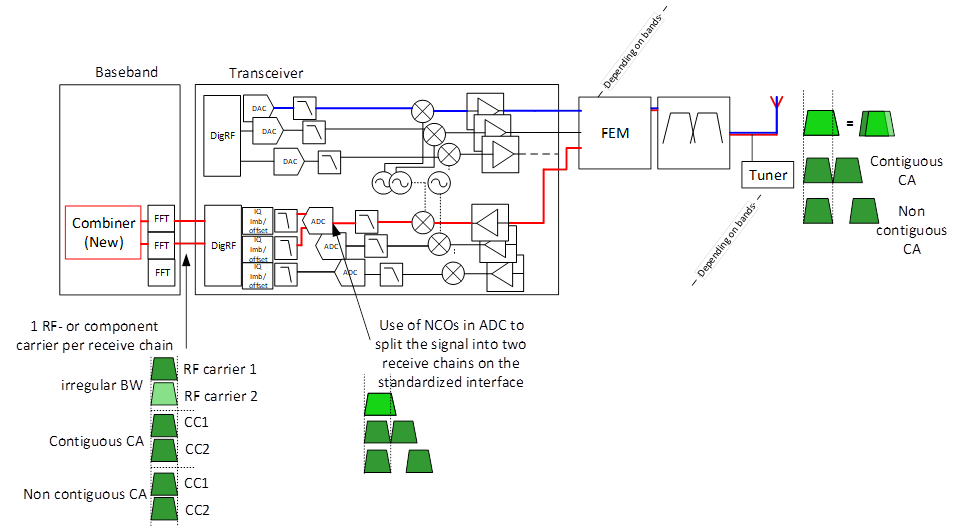


Figure 6.2.2.3-2: UE architecture for full BW support showing split by the use of NCOs

### 6.2.3 Overlapping CA (two cells)

#### 6.2.3.1 General Aspects

Using the Overlapping CA approach to support irregular spectrum is one of the methods without the need of introduction of new dedicated channel bandwidths for both UE and BS. Figure 6.2.3-1 shows overlapping CA from network perspective, in which BS supports the intra-band overlapping CA, while UEs only supports the single CC with the existing channel bandwidth. And figure 6.2.3-2 shows overlapping CA from UE perspective, in which both BS and UE support the intra-band overlapping CA to use all RBs, and the UE supports intra-band non-contiguous CA for the combination as well.

Even two CCs are overlapped in frequency domain, the network can configure different CCs with non-overlapping BWP to avoid the conflict of physical signals or channels.



Figure 6.2.3-1: Overlapping CA from network perspective



Figure 6.2.3-2: Overlapping CA from UE perspective

In summary,

- No new gNB channel bandwidth is required

- Legacy UE using existing lower regular NR channel bandwidth can operate in either carrier

- Overlapping CA approach needs to have PRB grid alignment between overlapping CCs

- From UE perspective, overlapping CA is optional supported in DL only

- Irregular bandwidth utilizing overlapping CA approach cannot be combined with NR CA combinations

- From UE perspective, the solution requires UE support of intra-band non-contiguous CA for the combination

#### 6.2.3.2 Configuration and signalling aspects

In this approach, network configures two cell-defining SSB in the allocated irregular spectrum block and the two cells are configured with overlapping regular channel bandwidth. From procedure wise, the network can indicate UE the location and bandwidth by using the existing procedures on individual CC. From UE perspective, there are two independent cells with overlapped bandwidth. For a particular UE, CA with overlapped cells can be configured to fully utilize the network bandwidth.

## 6.3 Complexity and efficiency study

### 6.3.1 Larger Channel BW than licensed BW

UE needs to support the asymmetric bandwidth combinations where UL CBW is SmallerCBW and DL CBW is WiderCBW. The asymmetric UL and DL channel bandwidth combination set should be specified in the specification TS 38.101-1.

### 6.3.2 Overlapping UE CBW from Network Perspective

gNB has to support the irregular channel BW. It is up to the network implementation how it can be implemented, e.g. through a new channel bandwidth, or through RF combining of 2 existing regular channel bandwidths.

### 6.3.3 Combined UE CBW (one cell)

- Does not require new channel filters for UE and gNB to be designed and tested

- Requires support of two RF carriers phase aligned on the Tx side to ensure phase continuity on the Rx side

- Requires split of the irregular bandwidth into two sets of PRBs that may be filtered through the next smaller bandwidth after which the signal is combined at the receiver’s baseband as a single carrier. For such processing, UE may benefit from supporting intra-band non-contiguous CA.

- Requires UE architecture with capability to split LNA output signal to two separate LO paths for down-conversion. Also requires UE architecture with the ability to combine baseband signals.

- Possible UE architecture alternative to requiring a split LNA, is to use an ADC with a large dynamic range and a subsequent split of the digital signal in two paths with separate NCOs and digital channel filters. Also requires UE architecture with the ability to combine baseband signals.

- For scenarios with less than 10 MHz, second SSB is not excluded but not recommended due to significant additional overhead (duplicated SSB transmission as well as other radio resources such as PDCCH, CSI-RS, PDSCH (for SIB), CSI for Tracking, etc.). However, second SSB could enable or improve the legacy UEs' use of the further PRBs provided by the additional RF carrier in spectrum scenarios with less than 10 MHz.

- “Additional RF carrier” not to be on the channel raster to increase spectrum utilization (up to 2 PRBs), it should be noted that the complete “additional RF carrier” is used only by UEs which support this solution “additional RF carrier” can be used partially (with up to 2 PRBs not available) by legacy UEs which are on the channel raster.

- Proposed BWPs size of the irregular spectrum chunk may have an impact on performance requirements and additional testing

- High spectrum utilization:

- due to low internal guard band. The spectrum utilization values in the table below use guard band values according to the minimum guard bands defined for the smallest possible channel bandwidths that could be theoretically considered as part of each combined UE CBW. The actual minimum guard band requirements for combined UE CBW configurations would require further discussion in any follow-up WI.

- as well as no additional CA overhead (duplicated common channels and signals such as SSB, PDCCH and CSI-RS configured both in Pcell and Scell, in addition of the MAC processes associated with CA) due to single baseband carrier usage:

Table 6.3.3-1: spectrum utilization

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Spectrum block [MHz] | Number of PRBs  (15kHz SCS without 100kHz raster alignment) | Spectrum utilization for new UE (without 100kHz raster alignment) [%] | Number of PRBs  (15kHz SCS with 100kHz raster alignment) | Spectrum utilization for new UE (with 100kHz raster alignment) [%] |
| 6 | 30 | 90 | 30 | 90 |
| 7 | 36 | 92.6 | 35 | 90 |
| 11 | 58 | 94.9 | 57 | 93.3 |
| 12 | 63 | 94.5 | 62 | 93 |
| 13 | 69 | 95.5 | 67 | 92.8 |

### 6.3.4 Overlapping CA (two cells)

From network perspective:

For gNB, no new filter for RF channel is needed. The CA implementation can be reused. The only update is to allow the configuration that the two carriers can be partially overlapped by adjusting the channel spacing. The network can prevent collisions between the two component carriers.

For UE, there is no impact and fully backwards compatible.

From UE perspective:

For gNB, the two RF carriers aggregated by the UE would need to be time-aligned by the gNB to at least the same level required for existing intra-band contiguous CA (TS 38.104 Timing Adjustment Error) to allow UE reception. It is FFS as to whether finer timing alignment would be required.

For UE, it is optional support in DL only. For the UE supports DL intra-band non-contiguous CA with corresponding channel bandwidth(s), overlapping CA can be considered by support the configuration with partially overlapping carriers. And in the case no new channel filter for UE is needed.

For overlapping CA solution, the legacy channel bandwidth should be supported, hence the minimum guardband should not be less than the minimum guardband of lower UE channel bandwidth than operator licensed bandwidth. To support legacy UEs, channel raster should be applied for each UE channels. And in order to simplify the resource schedule and make the use of single SSB (for irregular bandwidths larger than 10MHz) for CA operation, RB alignment is required. Table 6.3.4-1 shows the channel spacing and spectrum utilization for the example channel bandwidths assuming symmetric CA channel bandwidth.

Table 6.3.4-1: channel spacing and spectrum utilization

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Irregular Bandwidth(MHz) | SCS(kHz) | CA combos | Nominal channel spacing (MHz) | Transmission bandwidth configuration NRB | Spectrum utilization (%) |
| 6 | 15 | 5+5 | 0.9 | 30 | 90 |
| 7 | 15 | 5+5 | 1.8 | 35 | 90 |
| 11 | 15 | 10+10 | 0.9 | 57 | 93.3 |
| 12 | 15 | 10+10 | 1.8 | 62 | 93 |
| 13 | 15 | 10+10 | 2.7 | 67 | 92.8 |

## 6.4 Generic solutions guidance

### 6.4.1 Larger Channel BW than licensed BW

Does not require new channel filters for UE to be designed and tested.

### 6.4.2 Overlapping UE CBW from Network Perspective

This approach can be also be applied to all irregular channel bandwidths with only consideration of different spectral utilization considerations. However the single CORESET#0 and SSB is only applicable for bandwidths greater than 10 MHz. For all irregular channel bandwidths two SSBs can be used (in irregular channel bandwidths < 10 MHz SSB can be TDM).

Does not require new channel filters for UE to be designed and tested.

### 6.4.3 Combined UE CBW (one cell)

- Given the availability of a new UE with the required architecture, a future proof solution, the channel bandwidth can be tailored with the resolution of 1PRB. Able to support any irregular channel bandwidth even to the band edge.

- Ensured co-existence with very limited specification impact since both the “main RF carrier” and the “additional RF carrier” and the separate signal processing paths before the equalization would conform to existing 3GPP requirements

- Does not require new channel filters for UE and gNB to be designed and tested

### 6.4.4 Combined UE CBW (two cell)

This approach can be applied to various size of irregular channel bandwidths, and it does not require to define new channel filters to be designed and tested for BS and UE.

Does not require new channel filters for UE to be designed and tested.

## 6.5 RAN1 and RAN2 impact

### 6.5.1 Larger Channel BW than licensed BW

For TDD bands RAN1 requires that the active UL and DL BWP pair must have the same centre frequency.

### 6.5.2 Void

### 6.5.3 Void

### 6.5.4 Combined UE CBW (two cells)

CSI-RS measurement and reporting for the component carriers are specified in TS 38.213 and to be performed independently per-carrier, similarly for PDCCH. It is up to the gNB scheduler to avoid collisions of different transmissions for the overlapping part with overlapping CA cross-carrier scheduling.

Existing UE capability signalling does not provide any possibility for UE to indicate support of overlapped CA. New signalling would be required in order for this approach to become feasible.

## 6.6 Legacy UE impact

### 6.6.1 Void

### 6.6.2 Overlapping UE CBW from Network Perspective

Overlapping channels from the network perspective works with all the legacy UEs. As presented in previous sub-clauses, from an individual UE perspective, this is just a standard Rel-15 channel and no special UE side enhancements are needed. Thus an operator can use this solution with the whole ecosystem of available devices.

### 6.6.3 Combined UE CBW (one cell)

- No impact to legacy UEs. UEs which support this solution would be reconfigured in RRC\_CONNECTED, there is no change to UE behaviour in IDLE mode which could create potential issue with legacy UE compatibility

This option is for UEs that have no support for using an irregular bandwidth. Such a UE will apply the next smaller bandwidth referring to the channel filtering. It will never receive more than the PRBs defined for the next smaller bandwidth and it follows the conventional way of aligning the center frequency of the channel in both DL and UL. These UEs will camp on the same frequency part of the channel since the SIB1 only has one allocation. In CONNECTED mode, the network can configure UE with the UE specific *ServingCellConfig* IE which configures the point A reference that may shift the UE to operate either at the lower side or the upper side of the irregular bandwidth. In most of the configurations with an irregular BW below 10 MHz, legacy UEs can only use one side of the irregular BW unless – as in the case of overlapping CBWs from network perspective – a second, time-staggered SSB is spent.



Figure 6.6.3-1: Legacy UE may be configured for either of the two carriers

6.6.4 Overlapping CA (two cells)

This approach works with legacy UEs in single carrier operation. It is unclear whether legacy UEs would support a CA configuration or UE behavior is undefined with overlapping channel bandwidths as this has not been discussed in RAN2 when designing current UE capabilities and therefore do not consider any frequency overlap in the CA case. Current channel spacing in RAN4 does not assume overlapping carriers so RAN4 specs do not support overlapping CA.

## 6.7 RAN4 standard impact identification

### 6.7.1 Larger Channel BW than licensed BW

UE asymmetric bandwidth combinations for the corresponding spectrum scenarios are needed, handled on band by band basis or by generic requirement.

### 6.7.2 Combined UE CBW (one cell)

Overall impact limited since both the “main RF carrier” and the “additional RF carrier” would conform to existing 3GPP requirements, to guarantee co-existence

### 6.7.3 Overlapping CA (two cells)

The CA framework defines the transmitter emission and receiver blocking at the edge of carriers. Limited impacted is expected to enable coexistence with neighbouring channels for this scenario. Overlapping CA channel spacing need to be updated to consider channel raster, minimum guard band and RB alignment.

For 15 KHz SCS and 100 KHz channel raster,

For NR *operating bands* with 15 kHz channel raster,

with

Where BW is the bandwidth not aligned with the existing NR channel bandwidths, BWchannel(1) and BWchanel(2) are channel bandwidths of the overlapping carriers respectively.

For overlapping CA approach, the only difference compared to normal CA is that overlapping CA can further adjust the channel spacing to fit the irregular spectrum. Hence gNB supporting the corresponding normal CA could also meet the existing unwanted emission and ACS requirement when operating in overlapping CA case and no need to redo Base Station conformance testing.

### 6.7.4 Overlapping UE CBWs from Network Perspective

The required guard band is based on the next smaller channel bandwidth for the legacy UE. Hence BS can use the same implementation as overlapping CA, i.e. to use two existing BS filters (other implementations are not excluded). If manufacturer declares to use two existing filter implementation, and gNB supports the corresponding normal CA, the gNB could also meet the existing unwanted emission and ACS requirement and hence no need to redo conformance testing.

### 6.7.5 Dedicated BS channel bandwidths

If the irregular channel bandwidths are explicitly defined in the specification, it will create huge technical specification work. For each channel bandwidth, the guard band size and the transmission bandwidth configuration need to be specified and used as a basis for defining transmitter and receiver requirements. The identified impact to BS core specification for a new channel BW is shown in following Table 6.7.5-1.

Table 6.7.5-1 Analysis on the impact to BS core specification for a new channel BW

|  |  |  |  |
| --- | --- | --- | --- |
| Subject | Clause in 38.104 | Requirement | Assessment for new channel BW |
| General | 5.3.2 | Transmission bandwidth configuration | the Transmission bandwidth configuration NRB for the new CBW need to be defined |
| 5.3.3 | Minimum guardband and transmission bandwidth configuration | The minimum guardband for the new CBW need to be defined |
| 5.3.5 | BS channel bandwidth per operating band | new CBW need defined per band |
| Transmitter | 6.3.3 | Total power dynamic range | it is a NRB related requirement |
| 6.6.2 | Occupied bandwidth | BS channel bandwidth should be defined |
| 6.6.3 | ACLR | The filter are set using transmission bandwidth configuration (BWConfig). It need to be defined for testing |
| 6.7 | Transmitter intermodulation | the interfering is defined according to BS channel bandwidth |
| Receiver | 7.2 | Reference sensitivity level | for 15 KHz SCS, 25 RB and 106 RB FRC which can be reused |
| 7.3 | Dynamic range | interfering signal level is according to BS channel bandwidth |
| 7.4 | In-band selectivity and blocking | the position of interfering signal is defined according to BS channel bandwidth/transmission bandwidth configuration |
| 7.7 | Receiver intermodulation | the position of interfering signal is defined according to BS channel bandwidth/transmission bandwidth configuration |
| 7.8 | In-channel selectivity | it is defined according to BS channel bandwidth |

It is concluded that new dedicated BS channel bandwidths for irregular channel bandwidths are not defined explicitly in the specification.

### 6.7.6 Additional enhancements

#### 6.7.6.1 Channel raster enhancements

All FR1 low-frequency bands have channel raster in steps of 100kHz defined by RAN WG4 as the global raster (5kHz) x 20. RAN WG2 signalling also uses the global raster of 5kHz in principle not preventing a channel of being on any 5kHz channel raster point. While configuring the NR channel on the 100kHz raster is not a big limitation for standard spectrum blocks, such as 5 or 10MHz, it may result in less efficient spectrum utilisation in certain irregular channels. Furthermore, it might be difficult (and sometimes even impossible) to configure the dedicated UE channel bandwidth so that it is aligned on the 100kHz raster and at the same time is the RB aligned with the SIB1 channel bandwidth if the latter is also on the 100kHz raster.

One exemplary benefit of allowing carriers on the non-100kHz raster is presented in Figure x-1 below for the 7MHz irregular channel. If, for the sake of example, we assume overlapping carriers from the network perspective as potential solution, then the first and the second carrier must have offsets in multiple of 900kHz, whereupon 900kHz is the common multiplier between the 100kHz raster and 180kHz RB size. So, for the 7MHz channel we can shift the second carrier by 1800kHz, i.e., 10RBs; but the resulting guard bands will be noticeably larger than the minimum requirements for the 5MHz carrier. If there is a way to put the carrier on the non-100kHz raster, then the overall system capacity can be increased to 36 RBs still ensuring the minimum guard-band requirements of the 5MHz carrier.



Figure 6.7.6.1-1: Exemplary usage of overlapping carriers with 100kHz and non-100kHz alignment (7MHz irregular channel).

Thus, a potential enhancement is to extend available channel raster points so that the 100kHz raster alignment is not mandated at least for the dedicated UE channel bandwidth. It can be implemented as a common feature of the whole release or as a UE capability. Nevertheless, irrespective how it is introduced, once the network knows the UE capabilities, it can decide whether the dedicated UE channel bandwidth should stay on the 100kHz raster (for legacy devices) or can be re-configured to a non-100kHz raster channel.

In the example of Figure x-1, the network can configure two carriers (each with its own SSB, shown at the top and in the middle of Figure x-1) in accordance with the 100kHz requirement and these carriers will serve legacy devices. And since the network is aware of the UE capabilities, it can always consider configuring another overlapping carrier on the non-100kHz raster after the UE completed the attachment procedure through the legacy carrier shown in the middle row of Figure x-1. This way the network can handle both legacy and new devices and it will be the network scheduler responsibility to decide how to schedule resources over three overlapping carriers.

#### 6.7.6.2 UE channel larger than SIB1 channel enhancement

When a UE camps on the cell, it reads the corresponding system information to understand the position of the channel, its size, the initial bandwidth part configuration, etc. Once a UE enters the cell, the network has an ability to re-configure the UE whereupon the network can also provide a new channel configuration that will be specific to that UE. While the most common re-configuration case is to configure a UE with the dedicated channel and/or bandwidth part that is within the SIB1 channel bandwidth, there are also use cases when a UE might be configured with the channel size or position of which is outside the SIB1 configuration. Thus, to enable better utilisation of irregular channels it would be preferrable that UEs can support a re-configuration scenario when the dedicated UE channel is outside the SIB1 boundaries.

# 7 Conclusion

## 7.1 Comparison Between Different Schemes

This section provides a comparison of the proposed schemes using different criteria.

The comparison between different schemes is summarized Table 7.2.1.

Table 7.2.1. Comparison of different schemes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Comparison Criteria | Overlapping CA (two cells) – described in Section 6.2.3 | Combined UE CBW (One cell) – described in Section 6.2.2 | Overlapping UE CBW – described in Section 6.2.1 | Larger CBW (one cell) – described in Section 6.1 |
| Regulatory requirement | No issue | No issue | No issue | Potential issue on the BS side, gNB filters will be needed depending on BS implementation. |
| UE performance degradation relative to minimum requirements | Possible impact on Rx sensitivity vs regular CBW, if single carrier Tx-Rx separation is not maintained. | Possible impact on Rx sensitivity vs regular CBW, if single carrier Tx-Rx separation is not maintained. | No issue | UE ACS and in-band blocking degradation.  Possible impact on Rx sensitivity vs regular CBW, if single carrier Tx-Rx separation is not maintained. |
| gNB complexity | gNB has to support CA and schedule the data without collision in the two CC’s overlapping PRBs | gNB has to support splitting the signal into 2 RF carriers with a predefined phase relationship | gNB has to support the irregular channel BW (can also be implemented through RF combining of 2 channels) | No changes needed if the BS can meet regulatory requirements with the RF front end of the wider channel BW. Otherwise, gNB has to support the irregular channel BW |
| UE complexity | UE has to support intra-band NC CA.  1 less CC can be supported when irregular BW is used in combination from other bands, or more total CCs needed. | UE has to support RF architecture as in intra-band NC CA.  Needs new capability to aggregate 2 RF channels in baseband.  Complexity higher than CA because the baseband will need a new "combiner" module.  1 less CC can be supported when irregular BW is used in combination from other bands, or more total CCs needed. | No changes needed, supported by legacy UEs | No changes needed, supported by legacy UE |
| UE throughput | UEs supporting the feature can use the entire spectrum allocation, legacy UEs can use an already supported channel BW | UEs supporting the feature can use the entire spectrum allocation, legacy UEs can use an already supported channel BW | UE throughput based on existing channel BWs (5MHz for holdings <10MHz, 10MHz for holdings <15MHz, etc) | UE throughput based on how many RBs can be used |
| Spectral utilization | Channel edge guardband based on the aggregated channel BW (5MHz for <10MHz, 10MHz for <15MHz, etc), 2 SSBs are needed | Channel edge guardband based on the aggregated RF carrier BW (5MHz for <10MHz, 10MHz for <15MHz, etc), single SSB needed | Channel edge guardband based on the actual holding (can be same as Overlapping CA), 2 SSBs are needed | Depends on the usable number of RBs, single SSB needed |
| Cell Spectral utilization | Entire spectrum holding can be used even only with legacy UEs | Entire spectrum holding can be used even only with legacy UEs for some scenarios depending on whether a single SSB can be used to configure legacy channels at both edges of the spectrum holding. Otherwise, entire spectrum can be used only by new UEs, all legacy UEs have to use the same regular channel BW part of the spectrum holding. | Entire spectrum holding can be used even only with legacy UEs | Entire spectrum holding, but with wider guard bands than in the other methods, can be used even only with legacy UEs |
| Network capacity | Entire spectrum can be used by multiplexing different UEs(even legacy UEs) | Entire spectrum can only be used for new UEs, whether legacy UEs can be multiplexed to cover entire channel depends on the configuration and bandwidth | Entire spectrum can be used by multiplexing different UEs in the frequency domain | Entire spectrum can be used by any UE |
| Legacy UE support | Legacy UEs supported, can use one of the aggregated CCs | Legacy UEs can use part of the spectrum that contains the SSB | Legacy UEs supported | Legacy UEs supported |
| RAN1/2/4 Specification impact | RAN1/2 – new UE capabilities needed,  RAN4 – new band combinations, changes to channel spacing definition, Overlapping CA reqs applicability, new demod requirements for UEs | RAN2 – impact on new capability  RAN4 –core requirements equivalent to new channel BW for BS, new demod requirements for UEs | RAN4 – BS requirements for new channel BW | RAN4 – BS requirements for new channel BW, possibly restrictions of the suitable scenarios.  New asymmetric bandwidth combinations for UE are needed. However these combinations would be “regular” BW combinations, so existing process. |

## 7.2 Study Item Conclusions

The method of using a larger Channel BW than the licensed BW is based on blanking (not scheduling) PRBs within the larger BW but outside the irregular BW. If applied for the DL only, this method can be supported by specifying an asymmetric UE CHBW bandwidth configuration for band such that its UL CHBW is contained within the irregular UL block and the DL CHBW is larger than the irregular DL block. In this way UE unwanted emission requirement in the UL can be met by means of the regular UE CHBW. The larger DL UE CHBW implies a degraded UE adjacent channel selectivity and blocking performance when the interferer is close to the irregular DL block. However, the method can be supported by using existing UE architectures (since asymmetric bandwidths are supported by the current standard) in combination with new asymmetric CHBW combinations. The method works for both FDD and TDD.

Overlapping channels from the network perspective can be used to support irregular spectrum allocations. This method can provide the full network capacity improvement in DL and UL to a spectrum utilization ≥90 % of the irregular BW (at 15 kHz SCS). This method can be used with legacy UE, even Rel-15, not requiring any changes at the UE side. Since a UE is configured with standard channel bandwidth, there are no issues with UE performance degradation relative to minimum requirements and all the regulatory requirements can be met as per legacy operation. The ACS and the blocking performance are not affected, hence there will be no impact on the network planning. The gNB has to support the irregular channel BW because from the network perspective RBs are scheduled across the whole spectrum block. That might also require new BS requirements for new irregular channels. This method provides a fast, generic, safe, and efficient solution for FDD and TDD bands.

Annex A (informative):  
The case of n12 and n85

## A.1 Support for n12 and n85 at the lower edge of the bands

In the USA the lower 700 MHz band is licensed in 6 MHz blocks. The lower 700 MHz A block covers 698-704 MHz UL and 728-734 MHz in the downlink. NR band n12 covered all but the lowest 1 MHz of the A block. NR band n85 covers the entire A Block. Hence, NR band n85 extends 1 MHz lower than NR band n12. Because some devices will support n12 while others will support n85, it would be beneficial if n12 capable UEs could use the 5 MHz at the bottom of n12 downlink while n85 capable UEs are able to use the 6 MHz at the bottom of the n85 downlink.

Chart

Description automatically generated with medium confidence

Figure 6.1.4-1: Overlap at the bottom of n12 and n85

## A.2 Support for n12 and n85 overlap using the next wider channel bandwidth approach

One way to allow n12 UEs to use 729-234 MHz DL and n85 UEs to use 728-734 MHz DL would be to use the next wider channel bandwidth approach. The network could configure an n85 cell with a downlink of 729-234 MHz and include n12 in the MultiFrequencyBandListNR in the SIB. Then both n12 capable and n85 capable UEs could access the cell. After the gNB processes the UE capabilities, the network could assign n85 capable UEs a UE-Specific downlink channel bandwidth covering 728-738 MHz. Based on feedback from RAN2 in R4-2200031 signalling supports the configuration of a channel that is larger than the channel bandwidth in the SIB and/or extends beyond the edge of the channel in the SIB as long as it is within the band. However, since this behavior might not be supported by all UEs, new capability signalling may be required to enable the n85 capable UE to indicate that it supports such a configuration. Also, because the uplink configuration would be 5 MHz, the n85 UEs would also need to indicate support to an asymmetric channel bandwidth.

## A.3 Support for n12 and n85 overlap using the overlapping channel bandwidth approaches

One way to allow n12 UEs to use 729-234 MHz DL and n85 UEs to use 728-734 MHz DL would be to use one of the overlapping channel bandwidth approaches. The network could configure an n85 cell with a downlink of 729-234 MHz and include n12 in the MultiFrequencyBandListNR in the SIB. Then both n12 capable and n85 capable UEs could access the cell. After the gNB processes the UE capabilities, the network could configure n85 capable UEs with one of the overlapping channel bandwidth approaches using the 5 MHz at the bottom of n85 (728-733 MHz) and the next 5 MHz (739-734 MHz). Legacy UEs would only use 729-234 MHz.

Annex B (informative):  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
|  | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2020-11 | RAN4#97 | R4-2015722 |  |  |  | TR Skeleton | 0.0.1 |
| 2020-11 | RAN4#97 | R4-2016930 |  |  |  | TR Skeleton (revised) | 0.0.1 |
| 2021-01 | RAN4#98 | R4-2101555 |  |  |  | Updated TR 38.844 | 0.0.2 |
| 2021-01 | RAN4#98 | R4-2103262 |  |  |  | Updated TR 38.844 (revised) | 0.0.2 |
| 2021-04 | RAN4#98bis | R4-2106690 |  |  |  | TP to the TR 38.844: Terminology | 0.0.2 |
| 2021-04 | RAN4#98bis | R4-2105420 |  |  |  | TP to the TR 38.844: Terminology (revised) | 0.0.2 |
| 2021-05 | RAN4#99-e | R4-2110487 |  |  |  | Update TR 38.844 with TP | 0.0.3 |
| 2021-05 | RAN4#99-e | R4-2108021 |  |  |  | TP on the use of overlapping channel bandwidths from UE perspective | 0.0.3 |
| 2021-05 | RAN4#99-e | R4-2107885 |  |  |  | TP to TR38.844 on wider channel BW method | 0.0.3 |
| 2021-05 | RAN4#99-e | R4-2108022 |  |  |  | TP to TR38.844 on wider channel BW method (revised) | 0.0.3 |
| 2021-05 | RAN4#99-e | R4-2109436 |  |  |  | TP on using overlapping channels from the network perspective solution | 0.0.3 |
| 2021-05 | RAN4#99-e | R4-2107887 |  |  |  | TP on using overlapping channels from the network perspective solution (revised) | 0.0.3 |
| 2021-05 | RAN4#99-e | R4-2108112 |  |  |  | TP on using overlapping channels from the network perspective solution (revised) | 0.0.3 |
| 2021-08 | RAN4#100-e | R4-2113948 |  |  |  | Updated TR 38.844 | 0.0.4 |
| 2021-08 | RAN4#100-e | R4-2114239 |  |  |  | TP for TR 38.844: 6 MHz for n85 with overlapping CHBW | 0.0.4 |
| 2021-08 | RAN4#100-e | R4-2112365 |  |  |  | TP on using next larger channel bandwidth solution | 0.0.4 |
| 2021-08 | RAN4#100-e | R4-2114999 |  |  |  | TP on using next larger channel bandwidth solution (revised) | 0.0.4 |
| 2021-08 | RAN4#100-e | R4-2115114 |  |  |  | TP on using next larger channel bandwidth solution (revised) | 0.0.4 |
| 2021-08 | RAN4#100-e | R4-2113046 |  |  |  | TP on overlapping UE channel bandwidths (Overlapping CA) | 0.0.4 |
| 2021-08 | RAN4#100-e | R4-2115000 |  |  |  | TP on overlapping UE channel bandwidths (Overlapping CA) (revised) | 0.0.4 |
| 2021-08 | RAN4#100-e | R4-2113949 |  |  |  | TP to TR 38.844: Section 6.2 Overlapping UE Channel BWs | 0.0.4 |
| 2021-08 | RAN4#100-e | R4-2115050 |  |  |  | TP to TR 38.844: Section 6.2 Overlapping UE Channel BWs (revised) | 0.0.4 |
| 2021-11 | RAN4#101-e | R4-2118777 |  |  |  | Updated TR 38.844 | 0.0.5 |
| 2021-11 | RAN4#101-e | R4-2120012 |  |  |  | TP to TR 38.844 Section 6.3.2 | 0.0.5 |
| 2021-11 | RAN4#101-e | R4-2117954 |  |  |  | TP with further information on UE channel filter assumptions | 0.0.5 |
| 2021-11 | RAN4#101-e | R4-2120013 |  |  |  | TP with further information on UE channel filter assumptions (revised) | 0.0.5 |
| 2021-11 | RAN4#101-e | R4-2117955 |  |  |  | TP with corrections for overlapping channels from the network perspective | 0.0.5 |
| 2021-11 | RAN4#101-e | R4-2120015 |  |  |  | TP with corrections for overlapping channels from the network perspective  (revised) | 0.0.5 |
| 2021-11 | RAN4#101-e | R4-2119230 |  |  |  | TP to TR 38.844: on the use of overlapping channel bandwidths from UE perspective | 0.0.5 |
| 2021-11 | RAN4#101-e | R4-2120016 |  |  |  | TP to TR 38.844: on the use of overlapping channel bandwidths from UE perspective (revised) | 0.0.5 |
| 2021-11 | RAN4#101-e | R4-2118778 |  |  |  | TP to TR 38.844: Overlapping CBW from UE perspective utilizing intra-band CA approach | 0.0.5 |
| 2021-11 | RAN4#101-e | R4-2120017 |  |  |  | TP to TR 38.844: Overlapping CBW from UE perspective utilizing intra-band CA approach (revised) | 0.0.5 |
| 2022-01 | RAN4#101-bis-e | R4-2201485 |  |  |  | Updated TR 38.844 | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2201794 |  |  |  | Revision on TR 38.344 Section 6.2.3 | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2202046 |  |  |  | TP for TR 38.844: Proposal for n12 and n85 | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2202416 |  |  |  | TP for TR 38.844: Proposal for n12 and n85 (revised) | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2201511 |  |  |  | On overlapping CBWs from Network perspective | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2202377 |  |  |  | On overlapping CBWs from Network perspective (revised) | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2201993 |  |  |  | TP to TR 38.844: on combined UE CBW (one cell) – signalling aspects | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2202378 |  |  |  | TP to TR 38.844: on combined UE CBW (one cell) – signalling aspects (revised) | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2201487 |  |  |  | TP to TR 38.844: Section 6.1.2 Signalling for Overlapping CA Approach | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2202379 |  |  |  | TP to TR 38.844: Section 6.1.2 Signalling for Overlapping CA Approach (revised) | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2201885 |  |  |  | TP to TR 38.844: Wider CBW method | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2202375 |  |  |  | TP to TR 38.844: Wider CBW method | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2202423 |  |  |  | TP to TR 38.844: Wider CBW method (revised) | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2202381 |  |  |  | TP to TR 38.844: Clause 6.1.2 Signalling and configuration aspects | 0.0.6 |
| 2022-01 | RAN4#101-bis-e | R4-2202382 |  |  |  | TP to TR 38.844: Clause 7 | 0.0.6 |
| 2022-02 | RAN4#102-e | R4-2206552 |  |  |  | Updated TR 38.844 | 0.0.7 |
| 2022-02 | RAN4#102-e | R4-2203668 |  |  |  | Further corrections to the solution based on overlapping channels from the network perspective | 0.0.7 |
| 2022-02 | RAN4#102-e | R4-2206554 |  |  |  | TP to TR 38.844: Editorial clean up | 0.0.7 |
| 2022-02 | RAN4#102-e | R4-2206555 |  |  |  | TP to TR 38.844: corrections | 0.0.7 |
| 2022-02 | RAN4#102-e | R4-2206557 |  |  |  | TP to TR 38.844 on Larger CBW approach: Signalling and configuration aspects | 0.0.7 |
| 2022-02 | RAN4#102-e | R4-2206558 |  |  |  | TP for overlapping CA | 0.0.7 |
| 2022-02 | RAN4#102-e | R4-2206595 |  |  |  | TP to TR 38.844: Clause 6.1.2.x Spec impact identification | 0.0.7 |
| 2022-02 | RAN4#102-e | R4-2209136 |  |  |  | Updated TR 38.844 | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2208041 |  |  |  | TP to TR 38.844: General Updates | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2210796 |  |  |  | TP to TR 38.844: General Updates (revised) | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2208554 |  |  |  | TP for wider channel bandwidth | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2210797 |  |  |  | TP for wider channel bandwidth (revised) | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2210343 |  |  |  | Further input on performance when using the next larger channel | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2210798 |  |  |  | Further input on performance when using the next larger channel (revised) | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2209031 |  |  |  | Further discussion on the Wider CBW approach | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2210802 |  |  |  | Further discussion on the Wider CBW approach (revised) | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2208555 |  |  |  | TP for Overlapping UE CBWs from Network Perspective | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2210804 |  |  |  | TP for Overlapping UE CBWs from Network Perspective (revised) | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2208556 |  |  |  | TP for overlapping CA | 0.0.8 |
| 2022-05 | RAN4#103-e | R4-2210808 |  |  |  | TP for overlapping CA (revised) | 0.0.8 |
| 2022-08 | RAN4#104-e | R4-2212866 |  |  |  | Updated TR 38.844 | 0.0.9 |
| 2023-02 | RAN4#106 | R4-2300371 |  |  |  | TP on additional enhancements for irregular channels | 0.0.9 |
| 2023-02 | RAN4#106 | R4-2303497 |  |  |  | TP on additional enhancements for irregular channels (revised) | 0.0.9 |
| 2023-02 | RAN4#106 | R4-2300750 |  |  |  | TP for 38.844: Configuration for the case of larger channel bandwidths than licensed bandwidth and conclusions | 0.0.9 |
| 2023-02 | RAN4#106 | R4-2303501 |  |  |  | TP for 38.844: Configuration for the case of larger channel bandwidths than licensed bandwidth and conclusions (revised) | 0.0.9 |
| 2023-02 | RAN4#106 | R4-2301606 |  |  |  | TP on the larger channel bandwidth approach (Section 6.1.1) for TR 38.844 | 0.0.9 |
| 2023-02 | RAN4#106 | R4-2303502 |  |  |  | TP on the larger channel bandwidth approach (Section 6.1.1) for TR 38.844 (revised) | 0.0.9 |
| 2023-02 | RAN4#106 | R4-2300202 |  |  |  | TP to TR 38.844 on Overlapping UE CBWs from Network Perspective | 0.0.9 |
| 2023-02 | RAN4#106 | R4-2303503 |  |  |  | TP to TR 38.844 on Overlapping UE CBWs from Network Perspective (revised) | 0.0.9 |
| 2023-02 | RAN4#106 | R4-2302436 |  |  |  | TP for 38.844: conclusions for overlapping CBWs from network perspective | 0.0.9 |
| 2023-02 | RAN4#106 | R4-2302237 |  |  |  | Updated draft TR 38.844 | 0.1.0 |
| 2023-03 | RAN#99 | RP-230580 |  |  |  | TR 38.844 provided for approval | 1.0.0 |
| 2023-03 | RAN#99 | RP-230750 |  |  |  | TR 38.844 provided for approval (revised) | 1.0.1 |

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| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2023-03 | RAN#99 |  |  |  |  | Approved by plenary – Rel-18 spec under change control | 18.0.0 |