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| 3GPP TR 38.872 V18.1.0 (2023-06) | |
| Technical Report | |
| 3rd Generation Partnership Project;  Technical Specification Group Radio Access Network;  NR;  Study on enhancement for 700/800/900MHz band combinations  (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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where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

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.

# 1 Scope

The present document is the technical report for the study on enhancement for 700/800/900MHz band combinations [2] and sub-1GHz NR band combinations [5] under R18 time frame. The purpose is to gather the relevant background information and studies in order to address the study on enhancement for 600/700/800/900MHz band combinations in Table 1-1.

Table 1-1: Band combinations in the SI

|  |  |
| --- | --- |
| Configuration | Uplink configuration |
| CA\_n8-n20-n28 | CA\_n8-n20, CA\_n8-n28, CA\_n20-n28 |
| CA\_n5-n8 | CA\_n5-n8 |
| CA\_n5-n28 | CA\_n5-n28 |
| CA\_n5A-n105A | CA\_n5A-n105A |
| CA\_n28A-n105A | single UL in either n28 or n105 |
| CA\_n26A-n28A | CA\_n26A-n28A |
| CA\_n5A-n28A-n105A | CA\_n5A-n28A |
| CA\_n5A-n28A-n105A | CA\_n5A-n105A |
| CA\_n5A-n28A-n105A | single UL in either n28 or n105 |

# 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-221464, “Revised SI: Study on enhancement for 700/800/900MHz band combinations for NR”, RAN#96

[3] TS 38.101-1

[4] TS 38.101-3

[5] RP-230789, “ Study on enhancement for sub-1Ghz NR band combinations”. RAN 99

[6] 3GPP TR 38 892 , APT 600 MHz NR band.

[7] R4-2308581, Discussion on RF architecture and potential MSD issues for CA\_n5-n105, Huawei, HiSilicon, Spark NZ

[8] R4-2309299, Input on CA\_n5-n105 cross-band MSD and DeltaT/R, Skyworks Solutions Inc.

[9] R4-2309356, Considerations on CA\_n5-n105, Qualcomm France

[10] R4-2309358, Considerations on CA\_n26-n28, Qualcomm France

[11] R4-2306468, WF on CA\_n5-n28 and CA\_n8-n20-n28, Huawei, HiSilicon

[12] R4-2308583, Discussion on RF architecture and potential MSD issues for CA\_n26-n28, Huawei, HiSilicon

[13] R4-2307477, Input on CA\_n26-n28 requirements, Skyworks Solutions Inc.

[14] R4-2306470, WF on RF architecture and critical issues for CA\_n28-n105

# 3 Definitions of terms, symbols and abbreviations

## 3.1 Terms

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

## 3.2 Symbols

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

ΔRIB,c Allowed reference sensitivity relaxation due to support for inter-band CA operation, for serving cell *c*

ΔTIB,c Allowed maximum configured output power relaxation due to support for inter-band CA operation, inter-band NR-DC operation and due to support for SUL operations, for serving cell *c*

## 3.3 Abbreviations

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

MRC Maximum Ratio Combining

MSD Maximum Sensitivity Degradation

RB Resource Block

UE User Equipment

# 4 Background

In RAN#95e, SI “enhancement for 700800900MHz band combinations” was approved. The objectives of SI are as follows:

1 Investigate the feasibility and solutions to enable simultaneous transmission on two UL bands and simultaneous reception on two or three bands for the band combination of 700, 800 and 900MHz spectrum for smart phone form factor

2 The following band combinations will be considered. And the feasibility study on three band combination will start after the completion of feasibility study of all the fallback band combinations.

- CA\_n8-n20-n28 with uplink configurations of CA\_n8-n20, CA\_n8-n28, CA\_n20-n28, and the fallback modes

- CA\_n5-n8 with uplink configuration of CA\_n5-n8, and the fallback modes

Note1: Spectrum restrictions should be studied to solve overlap of band n5 downlink and band n8 uplink

Note2: The current filter is used as the baseline. Further study whether or not to have new solutions.

- CA\_n5-n28 (full range) with uplink configuration of CA\_n5-n28.

In RAN 99 a new SI [5] was approved. This SI concerns the consideration of the APT 600 MHz band (n105) that has been recently has been introduced into 3GPP specifications [6]. After the completion of APT 600MHz band, operators have the further demands to combine this 600MHz band with other sub-1GHz bands together to achieve a good performance for the real deployment. However, some challenges were identified for a device with a smart phone form factor to support the combinations of those low bands including 600MHz band. For example, UE RF architecture need to be further studied due to larger antenna size for 600MHz band and some RF requirements need to be evaluated, e.g. MSD. The previous SI on Enhancement for 700/800/900MHz band combinations didn’t include the evaluation and studies for 600MHz band. Additionally band 26 is also considered.

Summary of band combinations considered in the SI

|  |  |  |  |
| --- | --- | --- | --- |
| Configuration | Uplink configuration | Supported operators | The status of fallback mode |
| CA\_n8-n20-n28 | CA\_n8-n20, CA\_n8-n28, CA\_n20-n28 | Vodafone, Telecom Italia, Orange, Deutsche Telekom |  |
| CA\_n5-n8 | CA\_n5-n8 | China Telecom, Spark NZ, China Unicom |  |
| CA\_n5-n28 | CA\_n5-n28 | Spark NZ |  |
| CA\_n5A-n105A | CA\_n5A-n105A | Spark NZ | DL\_n5A-n105A\_UL\_n5A\_BCS0 (New)  DL\_n5A-n105A\_UL\_n105A\_BCS0 (New) |
| CA\_n28A-n105A | CA\_n28A-n105A | Spark NZ | DL\_n28A-n105A\_UL\_n28A\_BCS0 (New)  DL\_n28A-n105A\_UL\_n105A\_BCS0 (New) |
| CA\_n26A-n28A | CA\_n26A-n28A | Telstra | DL\_n26A-n28A\_UL\_n28A\_BCS0 (Completed in RAN4#106)  DL\_n26A-n28A\_UL\_n26A\_BCS0 (New) |
| CA\_n5A-n28A-n105A1 | CA\_n5A-n28A | Spark NZ | DL\_n5A-n28A\_UL\_n5A-n28A\_BCS0 (Ongoing in a separate WI)  DL\_n5A-n28A-n105A\_UL\_n5A\_BCS0 (New)  DL\_n5A-n28A-n105A\_UL\_n28A\_BCS0 (New) |
| CA\_n5A-n28A-n105A1 | CA\_n5A-n105A | Spark NZ | DL\_n5A-n105A\_UL\_n5A-n105A\_BCS0 (New)  DL\_n5A-n28A-n105A\_UL\_n5A\_BCS0 (New)  DL\_n5A-n28A-n105A\_UL\_n105A\_BCS0 (New) |
| CA\_n5A-n28A-n105A1 | CA\_n28A-n105A | Spark NZ | DL\_n28A-n105A\_UL\_n28A-n105A\_BCS0 (New)  DL\_n5A-n28A-n105A\_UL\_n28A\_BCS0 (New)  DL\_n5A-n28A-n105A\_UL\_n105A\_BCS0 (New) |

NOTE 1: The study of 3 band combination can only start after completion of 2 bands fallbacks

NOTE 2: Check at RAN4#107 whether CA\_n5A-n28A-n105A could be included in the SI based on study progress for the fall back combinations listed in the above table.

The following aspects need be studied

- UE architecture including n-plexing, PA

- Study feasibility of low band wideband antenna

- Performance due to impacts including inter-modulation products

- Method to manage the inter-modulation product impacts

Note: Revisit in RAN#98 whether additional aspects need to be added.

Power class 3 (PC3) is considered in this study

3 Identify potential impacts to relevant RAN4 requirements.

The present document is the technical report for this Study Item.

## 4.1 TR Maintenance

A single company is responsible for introducing all approved TPs in the current TR, i.e. TR editor.

# 5 Specific Band combinations

## 5.1 CA\_n5-n8

### 5.1.0 General

Generally, in this study item, some high level implementations were discussed and shown as below.

1) Full band n5 and n8 RF filters implementation with option 1 and option2:

- Option 1: Only support 1UL/2DL CA. Single UL in n5

- Option 2: Support both 1UL/2DL and 2UL/2DL CA. Non-concurrent n5 DL and n8 UL

Note: Potential impacts on RAN2 are observed

2) Dedicated RF filters implementation with partial frequency range

- Option 3: Support both 1UL/2DL and 2UL/2DL CA. Dedicated filter to allow simultaneous n5 DL and n8 UL

### 5.1.1 UE RF architecture assumption

The following UE RF architectures can be assumed in the future meetings’ analysis for CA\_n5-n8: 2 antenna, 3 antenna. The antenna number is the total number of antennas to support Main UL/DL and diversity DL for all bands.

Due to the frequency range overlap between n5 DL and n8 UL, one possibility to enable CA\_n5-n8 operation with 2-antenna implementation is to allow non-simultaneous Rx/Tx between n5 DL and n8 UL or single UL in n5 only to avoid n5 REFSENS impact due to n8 UL transmission. With that the filter isolation between n5 DL and n8 UL would no longer be needed and a triplexer can be used to provide the semi-full-duplex carrier aggregation to a single antenna in the main path, as is shown in Figure 5.1.1-1. On the other hand, since the triplexer center band range is over 5% bandwidth ratio (band range divided by center frequency) and the frequency gap between center band and n8 DL is only 10 MHz which may pose design challenge on achieving acceptable filter isolation and insertion loss, the feasibility of a single triplexer for CA\_n5-n8 needs to be studied.





Figure 5.1.1-1 Possible CA\_n5-n8 UE architecture and operation diagram for semi-full-duplex CA

Another architecture variant with 2-antenna implementation is to move n8 UL to the diversity path as is shown in Figure 5.1.1-2 which may potentially ease the triplexer design in the main TRx path owing to the narrower middle band range and wider frequency separation between n5 DL and n8 DL. The filter design challenge however would be shifted to the diversity TRx path duplexer due to the wider band range to cover n5 DL and n8 UL.



Figure 5.1.1-2 Possible CA\_n5-n8 UE architecture based on 2-antenna implementation

For the 3-antenna implementation, the two of the three antenna are used in the main path to aggregate the n5 and n8 signals over the air, as shown in Figure 5.1.1-3. As n5 and n8 signals do not need to be combined through a multiplexer, there is no additional insertion loss in both n5 and n8 main signal paths as compared to single-band implementation.

Having two antenna in the main signal path not only avoids the more complicated multiplexer implementation and the associated additional insertion losses, but also allows narrower frequency coverage for each of the two antenna as compared to single-antenna implementation which can be up to 348 MHz (from n105 to n8) to support all the sub-1GHz bands above 600 MHz as defined in 3GPP. On the other hand, the additional antenna cannot be added without occupying more phone space. Therefore, the feasibility on placing more than two low-band antenna in a smartphone needs to be investigated with the concern of the expected narrower bandwidth and regressed radiating performance due to the limitation in form factor.



Figure 5.1.1-3 CA\_n5-n8 UE architecture based on the 3-antenna implementation

Despite the 3-antenna implementation can help reduce n8 UL interfering n5 DL via antenna isolation which however is far from sufficient even under the restricted frequency ranges for CA operation where n8 UL does not overlap with n5 DL. Therefore, semi-full-duplex operation with non-simultaneous Rx/Tx between n5 DL and n8 UL as diagramed in Figure 5.1.1-1 is still required for the CA combination.

In consideration of the operation frequency ranges restriction for this specific band combination as is shown below,

- n5r: UL 824 - 835 MHz; DL 869 - 880 MHz

- n8r: UL 904 - 915 MHz; DL 949 - 960 MHz



Figure 5.1.1-4 CA\_n5-n8 restricted spectrum range

Dedicated filter implementation may be considered to potentially enable 2UL/2DL simultaneous operation. Due to the frequency range restriction on the dedicated filters, additional full-band duplexers for either or both n5 and n8 would be required in order to support the single-band full-band operation. Figure 5.1.1-5 and Figure 5.1.1-6 show the architecture diagrams with dedicated quadplexer in main TRx path based on 2-antenna implementation where the former uses both partial ranges for n5 and n8 in the quadplexer and the latter uses partial range only for n8 UL in the quadplexer.



Figure 5.1.1-5 CA\_n5-n8 architecture with dedicated quadplexer using partial ranges in both n5 and n8



Figure 5.1.1-6 CA\_n5-n8 architecture with dedicated quadplexer using partial range in n8 UL only

Figure 5.1.1-7 and Figure 5.1.1-8 show the architecture diagrams with dedicated duplexers for both n5 and n8 and n8 UL only respectively in main TRx path based on 3-antenna implementation.

Dedicated filter based on specific frequency range restriction for operation bands usually is not a common practice in UE implementation as it adds additional cost and area to the devices.



Figure 5.1.1-7 CA\_n5-n8 architecture using dedicated duplexers with partial ranges in both n5 and n8



Figure 5.1.1-8 CA\_n5-n8 architecture using dedicated duplexers with partial range in n8 UL only



Figure 5.1.1-9 CA\_n5-n8 architecture using dedicated triplexers with partial range in n8 and n5

In the architecture of Figure 5.1.1-9, dedicated triplexers are used. In this architecture, UL’s are transmitted from different antennas, which may help in optimizing the TRP for each of the UL’s resulting in better coverage.

### 5.1.2 Common for 1 band UL and 2 bands UL of CA\_n5-n8

#### 5.1.2.1 Operating bands for CA

UE should support the full range of spectrum for single band operations on both n5 and n8

Use the following frequency ranges for further discussion for spectrum restriction to support uplink CA\_n5-n8.

Table 5.1.2.1-1: CA band combination of band n5+n8

|  |  |  |
| --- | --- | --- |
|  | UL | DL |
| Frequency 1 (800MHz) | 824MHz - 835MHz | 869MHz - 880MHz |
| Frequency 2 (900MHz) | 904MHz - 915MHz | 949MHz - 960MHz |

The frequency relation between band n8 and n5 is shown below as UL band n8 is overlapping with DL band n5

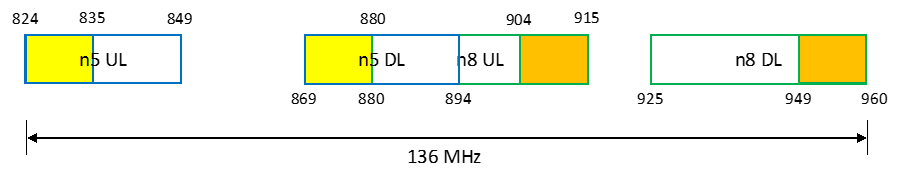


Figure 5.1.2.1-1: The frequency relation between band n8 and n5

#### 5.1.2.2 Channel bandwidths per operating band for CA

Based on WF R4-2214445, BCS0 for CA\_n5A-n8A can be specified as below.

Table 5.1.2.2-1: Supported bandwidths per CA band combination of band n5+n6

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NR CA configuration | Uplink CA configuration or single uplink carrier | NR Band | Channel bandwidth (MHz) | Bandwidth combination set |
| CA\_n5A-n8A | CA\_n5A-n8A | n5 | 5, 10 | 0 |
| n8 | 5, 10 |  |

#### 5.1.2.3 UE co-existence studies

Table 5.1.2.3-1/2 summarizes frequency ranges where harmonics and/or harmonics mixing occur for CA\_n5-n8.

Table 5.1.2.3-1: Impact of UL/DL Harmonic

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | 2nd Harmonic | | 3rd Harmonic | | 4th Harmonic | | 5th Harmonic | |
| Band | UL Low Band Edge | UL High Band Edge | DL Low Band Edge | DL High Band Edge | UL Low Band Edge | UL High Band Edge | UL Low Band Edge | UL High Band Edge | UL Low Band Edge | UL High Band Edge | UL Low Band Edge | UL High Band Edge |
| n5 | 824 | 849 | 869 | 894 | 1648 | 1698 | 2472 | 2547 | 3296 | 3396 | 4120 | 4245 |
| n8 | 880 | 915 | 925 | 960 | 1760 | 1830 | 2640 | 2745 | 3520 | 3660 | 4400 | 4575 |

Table 5.1.2.3-2: Impact of UL/DL Harmonic mixing

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | 2nd Harmonic | | 3rd Harmonic | | 4th Harmonic | | 5th Harmonic | |
| Band | UL Low Band Edge | UL High Band Edge | DL Low Band Edge | DL High Band Edge | DL Low Band Edge | DL High Band Edge | DL Low Band Edge | DL High Band Edge | DL Low Band Edge | DL High Band Edge | DL Low Band Edge | DL High Band Edge |
| n5 | 824 | 849 | 869 | 894 | 1738 | 1788 | 2607 | 2682 | 3476 | 3576 | 4345 | 4470 |
| n8 | 880 | 915 | 925 | 960 | 1850 | 1920 | 2775 | 2880 | 3700 | 3840 | 4625 | 4800 |

Based on the analysis above, there is no need to specify harmonics and harmonics mixing exception for CA\_n5-n8 as we didn’t specify them in current spec.

#### 5.1.2.4 ∆TIB,c and ∆RIB,c values

For CA\_n5-n8, the ΔTIB,c and ΔRIB,c are given in the tables below considering both 2-antenna and 3–antenna implementations. If 3-antenna implementation is assumed, there isn’t any additional insertion loss observed for CA\_n5-n8 compared with single carrier operation. If it’s assumed to derive the the delta Tib and Rib requirements for CA\_n5-n8 based on 3–antenna implementation, all the values can be zero. If 2-antenna implementation is assumed to derive these values, the some delta Tib and Rib values for CA\_n5-n8 are provided from interested companies as below.

Table 5.1.2.4-1: ΔTIB,c for 2-antenna implementation

| Inter-band CA Configuration | NR Band | Huawei | Skyworks | Qualcomm |
| --- | --- | --- | --- | --- |
| CA\_n5-n8 | n5 | 0.4 | 0.2 | 0.5 |
| n8 | 0.4 | 0.4 | 0.5 |

Table 5.1.2.4-2: ΔRIB,c for 2-antenna implementation

| Inter-band CA Configuration | NR Band | Huawei | Skyworks | Qualcomm |
| --- | --- | --- | --- | --- |
| CA\_n5-n8 | n5 | 0 | 0.3 | 0.5 |
| n8 | 0 | 0.2 | 0.5 |

#### 5.1.2.5 REFSENS evaluation

For option 1 of full band n5 and n8 RF filters implementation, the scheduling is restricted as DL\_n5-n8\_UL\_n5 and the concurrent operation between DL band n5 and UL band n8 can’t work. There may be some MSD for band n8 DL due to band n5 UL interference. Some legacy filters exhibit the flyback effect into n8 DL reducing the rejection of the n5 TX OOB leakage for no MSD

For option 3 of dedicated RF filters implementation with partial frequency range, the MSD test point and values due to cross band isolation between DL band n5 and UL band n8 in Table 5 are provided referring to R4-2300759.

Table 5.1.2.5-1: n8R UL cross band MSD in n5 for CA\_n5-n8

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n8 | n5 | 909 | 10 | 15 | 25 (RBstart=0) | 877.5 | 5 | [12.3] | ACLR2 |

### 5.1.3 Specific for 2 bands UL of CA\_n5-n8

#### 5.1.3.0 General

Option 2 full band n5 and n8 RF filters implementation can support both DL\_n8\_UL\_n5-n8 and DL\_n5-n8\_UL\_n5 features.

Option 3 dedicated RF filter(s) implementation with partial frequency range can support DL\_n5-n8\_UL\_n5-n8 feature.

Thus, the following technical analysis in clause 5.1.3 is based on these kinds of candidate options and implementations.

#### 5.1.3.1 Maximum output power for inter-band CA

Power class 3 is assumed for UL CA\_n5-n8.

#### 5.1.3.2 UE co-existence studies

Table 5.1.3.2-1 lists Band n5 + Band n8 2UL bands CA 2nd, 3rd, 4th and 5th order IMD for the UE-to-UE coexistence analysis.

Table 5.1.3.2-1: Band n5 and Band n8 UL IMD products with frequency range restriction

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **UE UL carriers** | **fx\_low** | **fx\_high** | **fy\_low** | **fy\_high** |
| UL frequency (MHz) | 824 | 835 | 904 | 915 |
| 2nd order IMD products | |fy\_low – fx\_high| | |fy\_high – fx\_low| | |fy\_low + fx\_low| | |fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 69 | 91 | 1728 | 1750 |
| Two-tone 3rd order IMD products | |2\*fx\_low – fy\_high| | |2\*fx\_high – fy\_low| | |2\*fy\_low – fx\_high| | |2\*fy\_high – fx\_low| |
| IMD frequency limits (MHz) | 733 | 766 | 973 | 1006 |
| Two-tone 3rd order IMD products | |2\*fx\_low + fy\_low| | |2\*fx\_high + fy\_high| | |2\*fy\_low + fx\_low| | |2\*fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 2552 | 2585 | 2632 | 2665 |
| Two-tone 4th order IMD products | |3\*fx\_low –1\* fy\_high| | |3\*fx\_high – 1\*fy\_low| | |3\*fy\_low – 1\*fx\_high| | |3\*fy\_high – 1\*fx\_low| |
| IMD frequency limits (MHz) | 1557 | 1601 | 1877 | 1921 |
| Two-tone 4th order IMD products | |3\*fx\_low +1\* fy\_low| | |3\*fx\_high + 1\*fy\_high| | |3\*fy\_low + 1\*fx\_low| | |3\*fy\_high + 1\*fx\_high| |
| IMD frequency limits (MHz) | 3376 | 3420 | 3536 | 3580 |
| Two-tone 4th order IMD products | |2\*fx\_low –2\* fy\_high| | |2\*fx\_high –2\* fy\_low| | |2\*fx\_low +2\* fy\_low| | |2\*fx\_high +2\* fy\_high| |
| IMD frequency limits (MHz) | 182 | 138 | 3456 | 3500 |
| Two-tone 5th order IMD products | |fx\_low – 4\*fy\_high| | |fx\_high – 4\*fy\_low| | |fy\_low – 4\*fx\_high| | |fy\_high – 4\*fx\_low| |
| IMD frequency limits (MHz) | 2836 | 2781 | 2436 | 2381 |
| Two-tone 5th order IMD products | |2\*fx\_low - 3\*fy\_high| | |2\*fx\_high - 3\*fy\_low| | |2\*fy\_low - 3\*fx\_high| | |2\*fy\_high -3\*fx\_low| |
| IMD frequency limits (MHz) | 1097 | 1042 | 697 | 642 |
| Two-tone 5th order IMD products | |fx\_low + 4\*fy\_low| | |fx\_high + 4\*fy\_high| | |fy\_low + 4\*fx\_low| | |fy\_high + 4\*fx\_high| |
| IMD frequency limits (MHz) | 4440 | 4495 | 4200 | 4255 |
| Two-tone 5th order IMD products | |2\*fx\_low + 3\*fy\_low| | |2\*fx\_high + 3\*fy\_high| | |2\*fy\_low + 3\*fx\_low| | |2\*fy\_high + 3\*fx\_high| |
| IMD frequency limits (MHz) | 4360 | 4415 | 4280 | 4335 |

Based on Table 5.1.3.2-1, there is no IMD issue for CA\_n5-n8 with the following frequency range restriction.

n5 UL: 824 MHz – 835 MHz DL: 869 MHz – 880 MHz;

n8 UL: 904 MHz – 915 MHz DL: 949 MHz – 960 MHz.

Table 5.1.3.2-2 lists the protected bands required for the 2UL bands CA configuration.

Table 5.1.3.2-2: Protected bands for the 2UL bands CA configuration

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR CA Configuration | Spurious emission | | | | | | |
| Protected band | Frequency range (MHz) | | | Maximum Level (dBm) | MBW (MHz) | NOTE |
| CA\_n5-n8 | E-UTRA Band 1, 28, 31, 34, 38, 40, 45, 50, 51, 65, 73, 74 | FDL\_low | - | FDL\_high | -50 | 1 |  |
| E-UTRA Band 3, 7, 41, 42, 43, 52  NR Band n77, n78, n79 | FDL\_low | - | FDL\_high | -50 | 1 | 2 |
| E-UTRA Band 8 | FDL\_low | - | FDL\_high | -50 | 1 | 4 |
| E-UTRA Band 11, 21 | FDL\_low | - | FDL\_high | -50 | 1 |  |
| Frequency range | 1884.5 | - | 1915.7 | -41 | 0.3 | 3 |
| NOTE 2: As exceptions, measurements with a level up to the applicable requirements defined in Table 6.5.3.1-2 are permitted for each assigned NR carrier used in the measurement due to 2nd, 3rd, 4th or 5th harmonic spurious emissions. Due to spreading of the harmonic emission the exception is also allowed for the first 1 MHz frequency range immediately outside the harmonic emission on both sides of the harmonic emission. This results in an overall exception interval centred at the harmonic emission of (2 MHz + N x LCRB x 180kHz), where N is 2, 3, 4, 5 for the 2nd, 3rd, 4th or 5th harmonic respectively. The exception is allowed if the measurement bandwidth (MBW) totally or partially overlaps the overall exception interval.  NOTE 3: Applicable when co-existence with PHS system operating in 1884.5 -1915.7 MHz  NOTE 4: These requirements also apply for the frequency ranges that are less than FOOB (MHz) in Table 6.5.3.1-1 from the edge of the channel bandwidth. | | | | | | | |

#### 5.1.3.3 REFSENS evaluation

Based on the assumption of restricted frequency range for CA\_n5-n8, there is no MSD issue due to intermodulation interference. 2UL Cross-band MSD may be needed.

### 5.1.4 Feasible RF implementations

Referring to clause 5.1.0 and 5.1.1 UE RF architecture assumption, it can be observed that two sets of different RF implementations are included currently:

One is full band n5 and n8 RF filters implementation.

Another one is dedicated RF filters implementation with partial frequency range.

These two implementation may have different RF requirements and scheduling restriction. In study phase, we list all the implementations on the table and further trade off each implementation as below.

Table 5.1.4-1: Trade-off between the feasible RF implementations

| Type of implementation | Options | Pros | Cons |
| --- | --- | --- | --- |
| Full band n5 and n8 RF filters implementation | Option 1 | 1. Current RF components can be reused easily.  2. The same RF filters can support both single carrier operation and CA operation.  3. UE cost may not be improved too much. | 1. UL\_n5-n8 can’t be supported. Only DL\_n5-n8\_UL\_n5 can be supported. |
| Option 2 | 1. Current RF components can be reused.  2. The same RF filters can support both single carrier operation and CA operation.  3. Compared to option 1, DL\_n8\_UL\_n5-n8 can be supported additionally. | 1. Non-concurrent n5 DL and n8 UL limiting DL throughput  2. At least one additional n8 RX filter is required compared to option 1  3. There may be RF additional performance impacts caused by managing the non-concurrency between n5DL and n8UL  4. Potential impacts on RAN2 are observed |
| Dedicated RF filters implementation with partial frequency range | Option 3 | 1. DL\_n5-n8\_UL\_n5-n8 can be supported by UE within partial frequency range. Operators’ demands can be met.  2. There is no scheduling restriction for CA operation, but the specific partial frequency range. | 1. At least, but not necessary limited to one n8 UL dedicated filter with UL partial frequency range need to be developed for this specific CA operation.  2. n5 RX filtering may be impacted to avoid n8 UL at 904-914 blocking n5RX  3. Dedicated filter and full band filter need to be switched between single carrier operation and CA operation. |

As all the implementations are not excluded and UE can support them optionally, a solution is needed to further distinguish these different implementations. The following options can be further discussed.

- Option 1: New bands would be required.

- Option 2: New bands would not be required. An optional signalling/capability solution can be designed for the BS and UE to distinguish these different implementations.

- Option 3: Other are not precluded.

## 5.2 CA\_n5-n28

### 5.2.1 UE RF architecture assumption

The n5 filter parameter assumption in the analysis is based on without sharing path of band n26.

The UE RF architectures with 2 antenna and 3 antenna can be assumed in the feasibility study for CA\_n5-n28.The antenna number is the total number of antennas to support Main UL/DL and diversity DL for all bands. Figure 5.2.1.0-1 shows the aggregated spectrum allocation for CA\_n5-n28 where no frequency range restriction has been indicated for either of the constituent bands.



Figure 5.2.1.0-1 CA\_n5-n28 aggregated spectrum allocation

#### 5.2.1.1 UE RF architecture with two antennas

For CA\_n5-n28 with 2-antenna implementation, there are two potential UE RF architectures as shown in Figure 5.2.1.1-1.



Figure 5.2.1.1-1 Potential UE architecture variants to support CA\_n5-n28 with 2 antenna

The topology for 2 antenna architecture a is listed as below.

- 1) n28UL+n28DL+n5UL+n5DL quadplexer on antenna 1

- 2) n5DL+n28DL duplexer on antenna 2

The topology for 2 antenna architecture b is listed as below.

- 1) n5UL+n5DL+n28DL triplexer on antenna 1

- 2) n28UL+n28DL+n5DL triplexer on antenna 2

[Considering the maximum simultaneously covered spectrum range and closely spaced UL and DL bands, the following challenges and issues impacting UE RF performance for 2-antenna architecture variant (a) can be anticipated:

- The main antenna design needs to cover the entire spectrum range of 191 MHz simultaneously as shown in Figure 5.2.1-1, which is equivalent to a 24% bandwidth ratio and that would exceed the bandwidth ratio for a typical planar antenna design in a smartphone. As a result, the radiative performance for the combination likely would be compromised.

- The feasibility of a single quadplexer is questionable as n28 alone already requires a dual duplexer to reduce the band range to duplex gap ratio in order to achieve the acceptable filter isolation and insertion loss performance. Dual quadplexer has the implication on UE front-end design complexity, area, and cost impacts.

- REFSENS degradation (MSD) on n28 DL caused by frequency proximity between n5 UL and n28 DL and insufficient cross-band isolation.

For 2-antenna architecture variant (b), the following challenges and issues impacting UE RF performance can be anticipated:

- Compared to variant (a), though the main path frequency range is reduced from 191 MHz to 136 MHz, the diversity path frequency range however is increased from 136 MHz to 191 MHz. From antenna design perspective, the same challenge with 24% antenna bandwidth ratio as in variant (a) is expected.

- The feasibility of a single triplexer for diversity path is questionable as n28 alone already requires a dual duplexer to reduce the band range to duplex gap ratio in order to achieve the acceptable filter isolation and insertion loss performance. Dual triplexer in diversity path in conjunction with a single or dual triplexer in main path has the implication on UE front-end design complexity, area, and cost impacts.

- REFSENS degradation (MSD) on n28 DL caused by frequency proximity between n5 UL and n28 DL and insufficient cross-band isolation.]

#### 5.2.1.2 UE RF architecture with three antennas

For CA\_n5-n28 with 3-antenna implementation, the following UE RF architectures can be considered, as shown in Figure 5.2.1.2-1.



Figure 5.2.1.2-1 CA\_n5-n28 UE architecture based on the 3-antenna implementation

The topology for the above 3 antenna architecture is listed as below:

1) n28UL+n28DL duplexer on antenna 1

2) n5UL+n5DL duplexer on antenna 2

3) n5DL+n28DL duplexer on antenna 3

### 5.2.2 Common for 1 band UL and 2 bands UL of CA\_n5-n28

#### 5.2.2.0 General

According to the current spec TS 38.101-1, DL CA\_n5A-n28A\_BCS0 has been specified. Thus, some of RF requirements can be reused as below.

#### 5.2.2.1 Operating bands for CA

Table 5.2.2.1-1: CA band combination of band n5+n28

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR Band | Uplink (UL) band | | | Downlink (DL) band | | | Duplex  mode |
| BS receive / UE transmit | | | BS transmit / UE receive | | |
| FUL\_low – FUL\_high | | | FDL\_low – FDL\_high | | |
| n5 | 824 MHz | – | 849 MHz | 869 MHz | – | 894 MHz | FDD |
| n28 | 703 MHz | – | 748 MHz | 758 MHz | – | 803 MHz | FDD |

#### 5.2.2.2 Channel bandwidths per operating band for CA

Referring to table 5.5A.3.1-1e of TS 38.101-1, DL\_n5A-n28A\_BCS0 has been specified

#### 5.2.2.3 UE co-existence studies

There is no need to specify harmonics and harmonics mixing exception for CA\_n5-n28 as we didn’t specify them in current spec.

#### 5.2.2.4 ∆TIB,c and ∆RIB,c values

For CA\_n5-n28 with 2 antenna implementation, the ΔTIB,c and ΔRIB,c values has been specified in TS 38.101-1.

Referring to contribution R4-2300657, it is suggest to reuse the DC\_28\_n5 ΔTIB,c and ΔRIB,c values with an additional 0.2dB to all to enable the two-antenna n-plexers in the future and including the support of full band n28, which are shown below:

Table 5.2.2.4-0: ΔTIB,c

|  |  |  |
| --- | --- | --- |
| Inter-band CA Configuration | NR Band | ΔTIB,c [dB] |
| CA\_n5A-n28A | n5 | 0.7 |
| n28 | 0.7 |

Table 5.2.2.4-0a: ΔRIB,c

|  |  |  |
| --- | --- | --- |
| Inter-band CA Configuration | NR Band | ΔRIB,c [dB] |
| CA\_n5A-n28A | n5 | 0.2 |
| n28 | 0.2 |

For CA\_n5-n28 with 3 antenna implementation, the ΔTIB,c and ΔRIB,c values are shown below.

Table 5.2.2.4-1: ΔTIB,c

|  |  |  |
| --- | --- | --- |
| Inter-band CA Configuration | NR Band | ΔTIB,c [dB] |
| CA\_n5A-n28A | n5 | 0 |
| n28 | 0 |

Table 5.2.2.4-2: ΔRIB,c

|  |  |  |
| --- | --- | --- |
| Inter-band CA Configuration | NR Band | ΔRIB,c [dB] |
| CA\_n5A-n28A | n5 | 0 |
| n28 | 0 |

#### 5.2.2.5 REFSENS evaluation

For CA\_n5-n28 with 2 antennas implementation, referring to contribution R4-2202036, the n28 MSD evaluation for CA\_n5-n28 is shown as below.

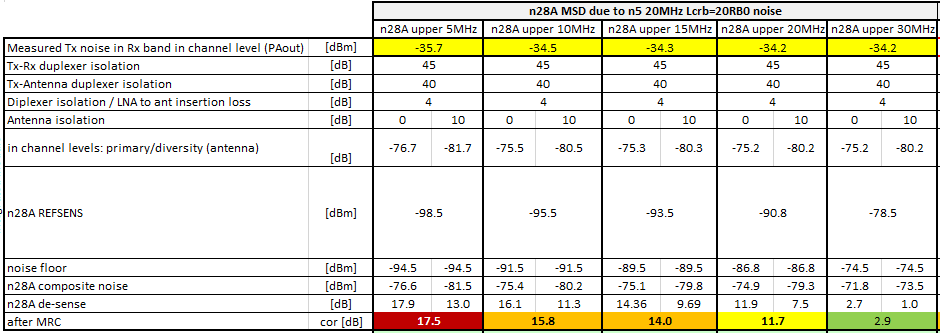


Figure 5.2.2.5-1 the n28 MSD evaluation for CA\_n5-n28

Based on the agreed CR R4-2206134, one MSD test configuration (n28 30MHz) can be a reference considering the impacts from band n5 UL.

Table 5.2.2.5-1 MSD due to cross band isolation for CA\_n5-n28

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n5 | n28 | 834 | 20 | 15 | 20 (RBstart=0) | 800.5 | 5 | 17.5 | ACLR2 |

For CA\_n5-n28 with 3 antennas implementation, referring to contribution R4-2301266, the n28 MSD evaluation on the same MSD test configuration (n28 30MHz) as 2 antennas implementation is shown as below.

Table 5.2.2.5-2 MSD due to cross band isolation for CA\_n5-n28

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n5 | n28 | 834 | 20 | 15 | 20 (RBstart=0) | 800.5 | 5 | 18.6 | ACLR2 |

### 5.2.3 Specific for 2 bands UL of fallback CA\_n5-n28

#### 5.2.3.1 Maximum output power for inter-band CA

Power class 3 is assumed for UL CA\_n5-n28.

#### 5.2.3.2 UE co-existence studies

Table 5.2.3.2-1 lists Band n5 + Band n28 2UL bands CA 2nd, 3rd, 4th and 5th order IMD for the UE-to-UE coexistence analysis.

Table 5.2.3.2-1: Band n5 and Band n28 UL IMD products

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| UE UL carriers | fx\_low | fx\_high | fy\_low | fy\_high |
| UL frequency (MHz) | 824 | 869 | 703 | 748 |
| 2nd order IMD products | |fy\_low – fx\_high| | |fy\_high – fx\_low| | |fy\_low + fx\_low| | |fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 166 | 76 | 1527 | 1617 |
| Two-tone 3rd order IMD products | |2\*fx\_low – fy\_high| | |2\*fx\_high – fy\_low| | |2\*fy\_low – fx\_high| | |2\*fy\_high – fx\_low| |
| IMD frequency limits (MHz) | 900 | 1035 | 537 | 672 |
| Two-tone 3rd order IMD products | |2\*fx\_low + fy\_low| | |2\*fx\_high + fy\_high| | |2\*fy\_low + fx\_low| | |2\*fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 2351 | 2486 | 2230 | 2365 |
| Two-tone 4th order IMD products | |3\*fx\_low –1\* fy\_high| | |3\*fx\_high – 1\*fy\_low| | |3\*fy\_low – 1\*fx\_high| | |3\*fy\_high – 1\*fx\_low| |
| IMD frequency limits (MHz) | 1724 | 1904 | 1240 | 1420 |
| Two-tone 4th order IMD products | |3\*fx\_low +1\* fy\_low| | |3\*fx\_high + 1\*fy\_high| | |3\*fy\_low + 1\*fx\_low| | |3\*fy\_high + 1\*fx\_high| |
| IMD frequency limits (MHz) | 3175 | 3355 | 2933 | 3113 |
| Two-tone 4th order IMD products | |2\*fx\_low –2\* fy\_high| | |2\*fx\_high –2\* fy\_low| | |2\*fx\_low +2\* fy\_low| | |2\*fx\_high +2\* fy\_high| |
| IMD frequency limits (MHz) | 152 | 332 | 3054 | 3234 |
| Two-tone 5th order IMD products | |fx\_low – 4\*fy\_high| | |fx\_high – 4\*fy\_low| | |fy\_low – 4\*fx\_high| | |fy\_high – 4\*fx\_low| |
| IMD frequency limits (MHz) | 2168 | 1943 | 2773 | 2548 |
| Two-tone 5th order IMD products | |2\*fx\_low - 3\*fy\_high| | |2\*fx\_high - 3\*fy\_low| | |2\*fy\_low - 3\*fx\_high| | |2\*fy\_high -3\*fx\_low| |
| IMD frequency limits (MHz) | 596 | 371 | 1201 | 976 |
| Two-tone 5th order IMD products | |fx\_low + 4\*fy\_low| | |fx\_high + 4\*fy\_high| | |fy\_low + 4\*fx\_low| | |fy\_high + 4\*fx\_high| |
| IMD frequency limits (MHz) | 3636 | 3861 | 3999 | 4224 |
| Two-tone 5th order IMD products | |2\*fx\_low + 3\*fy\_low| | |2\*fx\_high + 3\*fy\_high| | |2\*fy\_low + 3\*fx\_low| | |2\*fy\_high + 3\*fx\_high| |
| IMD frequency limits (MHz) | 3757 | 3982 | 3878 | 4103 |

Based on Table 5.2.3.2-1, there is no IMD issue for CA\_n5-n28.

Table 5.2.3.2-2 lists the protected bands required for the 2UL bands CA configuration.

Table 5.2.3.2-2: Protected bands for the 2UL bands CA configuration

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR CA Configuration | Spurious emission | | | | | | |
| Protected band | Frequency range (MHz) | | | Maximum Level (dBm) | MBW (MHz) | NOTE |
| CA\_n5-n28 | E-UTRA Band 2, 3, 5, 7, 8, 18, 19, 25, 26, 31, 34, 38, 40, 73  NR Band n79 | FDL\_low | - | FDL\_high | -50 |  |  |
| E-UTRA Band 4, 41, 42, 43, 50, 51, 52, 65, 66, 74 NR Band n77, n78 | FDL\_low | - | FDL\_high | -50 | 1 | 2 |
| E-UTRA Band 1 | FDL\_low | - | FDL\_high | -50 | 1 | 2, 11, 15 |
| E-UTRA Band 11, 21 | FDL\_low | - | FDL\_high | -50 | 1 | 2, 11, 12 |
| Frequency range | 1884.5 | - | 1915.7 | -41 | 0.3 | 3, 11 |
| Frequency range | 470 | - | 694 | -42 | 8 | 4, 14 |
| Frequency range | 470 | - | 710 | -26.2 | 6 | 13 |
| Frequency range | 662 | - | 694 | -26.2 | 6 | 4 |
| Frequency range | 758 | - | 773 | -32 | 1 | 4 |
| Frequency range | 773 | - | 803 | -50 | 1 |  |
| NOTE 2: As exceptions, measurements with a level up to the applicable requirements defined in Table 6.5.3.1-2 are permitted for each assigned NR carrier used in the measurement due to 2nd, 3rd, 4th or 5th harmonic spurious emissions. Due to spreading of the harmonic emission the exception is also allowed for the first 1 MHz frequency range immediately outside the harmonic emission on both sides of the harmonic emission. This results in an overall exception interval centred at the harmonic emission of (2 MHz + N x LCRB x 180kHz), where N is 2, 3, 4, 5 for the 2nd, 3rd, 4th or 5th harmonic respectively. The exception is allowed if the measurement bandwidth (MBW) totally or partially overlaps the overall exception interval.  NOTE 3: Applicable when co-existence with PHS system operating in 1884.5 -1915.7 MHz  NOTE 4: These requirements also apply for the frequency ranges that are less than FOOB (MHz) in Table 6.5.3.1-1 from the edge of the channel bandwidth.  NOTE 11:Applicable when the assigned NR carrier is confined within 718 MHz and 748 MHz and when the channel bandwidth used is 5 or 10 MHz.  NOTE 12: As exceptions, measurements with a level up to the applicable requirement of -38 dBm/MHz is permitted for each assigned NR carrier used in the measurement due to 2nd harmonic spurious emissions. An exception is allowed if there is at least one individual RB within the transmission bandwidth (see Figure 5.3.1-1) for which the 2nd harmonic totally or partially overlaps the measurement bandwidth (MBW).  NOTE 13: This requirement is applicable for 5 and 10 MHz NR channel bandwidth allocated within 718 - 728 MHz. For carriers of 10 MHz bandwidth, this requirement applies for an uplink transmission bandwidth less than or equal to 30 RB with RBstart > 1 and Rbstart < 48.  NOTE 14: This requirement is applicable in the case of a 10 MHz NR carrier confined within 703 MHz and 733 MHz, otherwise the requirement of -25 dBm with a measurement bandwidth of 8 MHz applies.  NOTE 15: As exceptions, measurements with a level up to the applicable requirement of -36 dBm/MHz is permitted for each assigned E-UTRA carrier used in the measurement due to 3rd harmonic spurious emissions. An exception is allowed if there is at least one individual RB within the transmission bandwidth (see Figure 5.6-1) for which the 3rd harmonic totally or partially overlaps the measurement bandwidth (MBW). | | | | | | | |

#### 5.2.3.3 REFSENS evaluation

Since there is no two UL IMD issue for CA\_n5-n28, no need to specify the MSD due to two UL IMD interference. The following reference exception can be further studied.

Referring to contribution R4-2300657, the estimation of the n5+n28 UL interference in band n28 DL versus n5 and n28 1UL case can be found in table 5.2.3.3-1.

Table 5.2.3.3-1: Estimation of the n5+n28 UL interference in band n28 DL versus n5 and n28 1UL case

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| n28DL CBW (MHz) at the top of band 28 | 5 |  | 15 | 20 | 25 | 30 |
| n28 UL transmitter output noise at 23dBm (dBm) | -58.5 |  | -52.2 | -50.0 | -42.3 | -28.1 |
| 38.101-1 n28 REFSENS de-sense due to Tx (dB) | 0.0 |  | 0.0 | 1.4 | 7.0 | 11.9 |
| n28 UL transmitter output noise at 20dBm (dBm) | -61.5 |  | -55.3 | -53.8 | -50.5 | -39.2 |
| n5 UL transmitter output noise at 23dBm (dBm) | -45.2 |  | -41.1 | -41.0 | -40.8 | -40.7 |
| n5 UL transmitter output noise at 20dBm (dBm) | -53.8 |  | -49.6 | -48.9 | -47.8 | -48.9 |
| n28UL -> n28DL quadplexer isolation (dB) | 50 |  | 50 | 50 | 50 | 50 |
| n5UL -> n28DL quadplexer isolation (dB) | 45 |  | 45 | 45 | 45 | 45 |
| n28 transmitter output noise at 23dBm (dBm) at main LNA | -108.5 |  | -102.2 | -100.0 | -92.3 | -78.1 |
| n5+n28 transmitter output noise at 23dBm (dBm) at main LNA | -90.4 |  | -94.8 | -94.1 | -93.3 | -88.0 |
| delta n5+n28 vs n28 at 23dBm output noise at main LNA | *18.1* |  | 7.4 | 5.8 | -1.0 | -9.9 |

The resulting MSD (on top of n28 without self de-sense) with MRC calculations is provided in Table 5.2.3.3-1 to enable a two-antenna architecture in the long-term.

Table 5.2.3.3-2: 2UL cross band MSDs for CA\_n5-n28

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n5 | n28 | 834 | 20 | 15 | 20 (Rbstart=0) | 793 | 20 | [3.6] | ACLR2 |
| n28 | 738 | 20 | 15 | 25 (Rbstart=81) | ACLR2 |

Referring to contribution R4-2302097, the relationship for n28 DL impacted by both band n5 UL and n28 UL is shown in figure 1, when both band n5 UL and n28 UL are configured for CA\_n5-n28, band n28 DL receiver will be impacted by the leakage interference from band n5 UL and n28 UL.

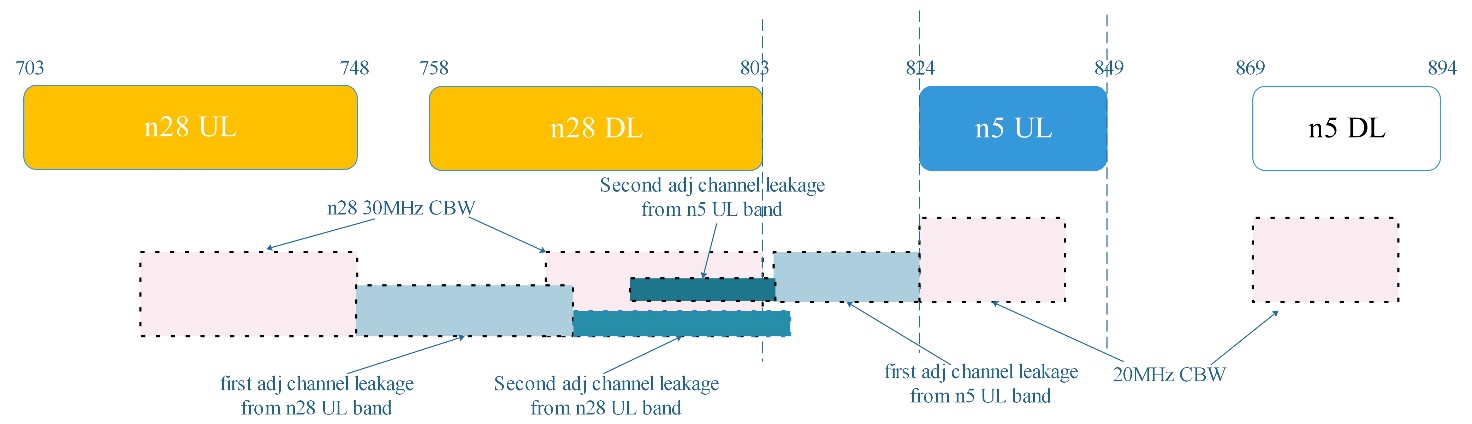


Figure 5.2.3.3-1 The relationship for band n28 DL impacted by both band n5 UL and n28 UL

Some measurement results were proposed in R4-2202036 for band n28 30MHz case. -32.4dBm Tx noise in n28 Rx band can be observed from band n5 PAout. Since 45dB Tx-Rx isolation between n5 UL band and n28 DL band was assumed, 2.9dB MSD can be observed based on n28 30MHz -78.5dBm REFSENS for 2 antenna implementation, which is shown in Table 5.2.3.3-3:

Table 5.2.3.3-3: 2UL cross band MSDs for CA\_n5-n28

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n5 | n28 | 834 | 20 | 15 | 20 (RBstart=0) | 788 | 30 | 2.9 | ACLR2 from n5 UL band  ACLR1+ACLR2 from n28 UL band |
| n28 | 733 | 30 | 15 | 25 (RBstart=135) |

Referring to contribution R4-2302253, the most straightforward way would be to use the same test point for 2UL MSD due to Cross-Band Isolation as has been used for 1UL Cross-band Isolation for 2 antenna implementation, which is shown in Table 5.2.3.3-4:

Table 5.2.3.3-4: 2UL cross band MSDs for CA\_n5-n28

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n5 | n28 | 834 | 20 | 15 | 20 (Rbstart=0) | 800.5 | 5 | 17.5 | n5 ACLR2 |
| n28 | 5 | 5 | 15 | 25 (Rbstart=0) |

Referring to contribution R4-2218129, for 2UL MSD due to Cross-Band Isolation as has been used for 1UL Cross-band Isolation for 3 antenna implementation is shown in Table 5.2.3.3-5. It includes a legacy filter rejection for n5 TX OOB leakage in n28DL. The antenna isolation helps attenuate the TX leakage to give a similar MSD result specified in Table 5.2.3.3-3 for a 30MHz DL.

Table 5.2.3.3-5: 2UL cross band MSDs for CA\_n5-n28

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n5 | n28 | 834 | 20 | 15 | 20 (RBstart=0) | 788 | 30 | 4.5 | ACLR2 from n5 UL band  ACLR1+ACLR2 from n28 UL band |
| n28 | 733 | 30 | 15 | 25 (RBstart=135) |

## 5.3 CA\_n8-n20-n28

### 5.3.1 UE RF architecture assumption

#### 5.3.1.0 General

The UE RF architectures with 2 antenna, 3 antenna, 4 antenna can be assumed to analyze and study for CA\_n8-n20-n28.The antenna number is the total number of antennas to support Main UL/DL and diversity DL for all bands. UE RF architecture with three antennas for CA\_n8-n20-n28 is used as baseline for evaluation. The UE RF architectures with two or four antennas are not precluded in the study item.

#### 5.3.1.1 UE RF architecture with three antennas

The assumption 1A for UE RF architecture with three antennas for CA\_n8-n20-n28 are shown as below.

1) n28UL/n20+n28DL/n20UL triplexer on antenna 1

2) n8UL/n8DL duplexer on antenna 2

3) n20+n28DL/n8DL duplexer on antenna 3

4) 10dB antenna isolation is used for MSD calculations

The assumption 1B for UE RF architecture with three antennas for CA\_n8-n20-n28 are shown as below. Comparing to assumption 1a, n8UL/n8DL duplexer on antenna 2 was replaced by n8UL/n8DL/n20UL/n20DL quadplexer.

1) n28UL/n20+n28DL/n20UL triplexer on antenna 1

2) n8UL/n8DL/n20UL/n20DL quadplexer on antenna 2

3) n20+n28DL/n8DL duplexer on antenna 3

4) 10dB antenna isolation is used for MSD calculations

The assumption 1C for UE RF architecture with three antennas for CA\_n8-n20-n28 are shown as Figure 5.3.1.1-1. These are two other variants based on assumption 1a. They may allow easier implementation of either triplexer or duplexer in main path owing to that the frequency separations between the sub-bands are wider than the architecture assumed for DC\_8-20\_n28. However, the downside with two variants is that the widest frequency range which needs to be covered by any of the antenna is still relatively wide at 212 MHz and 257 MHz respectively.



Figure 5.3.1.1-1 Potential UE architecture variants to support CA\_n8-n20-n28 with 3 antenna

#### 5.3.1.2 UE RF architecture with two antennas

The assumption 2A for UE RF architecture with two antennas for CA\_n8-n20-n28 are shown as below. Pentaplexer design is considered.

1) n28UL/n20+n28DL/n20UL/n8UL/n8DL pentaplexer on antenna 1

2) n20+n28DL/n8DL duplexer on antenna 2

3) 10dB antenna isolation is used for MSD calculations

The assumption 2B for UE RF architecture with two antennas for CA\_n8-n20-n28 are shown as below. Quadplexer design is considered.

1) n28UL/n20+n28DL/n20UL/n8DL quadplexer on antenna 1

2) n20+n28DL/n8UL/n8DL triplexer or n20+n28DL/n20UL/n8UL/n8DL quadplexer on antenna 2

3) 10dB antenna isolation is used for MSD calculations

There are two potential implementation challenges with 2-antenna architectures. The first challenge is that the antenna design needs to cover the entire spectrum range of 257 MHz simultaneously as shown in Figure 5.3.1-1 for either of the variants, which is equivalent to a 31% bandwidth ratio and that would far exceed the bandwidth ratio for a typical planar antenna design in a smartphone. As a result, the radiative performance for the combination is expected to be compromised.

The second challenge is on the feasibility of a pentaplexer design for variant (a) to aggregate five closely spaced spectrum ranges as shown in Figure 5.3.1-1, not only with sufficient filter isolation between self-band and cross-band but also with acceptable insertion loss. The variant (b) though avoids the use of pentaplexer, the design of the intended quadplexer is still relatively challenging considering the closely spaced spectrum ranges with nearly 8% bandwidth ratio for the n20/n28 combined DL range.

#### 5.3.1.3 UE RF architecture with four antennas

The assumption 3A and 3B for UE RF architecture with four antennas for CA\_n8-n20-n28 are shown as below.



Figure 5.3.1.3-1 The assumption 3A for UE RF architecture to support CA\_n8-n20-n28 with 4 antenna



Figure 5.3.1.3-2 The assumption 3B for UE RF architecture to support CA\_n8-n20-n28 with 4 antenna

For the 4-antenna implementation, the three of the four antenna are used in the main path to aggregate the n8, n20, and n28 signals over the air, as shown in Figures 5.3.1.3-1 and 5.3.1.3-2. As n8, n20, and n28 signals do not need to be combined through a multiplexer, there is no additional insertion loss in n8, n20, and n28 main signal paths as compared to single-band implementation.

Having 3 antenna in the main signal path not only avoids the more complicated multiplexer implementation and the associated additional insertion losses, but also allows narrower frequency coverage for each of the 3 antenna as compared to single-antenna implementation. However, the additional antenna cannot be added without occupying more phone space.

### 5.3.2 CA\_n8-n20

#### 5.3.2.0 General

According to the current spec TS 38.101-1, DL CA\_n8A-n20A\_BCS0 has been specified. Thus, some of RF requirements can be reused as below. Both DL\_n8A-n20A\_BCS0 and DL\_n8A-n20A\_UL\_n8A-n20A are fallback CA band combinations of DL\_n8A-n20A-n28A\_UL\_n8A-n20A.

#### 5.3.2.1 Operating bands for CA

Table 5.3.2.1-1: CA band combination of band n8+n20

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR Band | Uplink (UL) band | | | Downlink (DL) band | | | Duplex  mode |
| BS receive / UE transmit | | | BS transmit / UE receive | | |
| FUL\_low – FUL\_high | | | FDL\_low – FDL\_high | | |
| n8 | 880 MHz | – | 915 MHz | 925 MHz | – | 960 MHz | FDD |
| n20 | 832 MHz | – | 862 MHz | 791 MHz | – | 821 MHz | FDD |

#### 5.3.2.2 Channel bandwidths per operating band for CA

Referring to table 5.5A.3.1-1e of TS 38.101-1, DL\_n8A-n20A\_BCS0 has been specified.

#### 5.3.2.3 UE co-existence studies

There is no need to specify harmonics and harmonics mixing exception for CA\_n8-n20 as we didn’t specify them in current spec.

#### 5.3.2.4 ∆TIB,c and ∆RIB,c values

For CA\_n8-n20, the ΔTIB,c and ΔRIB,c values have been specified in TS 38.101-1.

#### 5.3.2.5 REFSENS requirements

As CA\_n8-n20 has been specified into current spec TS 38.101-1, there is no harmonics, cross band isolation and harmonics mixing exception.

#### 5.3.2.6 Maximum output power for UL inter-band CA

Power class 3 is assumed for UL CA\_n8-n20.

#### 5.3.2.7 UE co-existence studies for UL inter-band CA

Table 5.3.2.7-1 lists Band n8 + Band n20 2UL bands CA 2nd, 3rd, 4th and 5th order IMD for the UE-to-UE coexistence analysis.

Table 5.3.2.7-1: Band n8 and Band n20 UL IMD products

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| UE UL carriers | fx\_low | fx\_high | fy\_low | fy\_high |
| UL frequency (MHz) | 880 | 915 | 832 | 862 |
| 2nd order IMD products | |fy\_low – fx\_high| | |fy\_high – fx\_low| | |fy\_low + fx\_low| | |fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 83 | 18 | 1712 | 1777 |
| Two-tone 3rd order IMD products | |2\*fx\_low – fy\_high| | |2\*fx\_high – fy\_low| | |2\*fy\_low – fx\_high| | |2\*fy\_high – fx\_low| |
| IMD frequency limits (MHz) | 898 | 998 | 749 | 844 |
| Two-tone 3rd order IMD products | |2\*fx\_low + fy\_low| | |2\*fx\_high + fy\_high| | |2\*fy\_low + fx\_low| | |2\*fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 2592 | 2692 | 2544 | 2639 |
| Two-tone 4th order IMD products | |3\*fx\_low –1\* fy\_high| | |3\*fx\_high – 1\*fy\_low| | |3\*fy\_low – 1\*fx\_high| | |3\*fy\_high – 1\*fx\_low| |
| IMD frequency limits (MHz) | 1778 | 1913 | 1581 | 1706 |
| Two-tone 4th order IMD products | |3\*fx\_low +1\* fy\_low| | |3\*fx\_high + 1\*fy\_high| | |3\*fy\_low + 1\*fx\_low| | |3\*fy\_high + 1\*fx\_high| |
| IMD frequency limits (MHz) | 3472 | 3607 | 3376 | 3501 |
| Two-tone 4th order IMD products | |2\*fx\_low –2\* fy\_high| | |2\*fx\_high –2\* fy\_low| | |2\*fx\_low +2\* fy\_low| | |2\*fx\_high +2\* fy\_high| |
| IMD frequency limits (MHz) | 36 | 166 | 3424 | 3554 |
| Two-tone 5th order IMD products | |fx\_low – 4\*fy\_high| | |fx\_high – 4\*fy\_low| | |fy\_low – 4\*fx\_high| | |fy\_high – 4\*fx\_low| |
| IMD frequency limits (MHz) | 2568 | 2413 | 2828 | 2658 |
| Two-tone 5th order IMD products | |2\*fx\_low - 3\*fy\_high| | |2\*fx\_high - 3\*fy\_low| | |2\*fy\_low - 3\*fx\_high| | |2\*fy\_high -3\*fx\_low| |
| IMD frequency limits (MHz) | 826 | 666 | 1081 | 916 |
| Two-tone 5th order IMD products | |fx\_low + 4\*fy\_low| | |fx\_high + 4\*fy\_high| | |fy\_low + 4\*fx\_low| | |fy\_high + 4\*fx\_high| |
| IMD frequency limits (MHz) | 4208 | 4363 | 4352 | 4522 |
| Two-tone 5th order IMD products | |2\*fx\_low + 3\*fy\_low| | |2\*fx\_high + 3\*fy\_high| | |2\*fy\_low + 3\*fx\_low| | |2\*fy\_high + 3\*fx\_high| |
| IMD frequency limits (MHz) | 4256 | 4416 | 4304 | 4469 |

Based on Table 5.3.2.6-1, 3rd and 5th order IMD may also fall into Rx frequencies of bands n8 or band n20.

Table 5.3.2.7-2 lists the protected bands required for the 2UL bands CA configuration.

Table 5.3.2.7-2: Protected bands for the 2UL bands CA configuration

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR CA Configuration | Spurious emission | | | | | | |
| Protected band | Frequency range (MHz) | | | Maximum Level (dBm) | MBW (MHz) | NOTE |
| CA\_n8-n20 | E-UTRA Band 1, 31, 32, 33, 34, 40, 50, 51, 65, 67, 68, 72, 74, 75, 76  NR Band n100, n104 | FDL\_low | - | FDL\_high | -50 | 1 |  |
| E-UTRA Band 3, 7, 22, 38, 42, 43, 52, 69  NR band n77, n78 | FDL\_low | - | FDL\_high | -50 | 1 | 2 |
| E-UTRA Band 8, 20 | FDL\_low | - | FDL\_high | -50 | 1 | 4 |
| Frequency range | 758 | - | 788 | -50 | 1 |  |
| NOTE 2: As exceptions, measurements with a level up to the applicable requirements defined in Table 6.5.3.1-2 are permitted for each assigned NR carrier used in the measurement due to 2nd, 3rd, 4th or 5th harmonic spurious emissions. Due to spreading of the harmonic emission the exception is also allowed for the first 1 MHz frequency range immediately outside the harmonic emission on both sides of the harmonic emission. This results in an overall exception interval centred at the harmonic emission of (2 MHz + N x LCRB x 180kHz), where N is 2, 3, 4, 5 for the 2nd, 3rd, 4th or 5th harmonic respectively. The exception is allowed if the measurement bandwidth (MBW) totally or partially overlaps the overall exception interval.  NOTE 4: These requirements also apply for the frequency ranges that are less than FOOB (MHz) in Table 6.5.3.1-1 from the edge of the channel bandwidth. | | | | | | | |

#### 5.3.2.8 REFSENS evaluation for UL inter-band CA

IMD3 MSD of DC\_20\_n8A in band 20 and n8 specified in TS 38.101-3 is a good reference for CA\_n8-n20 as below.

Table 5.3.2.8-1: REFSENS exceptions due to IMD interference for CA\_n8-n20

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Band / Channel bandwidth / NRB / Duplex mode | | | | | | | | Source of IMD |
| NR CA band combination | NR band | UL Fc  (MHz) | UL/DL BW  (MHz) | UL  LCRB | DL Fc (MHz) | MSD  (dB) | Duplex mode |  |
| CA\_n8-n20 | n8 | 892.5 | 5 | 25 | 937.5 | 25 | FDD | IMD3 |
| n20 | 849.5 | 5 | 25 | 808.5 | 25 | FDD | IMD3 |

### 5.3.3 CA\_n8-n28

#### 5.3.3.0 General

According to the current spec TS 38.101-1, DL CA\_n8A-n28A\_BCS0 has been specified. Thus, some of RF requirements can be reused as below. Both DL\_n8A-n28A\_BCS0 and DL\_n8A-n28A\_UL\_n8A-n28A are fallback CA band combinations of DL\_n8A-n20A-n28A\_UL\_n8A-n28A.

#### 5.3.3.1 Operating bands for CA

Table 5.3.3.1-1: CA band combination of band n8+n28

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR Band | Uplink (UL) band | | | Downlink (DL) band | | | Duplex  mode |
| BS receive / UE transmit | | | BS transmit / UE receive | | |
| FUL\_low – FUL\_high | | | FDL\_low – FDL\_high | | |
| n8 | 880 MHz | – | 915 MHz | 925 MHz | – | 960 MHz | FDD |
| n28 | 703 MHz | – | 748 MHz | 758 MHz | – | 803 MHz | FDD |

#### 5.3.3.2 Channel bandwidths per operating band for CA

Referring to table 5.5A.3.1-1e of TS 38.101-1, DL\_n8A-n28A\_BCS0 has been specified as below.

Table 5.3.3.2-1: Supported bandwidths per CA band combination of band n8+n28

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NR CA configuration | Uplink CA configuration or single uplink carrier | NR Band | Channel bandwidth (MHz) | Bandwidth combination set |
| CA\_n8A-n28A | CA\_n8A-n28A | n8 | 5, 10, 15, 20 | 0 |
| n28 | 5, 10, 15, 20, 30 |  |

#### 5.3.3.3 UE co-existence studies

There is no need to specify harmonics and harmonics mixing exception for CA\_n8-n28 as we didn’t specify them in current spec.

#### 5.3.3.4 ∆TIB,c and ∆RIB,c values

For CA\_n8-n28, the ΔTIB,c and ΔRIB,c values have been specified in TS 38.101-1.

#### 5.3.3.5 REFSENS requirements

As CA\_n8-n28 has been specified into current spec TS 38.101-1, there is no harmonics, cross band isolation and harmonics mixing exception.

#### 5.3.3.6 Maximum output power for UL inter-band CA

Power class 3 is assumed for UL CA\_n8-n28.

#### 5.3.3.7 UE co-existence studies for UL inter-band CA

Table 5.3.3.7-1 lists Band n8 + Band n28 2UL bands CA 2nd, 3rd, 4th and 5th order IMD for the UE-to-UE coexistence analysis.

Table 5.3.3.7-1: Band n8 and Band n28 UL IMD products

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **UE UL carriers** | **fx\_low** | **fx\_high** | **fy\_low** | **fy\_high** |
| UL frequency (MHz) | 880 | 915 | 703 | 748 |
| 2nd order IMD products | |fy\_low – fx\_high| | |fy\_high – fx\_low| | |fy\_low + fx\_low| | |fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 212 | 132 | 1583 | 1663 |
| Two-tone 3rd order IMD products | |2\*fx\_low – fy\_high| | |2\*fx\_high – fy\_low| | |2\*fy\_low – fx\_high| | |2\*fy\_high – fx\_low| |
| IMD frequency limits (MHz) | 1012 | 1127 | 491 | 616 |
| Two-tone 3rd order IMD products | |2\*fx\_low + fy\_low| | |2\*fx\_high + fy\_high| | |2\*fy\_low + fx\_low| | |2\*fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 2463 | 2578 | 2286 | 2411 |
| Two-tone 4th order IMD products | |3\*fx\_low –1\* fy\_high| | |3\*fx\_high – 1\*fy\_low| | |3\*fy\_low – 1\*fx\_high| | |3\*fy\_high – 1\*fx\_low| |
| IMD frequency limits (MHz) | 1892 | 2042 | 1194 | 1364 |
| Two-tone 4th order IMD products | |3\*fx\_low +1\* fy\_low| | |3\*fx\_high + 1\*fy\_high| | |3\*fy\_low + 1\*fx\_low| | |3\*fy\_high + 1\*fx\_high| |
| IMD frequency limits (MHz) | 3343 | 3493 | 2989 | 3159 |
| Two-tone 4th order IMD products | |2\*fx\_low –2\* fy\_high| | |2\*fx\_high –2\* fy\_low| | |2\*fx\_low +2\* fy\_low| | |2\*fx\_high +2\* fy\_high| |
| IMD frequency limits (MHz) | 264 | 424 | 3166 | 3326 |
| Two-tone 5th order IMD products | |fx\_low – 4\*fy\_high| | |fx\_high – 4\*fy\_low| | |fy\_low – 4\*fx\_high| | |fy\_high – 4\*fx\_low| |
| IMD frequency limits (MHz) | 2112 | 1897 | 2957 | 2772 |
| Two-tone 5th order IMD products | |2\*fx\_low - 3\*fy\_high| | |2\*fx\_high - 3\*fy\_low| | |2\*fy\_low - 3\*fx\_high| | |2\*fy\_high -3\*fx\_low| |
| IMD frequency limits (MHz) | 484 | 279 | 1339 | 1144 |
| Two-tone 5th order IMD products | |fx\_low + 4\*fy\_low| | |fx\_high + 4\*fy\_high| | |fy\_low + 4\*fx\_low| | |fy\_high + 4\*fx\_high| |
| IMD frequency limits (MHz) | 3692 | 3907 | 4223 | 4408 |
| Two-tone 5th order IMD products | |2\*fx\_low + 3\*fy\_low| | |2\*fx\_high + 3\*fy\_high| | |2\*fy\_low + 3\*fx\_low| | |2\*fy\_high + 3\*fx\_high| |
| IMD frequency limits (MHz) | 3869 | 4074 | 4046 | 4241 |

Based on Table 5.3.3.7-1, there is no IMD issue for CA\_n8-n28.

Table 5.3.3.7-2 lists the protected bands required for the 2UL bands CA configuration.

Table 5.3.3.7-2: Protected bands for the 2UL bands CA configuration

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR CA Configuration | Spurious emission | | | | | | |
| Protected band | Frequency range (MHz) | | | Maximum Level (dBm) | MBW (MHz) | NOTE |
| CA\_n8-n28 | E-UTRA Band 20, 31, 34, 38, 40, 72 | FDL\_low | - | FDL\_high | -50 | 1 |  |
| E-UTRA band 3, 7, 22, 41, 42, 43, 50, 51, 65, 73, 74, 75, 76  NR Band n77, n78, n79, n100 | FDL\_low | - | FDL\_high | -50 | 1 | 2 |
| E-UTRA Band 1 | FDL\_low | - | FDL\_high | -50 | 1 | 2, 11, 15 |
| E-UTRA Band 8 | FDL\_low | - | FDL\_high | -50 | 1 | 4 |
| E-UTRA Band 11, 21 | FDL\_low | - | FDL\_high | -50 | 1 | 11, 12 |
| Frequency range | 470 | - | 694 | -42 | 8 | 4, 14 |
| Frequency range | 470 | - | 710 | -26.2 | 6 | 13 |
| Frequency range | 662 | - | 694 | -26.2 | 6 | 4 |
| Frequency range | 758 | - | 773 | -32 | 1 | 4 |
| Frequency range | 773 | - | 803 | -50 | 1 |  |
| Frequency range | 1884.5 | - | 1915.7 | -41 | 0.3 | 3, 11 |
| NOTE 2: As exceptions, measurements with a level up to the applicable requirements defined in Table 6.5.3.1-2 are permitted for each assigned NR carrier used in the measurement due to 2nd, 3rd, 4th or 5th harmonic spurious emissions. Due to spreading of the harmonic emission the exception is also allowed for the first 1 MHz frequency range immediately outside the harmonic emission on both sides of the harmonic emission. This results in an overall exception interval centred at the harmonic emission of (2 MHz + N x LCRB x 180kHz), where N is 2, 3, 4, 5 for the 2nd, 3rd, 4th or 5th harmonic respectively. The exception is allowed if the measurement bandwidth (MBW) totally or partially overlaps the overall exception interval.  NOTE 3: Applicable when co-existence with PHS system operating in 1884.5 -1915.7 MHz  NOTE 4: These requirements also apply for the frequency ranges that are less than FOOB (MHz) in Table 6.5.3.1-1 from the edge of the channel bandwidth.  NOTE 11:Applicable when the assigned NR carrier is confined within 718 MHz and 748 MHz and when the channel bandwidth used is 5 or 10 MHz.  NOTE 12: As exceptions, measurements with a level up to the applicable requirement of -38 dBm/MHz is permitted for each assigned NR carrier used in the measurement due to 2nd harmonic spurious emissions. An exception is allowed if there is at least one individual RB within the transmission bandwidth (see Figure 5.3.1-1) for which the 2nd harmonic totally or partially overlaps the measurement bandwidth (MBW).  NOTE 13: This requirement is applicable for 5 and 10 MHz NR channel bandwidth allocated within 718 - 728 MHz. For carriers of 10 MHz bandwidth, this requirement applies for an uplink transmission bandwidth less than or equal to 30 RB with RBstart > 1 and Rbstart < 48.  NOTE 14: This requirement is applicable in the case of a 10 MHz NR carrier confined within 703 MHz and 733 MHz, otherwise the requirement of -25 dBm with a measurement bandwidth of 8 MHz applies.  NOTE 15: As exceptions, measurements with a level up to the applicable requirement of -36 dBm/MHz is permitted for each assigned E-UTRA carrier used in the measurement due to 3rd harmonic spurious emissions. An exception is allowed if there is at least one individual RB within the transmission bandwidth (see Figure 5.6-1) for which the 3rd harmonic totally or partially overlaps the measurement bandwidth (MBW). | | | | | | | |

#### 5.3.3.8 REFSENS requirements for UL inter-band CA

There is no REFSENS exception due to IMD interference for CA\_n8A-n28A.

### 5.3.4 CA\_n20-n28

#### 5.3.4.1 General

According to the current spec TS 38.101-1, DL\_n20A-n28A\_UL\_n20A-n28A\_BCS0 and DL\_n20A-n28A\_UL\_n20A-n28A\_BCS1 have already been specified. Thus, all of the related RF requirements have been analysed in clause 6.31 from TR 38.716-02-00 and can be reused as below. Both DL\_n20A-n28A\_BCS0 and DL\_n20A-n28A\_UL\_n20A-n28A\_BCS0 are fallback CA band combinations of DL\_n8A-n20A-n28A\_UL\_n20A-n28A.

1) The operating bands for CA\_n20-n28 were specified in table 5.2A.2.1-1 from TS 38.101-1 with note 2 that The frequency range in band n28 is restricted for this band combination to 703-733 MHz for the UL and 758-788 MHz for the DL.

2) The UL/DL configurations and bandwidth combination sets for DL\_n20A-n28A\_UL\_n20A-n28A\_BCS0 and DL\_n20A-n28A\_UL\_n20A-n28A\_BCS1 were specified in table 5.5A.3.1-1g from TS 38.101-1.

3) 23dBm Power class 3 for UL CA\_n20A-n28A was specified in Table 6.2A.1.3-1 from TS 38.101-1.

4) 0.5dB ΔTIB,c for CA\_n20-n28 was specified in Table 6.2A.4.2.3-1 from TS 38.101-1.

5) Spurious emissions for UE co-existence for Inter-band CA\_n20-n28 were specified in Table 6.5A.3.2.3-1 from TS 38.101-1.

6) Referring to UE co-existence studies in clause 6.31.2.1 from TR 38.716-02-00, there are no harmonic/harmonic mixing or IMD issues affecting own Rx frequencies of either band n20 or n28. Therefore, there is no need to specify the additional REFSENS exceptions for CA\_n20-n28.

7) 0dB ΔRIB,c for CA\_n20-n28 was specified in Table 6.31.1.4-2 from TR 38.716-02-00.

### 5.3.5 CA\_n8-n20-n28

#### 5.3.5.1 Operating bands for CA

Table 5.3.5.1-1: Inter-band CA operating bands involving FR1 (three bands)

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR Band | Uplink (UL) band | | | Downlink (DL) band | | | Duplex  mode |
| BS receive / UE transmit | | | BS transmit / UE receive | | |
| FUL\_low – FUL\_high | | | FDL\_low – FDL\_high | | |
| n8 | 880 MHz | – | 915 MHz | 925 MHz | – | 960 MHz | FDD |
| n20 | 832 MHz | – | 862 MHz | 791 MHz | – | 821 MHz | FDD |
| n28 | 703 MHz | – | 748 MHz | 758 MHz | – | 803 MHz | FDD |

It’s noted that the following sentence was clarified in clause 5.5A.0 from TS 38.101-1.

*“For a higher order band combination of which CA\_n20-n28 is a subset, the frequency range in band n28 is restricted for the higher order band combination to 703-733 MHz for the UL and 758-788 MHz for the DL.”*

Thus, this frequency range restriction is also applicable to CA\_n8-n20-n28.

#### 5.3.5.2 Channel bandwidths per operating band for CA

Table 5.3.5.2-1: Supported bandwidths per CA band combination of band n8+n20+n28

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NR CA configuration | Uplink CA configuration or single uplink carrier | NR Band | Channel bandwidth (MHz) | Bandwidth combination set |
| CA\_n8A-n20A-n28A | CA\_n8A-n20A  CA\_n8A-n28A  CA\_n20A-n28A | n8 | 5, 10, 15, 20 | 0 |
| n20 | 5, 10, 15, 20 |
| n28 | 5, 10, 15, 20 |

#### 5.3.5.3 ∆TIB,c and ∆RIB,c values

For CA\_n8-n20-n28, the ΔTIB,c and ΔRIB,c values for 2-antenna and 3-antenna architectures are captured in this part. However, only one set of values will be defined in the specification in the follow-up WI allowing all possible UE RF architectures.

For CA\_n8-n20-n28, the ΔTIB,c and ΔRIB,c values are derived from the existing CA\_n8-n28 and CA\_n20-n28 based on 3-antennas UE architecture as the baseline.

Table 5.3.5.3-1: ΔTIB,c

| Inter-band CA Configuration | NR Band | ΔTIB,c (dB) |
| --- | --- | --- |
| CA\_n8-n20-n28 | n8 | 0.6 |
| n20 | 0.5 |
| n28 | 0.5 |

Table 5.3.5.3-2: ΔRIB,c

| Inter-band CA Configuration | NR Band | ΔRIB,c (dB) |
| --- | --- | --- |
| CA\_n8-n20-n28 | n8 | 0.2 |
| n20 | 0 |
| n28 | 1 |

For CA\_n8-n20-n28, the ΔTIB,c and ΔRIB,c values are derived in Table 5.3.5.3-3 and Table 5.3.5.3-4 and enable a two-antenna architecture in the long-term.

Table 5.3.5.3-3: ΔTIB,c

| Inter-band CA Configuration | NR Band | ΔTIB,c (dB) |
| --- | --- | --- |
| CA\_n8-n20-n28 | n8 | 0.8 |
| n20 | 0.7 |
| n28 | 0.7 |

Table 5.3.5.3-4: ΔRIB,c

| Inter-band CA Configuration | NR Band | ΔRIB,c (dB) |
| --- | --- | --- |
| CA\_n8-n20-n28 | n8 | 0.3 |
| n20 | 0.2 |
| n28 | 0.2 |

#### 5.3.5.4 UE co-existence studies for UL inter-band CA

Table 5.3.5.4-1 lists Band n8 + Band n20 2UL bands CA 2nd, 3rd, 4th and 5th order IMD for the UE-to-UE coexistence analysis, which may fall into the Rx receiver of DL band n28.

Table 5.3.5.4-1: Band n8 and Band n20 UL IMD products

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **UE UL carriers** | **fx\_low** | **fx\_high** | **fy\_low** | **fy\_high** |
| UL frequency (MHz) | 880 | 915 | 832 | 862 |
| 2nd order IMD products | |fy\_low – fx\_high| | |fy\_high – fx\_low| | |fy\_low + fx\_low| | |fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 83 | 18 | 1712 | 1777 |
| Two-tone 3rd order IMD products | |2\*fx\_low – fy\_high| | |2\*fx\_high – fy\_low| | |2\*fy\_low – fx\_high| | |2\*fy\_high – fx\_low| |
| IMD frequency limits (MHz) | 898 | 998 | 749 | 844 |
| Two-tone 3rd order IMD products | |2\*fx\_low + fy\_low| | |2\*fx\_high + fy\_high| | |2\*fy\_low + fx\_low| | |2\*fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 2592 | 2692 | 2544 | 2639 |
| Two-tone 4th order IMD products | |3\*fx\_low –1\* fy\_high| | |3\*fx\_high – 1\*fy\_low| | |3\*fy\_low – 1\*fx\_high| | |3\*fy\_high – 1\*fx\_low| |
| IMD frequency limits (MHz) | 1778 | 1913 | 1581 | 1706 |
| Two-tone 4th order IMD products | |3\*fx\_low +1\* fy\_low| | |3\*fx\_high + 1\*fy\_high| | |3\*fy\_low + 1\*fx\_low| | |3\*fy\_high + 1\*fx\_high| |
| IMD frequency limits (MHz) | 3472 | 3607 | 3376 | 3501 |
| Two-tone 4th order IMD products | |2\*fx\_low –2\* fy\_high| | |2\*fx\_high –2\* fy\_low| | |2\*fx\_low +2\* fy\_low| | |2\*fx\_high +2\* fy\_high| |
| IMD frequency limits (MHz) | 36 | 166 | 3424 | 3554 |
| Two-tone 5th order IMD products | |fx\_low – 4\*fy\_high| | |fx\_high – 4\*fy\_low| | |fy\_low – 4\*fx\_high| | |fy\_high – 4\*fx\_low| |
| IMD frequency limits (MHz) | 2568 | 2413 | 2828 | 2658 |
| Two-tone 5th order IMD products | |2\*fx\_low - 3\*fy\_high| | |2\*fx\_high - 3\*fy\_low| | |2\*fy\_low - 3\*fx\_high| | |2\*fy\_high -3\*fx\_low| |
| IMD frequency limits (MHz) | 826 | 666 | 1081 | 916 |
| Two-tone 5th order IMD products | |fx\_low + 4\*fy\_low| | |fx\_high + 4\*fy\_high| | |fy\_low + 4\*fx\_low| | |fy\_high + 4\*fx\_high| |
| IMD frequency limits (MHz) | 4208 | 4363 | 4352 | 4522 |
| Two-tone 5th order IMD products | |2\*fx\_low + 3\*fy\_low| | |2\*fx\_high + 3\*fy\_high| | |2\*fy\_low + 3\*fx\_low| | |2\*fy\_high + 3\*fx\_high| |
| IMD frequency limits (MHz) | 4256 | 4416 | 4304 | 4469 |

Table 5.3.5.4-2 lists Band n8 + Band n28 2UL bands CA 2nd, 3rd, 4th and 5th order IMD for the UE-to-UE coexistence analysis, which may fall into the Rx receiver of DL band n20.

Table 5.3.5.4-2: Band n8 and Band n28 UL IMD products

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **UE UL carriers** | **fx\_low** | **fx\_high** | **fy\_low** | **fy\_high** |
| UL frequency (MHz) | 880 | 915 | 703 | 748 |
| 2nd order IMD products | |fy\_low – fx\_high| | |fy\_high – fx\_low| | |fy\_low + fx\_low| | |fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 212 | 132 | 1583 | 1663 |
| Two-tone 3rd order IMD products | |2\*fx\_low – fy\_high| | |2\*fx\_high – fy\_low| | |2\*fy\_low – fx\_high| | |2\*fy\_high – fx\_low| |
| IMD frequency limits (MHz) | 1012 | 1127 | 491 | 616 |
| Two-tone 3rd order IMD products | |2\*fx\_low + fy\_low| | |2\*fx\_high + fy\_high| | |2\*fy\_low + fx\_low| | |2\*fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 2463 | 2578 | 2286 | 2411 |
| Two-tone 4th order IMD products | |3\*fx\_low –1\* fy\_high| | |3\*fx\_high – 1\*fy\_low| | |3\*fy\_low – 1\*fx\_high| | |3\*fy\_high – 1\*fx\_low| |
| IMD frequency limits (MHz) | 1892 | 2042 | 1194 | 1364 |
| Two-tone 4th order IMD products | |3\*fx\_low +1\* fy\_low| | |3\*fx\_high + 1\*fy\_high| | |3\*fy\_low + 1\*fx\_low| | |3\*fy\_high + 1\*fx\_high| |
| IMD frequency limits (MHz) | 3343 | 3493 | 2989 | 3159 |
| Two-tone 4th order IMD products | |2\*fx\_low –2\* fy\_high| | |2\*fx\_high –2\* fy\_low| | |2\*fx\_low +2\* fy\_low| | |2\*fx\_high +2\* fy\_high| |
| IMD frequency limits (MHz) | 264 | 424 | 3166 | 3326 |
| Two-tone 5th order IMD products | |fx\_low – 4\*fy\_high| | |fx\_high – 4\*fy\_low| | |fy\_low – 4\*fx\_high| | |fy\_high – 4\*fx\_low| |
| IMD frequency limits (MHz) | 2112 | 1897 | 2957 | 2772 |
| Two-tone 5th order IMD products | |2\*fx\_low - 3\*fy\_high| | |2\*fx\_high - 3\*fy\_low| | |2\*fy\_low - 3\*fx\_high| | |2\*fy\_high -3\*fx\_low| |
| IMD frequency limits (MHz) | 484 | 279 | 1339 | 1144 |
| Two-tone 5th order IMD products | |fx\_low + 4\*fy\_low| | |fx\_high + 4\*fy\_high| | |fy\_low + 4\*fx\_low| | |fy\_high + 4\*fx\_high| |
| IMD frequency limits (MHz) | 3692 | 3907 | 4223 | 4408 |
| Two-tone 5th order IMD products | |2\*fx\_low + 3\*fy\_low| | |2\*fx\_high + 3\*fy\_high| | |2\*fy\_low + 3\*fx\_low| | |2\*fy\_high + 3\*fx\_high| |
| IMD frequency limits (MHz) | 3869 | 4074 | 4046 | 4241 |

Table 5.3.5.4-3 lists Band n20 + Band n28 2UL bands CA 2nd, 3rd, 4th and 5th order IMD for the UE-to-UE coexistence analysis, which may fall into the Rx receiver of DL band n8.

Table 5.3.5.4-3: Band n20 and Band n28 UL IMD products

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **UE UL carriers** | **fx\_low** | **fx\_high** | **fy\_low** | **fy\_high** |
| UL frequency (MHz) | 832 | 862 | 703 | 733 |
| 2nd order IMD products | |fy\_low – fx\_high| | |fy\_high – fx\_low| | |fy\_low + fx\_low| | |fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 159 | 99 | 1535 | 1595 |
| Two-tone 3rd order IMD products | |2\*fx\_low – fy\_high| | |2\*fx\_high – fy\_low| | |2\*fy\_low – fx\_high| | |2\*fy\_high – fx\_low| |
| IMD frequency limits (MHz) | 931 | 1021 | 544 | 634 |
| Two-tone 3rd order IMD products | |2\*fx\_low + fy\_low| | |2\*fx\_high + fy\_high| | |2\*fy\_low + fx\_low| | |2\*fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 2367 | 2457 | 2238 | 2328 |
| Two-tone 4th order IMD products | |3\*fx\_low –1\* fy\_high| | |3\*fx\_high – 1\*fy\_low| | |3\*fy\_low – 1\*fx\_high| | |3\*fy\_high – 1\*fx\_low| |
| IMD frequency limits (MHz) | 1763 | 1883 | 1247 | 1367 |
| Two-tone 4th order IMD products | |3\*fx\_low +1\* fy\_low| | |3\*fx\_high + 1\*fy\_high| | |3\*fy\_low + 1\*fx\_low| | |3\*fy\_high + 1\*fx\_high| |
| IMD frequency limits (MHz) | 3199 | 3319 | 2941 | 3061 |
| Two-tone 4th order IMD products | |2\*fx\_low –2\* fy\_high| | |2\*fx\_high –2\* fy\_low| | |2\*fx\_low +2\* fy\_low| | |2\*fx\_high +2\* fy\_high| |
| IMD frequency limits (MHz) | 198 | 318 | 3070 | 3190 |
| Two-tone 5th order IMD products | |fx\_low – 4\*fy\_high| | |fx\_high – 4\*fy\_low| | |fy\_low – 4\*fx\_high| | |fy\_high – 4\*fx\_low| |
| IMD frequency limits (MHz) | 2100 | 1950 | 2745 | 2595 |
| Two-tone 5th order IMD products | |2\*fx\_low - 3\*fy\_high| | |2\*fx\_high - 3\*fy\_low| | |2\*fy\_low - 3\*fx\_high| | |2\*fy\_high -3\*fx\_low| |
| IMD frequency limits (MHz) | 535 | 385 | 1180 | 1030 |
| Two-tone 5th order IMD products | |fx\_low + 4\*fy\_low| | |fx\_high + 4\*fy\_high| | |fy\_low + 4\*fx\_low| | |fy\_high + 4\*fx\_high| |
| IMD frequency limits (MHz) | 3644 | 3794 | 4031 | 4181 |
| Two-tone 5th order IMD products | |2\*fx\_low + 3\*fy\_low| | |2\*fx\_high + 3\*fy\_high| | |2\*fy\_low + 3\*fx\_low| | |2\*fy\_high + 3\*fx\_high| |
| IMD frequency limits (MHz) | 3773 | 3923 | 3902 | 4052 |

Based on Table 5.3.5.4-1, 3rd and 5th order IMD may also fall into Rx frequencies of third DL band n28 when CA\_n8-n20 is the UL configuration.

Based on Table 5.3.5.4-2, there is no IMD interference which may also fall into Rx frequencies of third DL band n20 when CA\_n8-n28 is the UL configuration.

Based on Table 5.3.5.4-3, 3rd order IMD may also fall into Rx frequencies of third DL band n8 when CA\_n20-n28 is the UL configuration.

#### 5.3.5.5 REFSENS evaluation

The MSD test configurations can be evaluated as below for band n8 MSD due to IMD3 of Tx band n20 + band n28 and band n28 MSD due to IMD3 of Tx band n8 + band n20.

Table 5.3.5.5-1: REFSENS exceptions due to IMD interference for CA\_n8-n20-n28

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Band / Channel bandwidth / NRB / Duplex mode | | | | | | | | Source of IMD |
| NR CA band combination | NR band | UL Fc  (MHz) | UL/DL BW  (MHz) | UL  CLRB | DL Fc (MHz) | MSD  (dB) | Duplex mode |  |
| CA\_n8-n20-n28 | n20 | 834.5 | 5 | 25 | 793.5 | N/A | FDD | N/A |
|  | n28 | 715.5 | 5 | 25 | 770.5 | N/A | FDD | N/A |
|  | n8 | 908.5 | 5 | 25 | 953.5 | 23.5 | FDD | IMD3 |
|  | n8 | 887.5 | 5 | 25 | 932.5 | N/A | FDD | N/A |
|  | n20 | 834.5 | 5 | 25 | 793.5 | N/A | FDD | N/A |
|  | n28 | 726.5 | 5 | 25 | 781.5 | 23 | FDD | IMD3 |

CA\_n8-n20-n28 2UL IMD3 MSDs are derived in Table 5.3.5.5-2 and enable a two-antenna architecture in the long-term.

Table 5.3.5.5-2: 3DL/2UL IMD3 MSDs for CA\_n8-n20-n28

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Band / Channel bandwidth / NRB / Duplex mode | | | | | | | | Source |
| NR CA band combination | NR band | UL Fc | UL/DL BW | UL | DL Fc (MHz) | MSD | Duplex mode | of IMD |
| **(MHz)** | **(MHz)** | **CLRB** | **(dB)** |
| CA\_n8-n20-n28 | n8 | N/A | 5 | 25 | 951.5 | [25] | FDD | IMD3 |
|  | n20 | 834.5 | 5 | 25 | 793.5 | N/A | FDD | N/A |
|  | n28 | 717.5 | 5 | 25 | 772.5 | N/A | FDD | N/A |
|  | n8 | 887.5 | 5 | 25 | 932.5 | N/A | FDD | N/A |
|  | n20 | 834.5 | 5 | 25 | 793.5 | N/A | FDD | N/A |
|  | n28 | N/A | 5 | 25 | 781.5 | [25] | FDD | IMD3 |

## 5.4 CA\_n5-n105

### 5.4.1 General

In this configuration the uplink is also CA\_n5A-n105A, but there are two fall back options:

DL\_n5A-n105A\_UL\_n5A\_BCS0

UL\_n5A-n105A\_UL\_n105A\_BCS0

The aggregated spectrum allocation for CA\_n5A-n105A is illustrated in Figure 5.4.1-1.

 Figure 5.4.1-1: Aggregated spectrum allocation for CA\_n5A-n105A

### 5.4.2 UE RF architecture assumption

The UE RF architectures with 2 antenna and 3 antenna are assumed in the feasibility study for CA\_n5-n105. The antenna number is the total number of antennas to support Main UL/DL and diversity DL for all bands.

#### 5.4.2.1 UE RF architecture with two antennas

For CA\_n5-n105 with 2-antenna implementation, there are two potential UE RF architectures as shown in Figure 5.4.2.1-1.

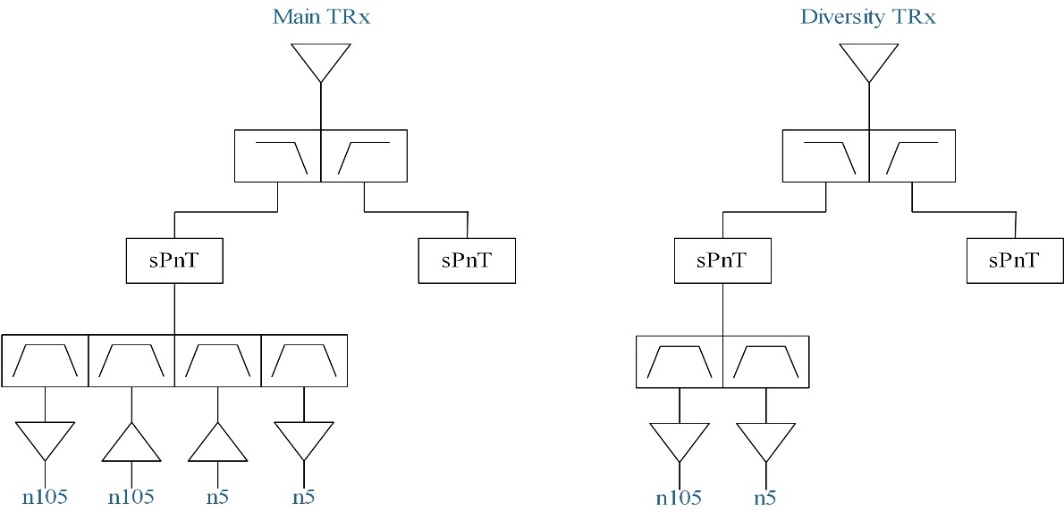


Figure 5.4.2.1-1a: Potential UE architecture with 2 antenna to support CA\_n5-n105

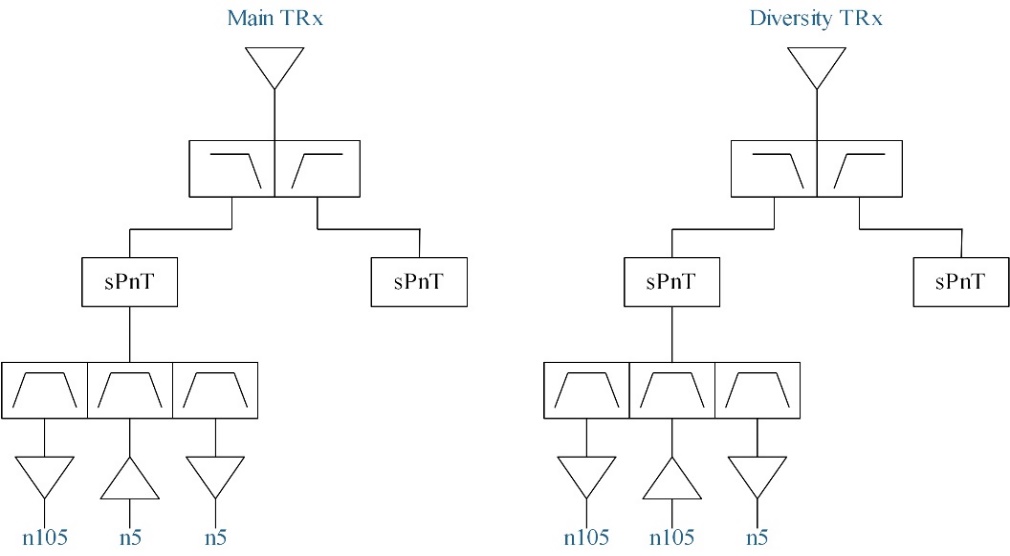


Figure 5.4.2.1-1b: Potential UE architecture with 2 antenna to support CA\_n5-n105

The topology for 2-antenna architecture illustrated in Figure 5.4.2.1-1a is listed as below.

- 1) n105UL+n105DL+n5UL+n5DL quadplexer on antenna 1

- 2) n5DL+n105DL duplexer on antenna 2

The topology for 2-antenna architecture illustrated in Figure 5.4.2.1-1b is listed as below.

- 1) n5UL+n5DL+n105DL triplexer on antenna 1

- 2) n105UL+n105DL+n5DL triplexer on antenna 2

#### 5.4.2.2 UE RF architecture with three antennas

Figure 5.4.2.2-1 illustrates the potential UE RF architecture for CA\_n5-n105 with a 3-antenna implementation.

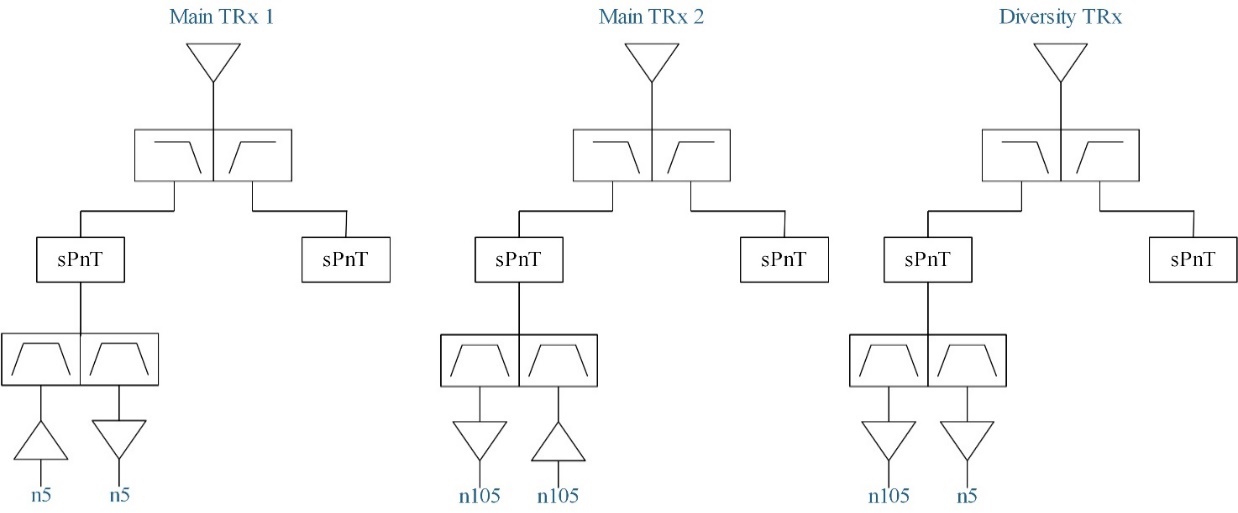


Figure 5.4.2.2-1: Potential UE architecture with 3 antenna to support CA\_n5-n105

The topology for 3-antenna architecture illustrated in Figure 5.4.2.2-1 is listed as below:

1) n105UL+n105DL duplexer on antenna 1

2) n5UL+n5DL duplexer on antenna 2

3) n5DL+n105DL duplexer on antenna 3

### 5.4.3 Common for 1 band UL and 2 bands UL of CA\_n5-n105

#### 5.4.3.1 Operating bands for CA

The operating bands for CA\_n5-n105 are provided in Table 5.4.3.1-1.

Table 5.4.3.1-1: CA band combination of band n5+n105

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR Band | Uplink (UL) band | | | Downlink (DL) band | | | Duplex  mode |
| BS receive / UE transmit | | | BS transmit / UE receive | | |
| FUL\_low – FUL\_high | | | FDL\_low – FDL\_high | | |
| n5 | 824 MHz | – | 849 MHz | 869 MHz | – | 894 MHz | FDD |
| n105 | 663 MHz | – | 703 MHz | 612 MHz | – | 652 MHz | FDD |

#### 5.4.3.2 Channel bandwidths per operating band for CA

The supported channel bandwidths for CA\_n5-n105 are provided in Table 5.4.3.2-1.

**Table 5.4.3.2-1: Supported bandwidths per CA band combination of band n5+n105**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NR CA configuration | Uplink CA configuration or single uplink carrier | NR Band | Channel bandwidth (MHz) | Bandwidth combination set |
| CA\_n5A-n105A | CA\_n5A-n105A | n5 | 5, 10, 15, 20 | 0 |
| n105 | 5, 10, 15, 20, 25, 30, 35 |

#### 5.4.3.3 Identify the potential MSD issues due to harmonic/harmonic mixing/cross band isolation

Table 5.4.3.3-1/2 summarizes frequency ranges where harmonics/harmonics mixing occur for CA\_n5-n105.

Table 5.4.3.3-1: Impact of UL/DL Harmonic

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | **2nd Harmonic** | | **3rd Harmonic** | | **4th Harmonic** | | **5th Harmonic** | |
| **Band** | **UL Low Band Edge** | UL High Band Edge | **DL Low Band Edge** | DL High Band Edge | UL Low Band Edge | UL High Band Edge | UL Low Band Edge | UL High Band Edge | UL Low Band Edge | UL High Band Edge | UL Low Band Edge | UL High Band Edge |
| n5 | 824 | 849 | 869 | 894 | 1648 | 1698 | 2472 | 2547 | 3296 | 3396 | 4120 | 4245 |
| n105 | 663 | 703 | 612 | 652 | 1326 | 1406 | 1989 | 2109 | 2652 | 2812 | 3315 | 3515 |

Table 5.4.3.3-2: Impact of UL/DL Harmonic mixing

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | **2nd Harmonic** | | **3rd Harmonic** | | **4th Harmonic** | | **5th Harmonic** | |
| **Band** | **UL Low Band Edge** | UL High Band Edge | DL Low Band Edge | DL High Band Edge | DL Low Band Edge | DL High Band Edge | DL Low Band Edge | DL High Band Edge | DL Low Band Edge | DL High Band Edge | DL Low Band Edge | DL High Band Edge |
| n5 | 824 | 849 | 869 | 894 | 1738 | 1788 | 2607 | 2682 | 3476 | 3576 | 4345 | 4470 |
| n105 | 663 | 703 | 612 | 652 | 1224 | 1304 | 1836 | 1956 | 2448 | 2608 | 3060 | 3260 |

Based on the above analysis, there is no need to study MSD due to harmonics and harmonics mixing for CA\_n5-n105.

#### 5.4.3.4 ∆TIB,c and ∆RIB,c values

Two-antenna architecture with dual triplexer can be used as a baseline to study ΔTIB,c and ΔRIB,c.By referring to contribution [7], it seems that two-antenna solutions with quadplexer or triplexer are not very challenging for CA\_n5-n105 as the frequency gap between band n5 UL part and band n105 DL part is larger than 100MHz. Thus, general values for low band combinations can be used for Delta Tib and Rib.

Table 5.4.3.4-1: ΔTIB,c for 2-antenna implementation

| Inter-band CA Configuration | NR Band | ΔTIB,c [dB] |
| --- | --- | --- |
| CA\_n5-n105 | n5 | 0.5 |
| n105 | 0.5 |

Table 5.4.3.4-2: ΔRIB,c for 2-antenna implementation

| Inter-band CA Configuration | NR Band | ΔRIB,c [dB] |
| --- | --- | --- |
| CA\_n5-n105 | n5 | 0 |
| n105 | 0 |

By referring to contribution [8], the two antenna implementation should drive the ΔTIB,c and ΔRIB,c values for CA\_n5-n105. Based on other LB-LB cases, and especially DC\_5\_n71, a Delta T of 0.5dB for both bands can be used. For Delta Rib, CA\_n5-n12 values can be reused.

Table 5.4.3.4-3: ΔTIB,c for 2-antenna implementation

| Inter-band CA Configuration | NR Band | ΔTIB,c [dB] |
| --- | --- | --- |
| CA\_n5-n105 | n5 | 0.5 |
| n105 | 0.5 |

Table 5.4.3.4-4: ΔRIB,c for 2-antenna implementation

| Inter-band CA Configuration | NR Band | ΔRIB,c [dB] |
| --- | --- | --- |
| CA\_n5-n105 | n5 | 0.5 |
| n105 | 0.3 |

By referring to contribution [9], the following values are derived for ΔTIB,c and ΔRIB,c:

Table 5.4.3.4-5: ΔTIB,c for 2-antenna implementation

| Inter-band CA Configuration | NR Band | ΔTIB,c [dB] |
| --- | --- | --- |
| CA\_n5-n105 | n5 | 0.5 |
| n105 | 0.5 |

Table 5.4.3.4-6: ΔRIB,c for 2-antenna implementation

| Inter-band CA Configuration | NR Band | ΔRIB,c [dB] |
| --- | --- | --- |
| CA\_n5-n105 | n5 | 0.2 |
| n105 | 0.2 |

#### 5.4.3.5 REFSENS exception evaluation for one UL band

By referring to contribution [7], the following evaluation for MSD due to cross band isolation is provided for CA\_n5-n105.

Table 5.4.3.5-1 MSD due to Cross band isolation from n5 to n105

|  |  |  |  |
| --- | --- | --- | --- |
|  | parameters | n105 main path | n105 diversity path |
| transmit power for n5, dBm |  | 23 | 23 |
| Tx band n5 BW(MHz, Lcrb) | 20 |  |  |
| RFFE loss, dB | **4** |  |  |
| Diplexer isolation at n5 uplink freq，dB | **10** |  |  |
| antenna isolation, dB | 10 |  |  |
| n105 receiver signal at ANT port, dBm |  | 13 | 13 |
|  |  |  |  |
| n105 filter rejection at 814~849MHz, dB | **40** |  |  |
| signal After n105 filter, dBm |  | -31 | -31 |
| Typical receiver IIP2, dB | 50 |  |  |
| TX IM2 noise level refer to RX LNA input, dBm |  | -112 | -112 |
| front-end loss | 4 |  |  |
| TX IM2 noise level at ANT port, dBm |  | -108 | -108 |
|  |  |  |  |
| noise figure dB | 11.8 |  |  |
| Thermal noise at RX ant port(dBm/Hz) | -162.2 |  |  |
| Rx band n105 BW(MHz, NRB) | 4.5 |  |  |
| Thermal noise, dBm |  | -95.67 | -95.67 |
|  |  |  |  |
| ACLR1, dB | 30 |  |  |
| ACLR2, dB | 43 |  |  |
| n5 PA leakage PSD at PA output port at 1st adjacent channel, dBm/MHz |  | -20.01 |  |
| n5 PA leakage PSD at PA output port at 2nd adjacent channel, dBm/MHz |  | -33.01 |  |
| n5 PA noise PSD at PA output port, dBm/Hz | **-130** |  |  |
| n5 PA noise PSD at PA output port, dBm/RxBW |  | -63.47 |  |
| n5 Tx filter rejection at 612~652MHz, dB | **30** |  |  |
| n5 PA noise power at Rx n105 ant port at 612~652MHz, dBm |  | -103.47 | -103.47 |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
| Total noise level at ANT port |  | -94.79 | -94.79 |
| SNR requirement for QPSK | -1 |  |  |
| REFSENSE (referred to antenna)(5MHz BW) |  | -95.79 | -95.79 |
| Implementation Margin, dB | 2 |  |  |
| combined REFSENS(5MHz BW), dBm | -96.80 |  |  |
| MSD | 0.40 |  |  |

Table 5.4.3.5-2 MSD due to Cross band isolation from n105 to n5

|  |  |  |  |
| --- | --- | --- | --- |
|  | parameters | n5 main path | n5 diversity path |
| transmit power for n105, dBm |  | 23 | 23 |
| Tx band n105 BW(MHz, Lcrb) | 20 |  |  |
| RFFE loss, dB | **4** |  |  |
| Diplexer isolation at n105 uplink freq，dB | **10** |  |  |
| antenna isolation, dB | 10 |  |  |
| n5 receiver signal at ANT port, dBm |  | 13 | 13 |
|  |  |  |  |
| n5 filter rejection at 663~703MHz, dB | **40** |  |  |
| signal After n5 filter, dBm |  | -31 | -31 |
| Typical receiver IIP2, dB | 50 |  |  |
| TX IM2 noise level refer to RX LNA input, dBm |  | -112 | -112 |
| front-end loss | 4 |  |  |
| TX IM2 noise level at ANT port, dBm |  | -108 | -108 |
|  |  |  |  |
| noise figure dB | 11 |  |  |
| Thermal noise at RX ant port(dBm/Hz) | -163 |  |  |
| Rx band n5 BW(MHz, NRB) | 4.5 |  |  |
| Thermal noise, dBm |  | -96.47 | -96.47 |
|  |  |  |  |
| ACLR1, dB | 30 |  |  |
| ACLR2, dB | 43 |  |  |
| n105 PA leakage PSD at PA output port at 1st adjacent channel, dBm/MHz |  | -20.01 |  |
| n105 PA leakage PSD at PA output port at 2nd adjacent channel, dBm/MHz |  | -33.01 |  |
| n105 PA noise PSD at PA output port, dBm/Hz | **-130** |  |  |
| n105 PA noise PSD at PA output port, dBm/RxBW |  | -63.47 |  |
| n105 Tx filter rejection at 869~894MHz, dB | **30** |  |  |
| n105 PA noise power at Rx n105 ant port at 869~894MHz, dBm |  | -103.47 | -103.47 |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
| Total noise level at ANT port |  | -95.43 | -95.43 |
| SNR requirement for QPSK | -1 |  |  |
| REFSENSE (referred to antenna)(5MHz BW) |  | -96.43 | -96.43 |
| Implementation Margin, dB | 2 |  |  |
| combined REFSENS(5MHz BW), dBm | -97.44 |  |  |
| MSD | 0.56 |  |  |

Based on the above evaluation, the REFSENS degradation can be neglected. Thus, there is no need to specify MSD due to cross band isolation for CA\_n5-n105.

By referring to contribution [8], the 1UL cross band interference is as follows for the IMD orders of the allocated UL Resource blocks (RBs) and its image:

For the n105 20MHz maximum UL CBW, the IMD interference order to n5 is >9 RBs

For the n5 20MHz maximum UL CBW, the IMD interference order to n105 is >9 RBs

Given this, there is no MSD due to IMDs. Nonetheless, the transmitter noise floor must be considered.

With the architecture aspects discussed above and the need to support multiple LBLB cases, conservative values should be considered:

45dB cross band Tx-Rx isolation for the triplexers

40dB Tx rejection in the other DL band

10dB antenna couplingf

4dB post PA losses

Transmitter noise floor of -125dBm/Hz.

Based on these assumptions, the MSD with MRC combining is calculated in Table 5.4.3.5-3.

Table 5.4.3.5-3: MRC calculations for band n5 and n105 Cross-band MSD.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | band | n105 | | n5 | |
| **CBW**/NRB | [MHz]/# | 5 | 25 | 5 | 25 |
| transmitter noise floor | [dBm/CBW] | -58.5 | | -58.5 | |
| 5MHz CBW REFSENS | [dBm/CBW] | -97.2 | | -98.0 | |
| RX noise floor wo Tx noise: **Main**/Div | [dBm/CBW] | -93.2 | -93.2 | -94.0 | -94.0 |
| **Tx-Rx** / Tx-Ant duplexer **isolation**/rejection | [dB] | 45 | 40 | 45 | 40 |
| LNA to antenna insertion loss | [dB] | 4 | | 4 | |
| Antenna isolation | [dB] | 0 | 10 | 0 | 10 |
| PC3 1Tx interference levels: **Main**/Div | [dBm/CBW] | -99.5 | -104.5 | -99.5 | -104.5 |
| noise floor degradation due to Tx noise: **Main**/Div | [dB] | 0.9 | 0.3 | 1.1 | 0.4 |
| noise floor degradation due to Tx noise: **Main**/Div | [lin] | 1.2 | 1.1 | 1.3 | 1.1 |
| REFSENS degradation after MRC | uncor [dB] | 0.6 | | 0.7 | |
| REFSENS degradation after MRC | cor [dB] | 1.1 | | 1.3 | |

1UL cross-band MSD for CA\_n5-n105 is proposed in Table 5.4.3.5-4.

Table 5.4.3.5-4: CA\_n5-n105 1UL cross-band MSD

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **UL band** | **DL band** | **UL Fc** | **UL BW** | **SCS of UL band** | **UL RB Allocation** | **DL Fc** | **DL BW** | **MSD** | **Cross-band**  **Interference**  **source** |
| **(MHz)** | **(MHz)** | **(kHz)** | **LCRB** | **(MHz)** | **(MHz)** | **(dB)** |
| n105 | n5 | 693 | 20 | 15 | 20 (RBstart=86) | 871.5 | 5 | 1.3 | >ACLR2 |
| n5 | n105 | 834 | 20 | 15 | 20 (RBstart=0) | 649.5 | 5 | 1.1 | >ACLR2 |

By referring to contribution [9], one aspect that needs to be pointed out is that n105 is a recently standardised band, with very challenging frequency arrangements from RF filtering point of view. Hence, especially given the band is new and implementations are just under development, we don’t see it possible to optimize the CA characteristics at the expense of attenuation at US CH36 and n105 TX/RX isolations. Please note that the numbers are not derived from dedicated triplexers, but instead from what can be achieved by matching DPX and RX filters together, without optimizations which may offer improved performance over time.

The MSD with MRC combining is calculated in Table 5.4.3.5-5 and Table 5.4.3.5-6.

Table 5.4.3.5-5 MSD due to cross band isolation n105 to n5



Table 5.4.3.5-6 MSD due to cross band isolation n5 to n105



1UL cross-band MSD for CA\_n5-n105 is proposed in Table 5.4.3.5-7.

Table 5.4.3.5-7: CA\_n5-n105 1UL cross-band MSD

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **UL band** | **DL band** | **UL Fc** | **UL BW** | **SCS of UL band** | **UL RB Allocation** | **DL Fc** | **DL BW** | **MSD** | **Cross-band**  **Interference**  **source** |
| **(MHz)** | **(MHz)** | **(kHz)** | **LCRB** | **(MHz)** | **(MHz)** | **(dB)** |
| n105 | n5 | 693 | 20 | 15 | 20 (RBstart=86) | 871.5 | 5 | 2.6 | >ACLR2 |
| n5 | n105 | 834 | 20 | 15 | 20 (RBstart=0) | 649.5 | 5 | 5.6 | >ACLR2 |

### 5.4.4 Specific for 2 bands UL of CA\_n5-n105

#### 5.4.4.1 Maximum output power for inter-band CA

Power class 3 is assumed for UL CA\_n5-n105

#### 5.4.4.2 UE co-existence studies

Table 5.4.4.2-1 lists Band n5 + Band n105 2UL bands CA 2nd, 3rd, 4th and 5th order IMD for the UE-to-UE coexistence analysis.

Table 5.4.4.2-1: Band n5 and Band n105 UL IMD products

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| UE UL carriers | fx\_low | fx\_high | fy\_low | fy\_high |
| UL frequency (MHz) | 663 | 703 | 824 | 849 |
| 2nd order IMD products | |fy\_low – fx\_high| | |fy\_high – fx\_low| | |fy\_low + fx\_low| | |fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 121 | 186 | 1487 | 1552 |
| Two-tone 3rd order IMD products | |2\*fx\_low – fy\_high| | |2\*fx\_high – fy\_low| | |2\*fy\_low – fx\_high| | |2\*fy\_high – fx\_low| |
| IMD frequency limits (MHz) | 477 | 582 | 945 | 1035 |
| Two-tone 3rd order IMD products | |2\*fx\_low + fy\_low| | |2\*fx\_high + fy\_high| | |2\*fy\_low + fx\_low| | |2\*fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 2150 | 2255 | 2311 | 2401 |
| Two-tone 4th order IMD products | |3\*fx\_low –1\* fy\_high| | |3\*fx\_high – 1\*fy\_low| | |3\*fy\_low – 1\*fx\_high| | |3\*fy\_high – 1\*fx\_low| |
| IMD frequency limits (MHz) | 1140 | 1285 | 1769 | 1884 |
| Two-tone 4th order IMD products | |3\*fx\_low +1\* fy\_low| | |3\*fx\_high + 1\*fy\_high| | |3\*fy\_low + 1\*fx\_low| | |3\*fy\_high + 1\*fx\_high| |
| IMD frequency limits (MHz) | 2813 | 2958 | 3135 | 3250 |
| Two-tone 4th order IMD products | |2\*fx\_low –2\* fy\_high| | |2\*fx\_high –2\* fy\_low| | |2\*fx\_low +2\* fy\_low| | |2\*fx\_high +2\* fy\_high| |
| IMD frequency limits (MHz) | 372 | 242 | 2974 | 3104 |
| Two-tone 5th order IMD products | |fx\_low – 4\*fy\_high| | |fx\_high – 4\*fy\_low| | |fy\_low – 4\*fx\_high| | |fy\_high – 4\*fx\_low| |
| IMD frequency limits (MHz) | 2733 | 2593 | 1988 | 1803 |
| Two-tone 5th order IMD products | |2\*fx\_low - 3\*fy\_high| | |2\*fx\_high - 3\*fy\_low| | |2\*fy\_low - 3\*fx\_high| | |2\*fy\_high -3\*fx\_low| |
| IMD frequency limits (MHz) | 1221 | 1066 | 461 | 291 |
| Two-tone 5th order IMD products | |fx\_low + 4\*fy\_low| | |fx\_high + 4\*fy\_high| | |fy\_low + 4\*fx\_low| | |fy\_high + 4\*fx\_high| |
| IMD frequency limits (MHz) | 3959 | 4099 | 3476 | 3661 |
| Two-tone 5th order IMD products | |2\*fx\_low + 3\*fy\_low| | |2\*fx\_high + 3\*fy\_high| | |2\*fy\_low + 3\*fx\_low| | |2\*fy\_high + 3\*fx\_high| |
| IMD frequency limits (MHz) | 3798 | 3953 | 3637 | 3807 |

Based on the above analysis, there is no IMD issue for CA\_n5-n105 with 2UL configuration.Table 5.4.4.2-2 lists the protected bands required for CA\_n5-n105 with 2UL configuration.

Table 5.4.4.2-2: Band n5 and Band n105 UL IMD products

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR CA Configuration | Spurious emission | | | | | | |
| Protected band | Frequency range (MHz) | | | Maximum Level (dBm) | MBW (MHz) | NOTE |
| CA\_n5-n105 | E-UTRA Band 1, 3, 4, 5, 8, 11, 18, 19, 21, 26, 28, 31, 38, 40, 43, 50, 51, 65, 66, 73, 74  NR Band n79 | FDL\_low | - | FDL\_high | -50 |  |  |
| E-UTRA Band 41, 52 NR Band n77, n78 | FDL\_low | - | FDL\_high | -50 | 1 | 2 |
| Frequency range | 1884.5 | - | 1915.7 | -41 | 0.3 | 8 |
| NOTE 2: As exceptions, measurements with a level up to the applicable requirements defined in Table 6.5.3.1-2 are permitted for each assigned NR carrier used in the measurement due to 2nd, 3rd, 4th or 5th harmonic spurious emissions. Due to spreading of the harmonic emission the exception is also allowed for the first 1 MHz frequency range immediately outside the harmonic emission on both sides of the harmonic emission. This results in an overall exception interval centred at the harmonic emission of (2 MHz + N x LCRB x 180kHz), where N is 2, 3, 4, 5 for the 2nd, 3rd, 4th or 5th harmonic respectively. The exception is allowed if the measurement bandwidth (MBW) totally or partially overlaps the overall exception interval.  NOTE 8: Applicable when co-existence with PHS system operating in 1884.5 - 1915.7 MHz. | | | | | | | |

#### 5.4.4.3 REFSENS exception evaluation for two UL band

It is not required to study the MSD due to two UL IMD interference since there is no two UL IMD issue for CA\_n5-n105.

## 5.5 CA\_n28-n105

### 5.5.1 General

Figure 5.5.1-1 shows the aggregated spectrum allocation for CA\_n28A-n105A where no frequency range restriction has been indicated for either of the constituent bands.



Figure 5.5.1-1 CA\_n28A-n105A spectrum allocation

In this study item, only a single UL configuration is considered for the combination due to the concern of 2UL IMD issue as described in sub-clause 5.5.2.3.

### 5.5.2 UE RF architectures assumption

Both 2-antenna and 3-antenna implementations are considered in the study item where the corresponding UE RF architectures are further detailed in the following sub-clauses.

#### 5.5.2.1 UE RF architectures with two antennas

For CA\_n28A-n105A with 2-antenna implementation, there can be two potential architecture variants, one with a triplexer and a quadplexer in the main signal path and a duplexer in the diversity signal path, as shown in Figure 5.5.2.1-1, the other is with dual triplexers in main signal path and a triplexer in diversity signal path, as shown in Figure 5.5.2.1-2.

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Figure 5.5.2.1-1 CA\_n28A-n105A UE RF first architecture variant with 2-antenna implementation

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Figure 5.5.2.1-2 CA\_n28A-n105A second architecture variant with 2-antenna implementation

The first architecture variant, due to the relatively wide frequency range (a single filter covering both n28 and n 105) in the middle sub-band for the main signal path triplexer, is considered rather challenging and impracticable for implementation and will not be further pursued in this study item.

For the second architecture variant, both the main antenna and diversity antenna design need to cover the entire spectrum range of 191 MHz simultaneously as shown in Figure 5.5.1-1, which is equivalent to a 27% bandwidth ratio and that would exceed the bandwidth ratio for a typical planar antenna design in a smartphone. As a result, the radiative performance for the combination likely would be compromised.

#### 5.5.2.2 UE RF architectures with three antennas

For the 3-antenna implementation, the two of the three antennas are used in the main path to aggregate the n28 and n105 signals over the air, as shown in Figure 5.5.2.2-1. As n28 and n105 signals do not need to be combined through a multiplexer, there is no additional insertion loss in both n28 and n105 main signal paths as compared to the single-band implementation.

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Description automatically generated

Figure 5.5.2.2-1 CA\_n28A-n105A UE RF architecture with 3-antenna implementation

Having two antenna in the main signal path not only avoids the more complicated multiplexer implementation and the associated additional insertion losses, but also allows narrower frequency coverage for each of the two antennas as compared to single-antenna implementation. However, the additional antenna cannot be added without occupying more phone space. Therefore, the feasibility on placing more than two low-band antennas in a smartphone needs to be investigated, with narrower bandwidth and regressed radiating performance expected due to the limitation in form factor.

#### 5.5.2.3 2UL IMD issue

2UL IMD3/IM5 may fall into either n105 DL or n28 DL or both DL bands simultaneously to cause REFSENS degradation (MSD), as conceptually illustrated in Figure 5.5.2.3-1.



Figure 5.5.2.3-1 Conceptual illustration on 2UL IMD3/IMD5 impact to DL bands for CA\_n28A-n105A

For both 2-antenna and 3-antenna implementations, depending on the carrier allocation and Tx filter isolation on the two UL carriers, the MSD caused by two simultaneous up links (2UL) IMD3 to n105 DL carrier could potentially be higher than 30 dB; especially when the n28 UL carrier is close to n105 UL band where the n105 Tx filter does not provide any rejection to n28 UL carrier and the n105 PA reverse IMD would dominate the MSD. For carrier allocations where both Tx filters can provide sufficient isolation to the cross-band UL carriers, the MSD caused by 2UL IMD3 could still be around 20 dB to either or both of the DL carriers which would be dominated by PA forward IMD.

Due to the concern of the 2UL IMD issue, only single UL configuration is considered in this study item where UL can be in either n28 or n105.

#### 5.5.2.4 Cross-band interference

Apart from the 2UL IMD concern, the combination may also be subject to cross-band UL to DL interference issue due to frequency proximity even under single UL operation where the REFSENS impact needs to be further analyzed.

### 5.5.3 Common for 1 band UL and 2 bands UL of CA\_ n28-n105

#### 5.5.3.0 General

This band combination is similar to the case of CA\_n71-n85 with the two UL bandwidths having no frequency gap between them. CA\_n71-n85 is being specified for 1UL only as 2 ULs showed significant MSD challenges.

#### 5.5.3.1 Operating bands for CA

Table 5.5.3.1-1: CA band combination of band n28+n105

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR Band | Uplink (UL) band | | | Downlink (DL) band | | | Duplex  mode |
| BS receive / UE transmit | | | BS transmit / UE receive | | |
| FUL\_low – FUL\_high | | | FDL\_low – FDL\_high | | |
| n28 | 703 MHz | – | 748 MHz | 758 MHz | – | 803 MHz | FDD |
| n105 | 663 MHz | – | 703 MHz | 612 MHz | – | 652 MHz | FDD |

#### 5.5.3.2 Channel bandwidths per operating band for CA

Based on WF [14], it was agreed that only 1UL configuration will be supported, the 2UL issues will be described in section 5.5.4. Thus, BCS0 for CA\_n28A-n105A can be specified as below.

Table 5.5.3.2-1: Supported bandwidths per CA band combination of band n28+n105

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| NR CA configuration | Uplink CA configuration or single uplink carrier | NR Band | Channel bandwidth (MHz) | Bandwidth combination set |
| CA\_n28A-n105A | - | n28 | 5, 10, 15, 20, 25, 30 | 0 |
| n105 | 5, 10, 15, 20, 251, 301, 351 |  |
| NOTE 1: These n105 channel bandwidths are valid in DL only | | | | |

#### 5.5.3.3 UE co-existence studies

Table 5.5.3.3-1/2 summarizes frequency ranges where UL harmonics and/or harmonic mixing occur for CA\_n28-n105.

Table 5.5.3.3-1: Impact of UL/DL Harmonic

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | |  | | **2nd Harmonic** | | **3rd Harmonic** | | **4th Harmonic** | | **5th Harmonic** | |
|  | **UL Low Band Edge** | **UL High Band Edge** | **DL Low Band Edge** | **DL High Band Edge** | **UL Low Band Edge** | **UL High Band Edge** | **UL Low Band Edge** | **UL High Band Edge** | **UL Low Band Edge** | **UL High Band Edge** | **UL Low Band Edge** | **UL High Band Edge** |
| n28 | 703 | 748 | 758 | 803 | 1406 | 1496 | 2109 | 2244 | 2812 | 2992 | 3515 | 3740 |
| n105 | 663 | 703 | 612 | 652 | 1326 | 1406 | 1989 | 2109 | 2652 | 2812 | 3315 | 3515 |

Based on the above table, there is no UL harmonic issue for CA\_n28-n105.

Table 5.5.3.3-2: Impact of UL/DL Harmonic mixing

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  | **2nd Harmonic** | | **3rd Harmonic** | | **4th Harmonic** | | **5th Harmonic** | |
| **Band** | **UL Low Band Edge** | **UL High Band Edge** | **DL Low Band Edge** | **DL High Band Edge** | **DL Low Band Edge** | **DL High Band Edge** | **DL Low Band Edge** | **DL High Band Edge** | **DL Low Band Edge** | **DL High Band Edge** | **DL Low Band Edge** | **DL High Band Edge** |
| n28 | 703 | 748 | 758 | 803 | 1516 | 1606 | 2274 | 2409 | 3032 | 3212 | 3790 | 4015 |
| n105 | 663 | 703 | 612 | 652 | 1224 | 1304 | 1836 | 1956 | 2448 | 2608 | 3060 | 3260 |

Based on the above table, there is no harmonic mixing issue for CA\_n28-n105.

Since the two bands are very close, cross-band isolation may be an issue as shown in Figure 5.5.3.3-3 below, the Table 5.5.3.3-4 provides the analysis for the potential IMD order of the UL configuration and its image for the largest channel bandwidths.

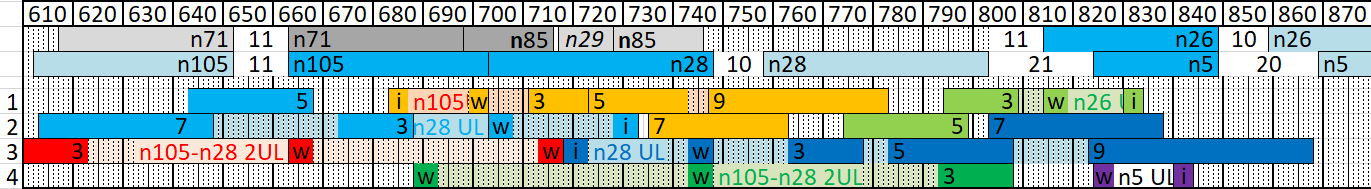


Figure 5.5.3.3-3: IMD landscape for 1UL and 2UL configurations of CA\_n28-n105

**Table 5.5.3.3-4: Cross band isolation issues**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **UL**  **Band** | **UL Low Band Edge** | **UL High Band Edge** | **DL**  **Band** | **DL Low Band Edge** | **DL High Band Edge** | **UL to DL distance** | **Maximum UL BW** | **Source of interference**  **(IMD order of UL RBs and their image)** |
| n28 | 703 | 748 | n105 | 612 | 652 | 51 | 30 | ACLR2 (IMD5) |
| n105 | 663 | 703 | n28 | 758 | 803 | 55 | 20 | ACLR3 (IMD7) |

As shown in the above Table 5.5.3.3-4, the band n28 30MHz CBW UL ACLR2 overlaps with the band n105 DL while the band n105 20MHz CBW UL ACLR3 overlaps with band n28 DL. Both MSDs need to be evaluated.

#### 5.5.3.4 ∆TIB,c and ∆RIB,c values

For CA\_n28-n105 the 2 antenna implementation should drive the ΔTIB,c and ΔRIB,c values, three companies provided input that is summarized in the two tbles below.

**Table 5.5.3.4-1: ΔTIB,c** **due to NR CA (two bands)**

|  |  |  |
| --- | --- | --- |
| **Inter-band CA combination** | **ΔTIB,c for NR bands (dB)9** | |
| **Component band in order of bands in configuration10**  **Proposed values by company A / B / C** | |
| CA\_n28-n105 | 1.0 / 0.7 / 0.8 | 1.0 / 0.7 / 0.8 |
| NOTE 9: “-” denotes ΔTIB,c = 0.  NOTE 10: The component band order in the configuration should be listed by the order of NR bands, such as for CA\_n1-n3 the band order from left to right is n1 and n3. | | |

**Table 5.5.3.4-2: ΔRIB,c due to NR CA (two bands)**

|  |  |  |
| --- | --- | --- |
| **Inter-band CA combination** | **ΔRIB,c for NR bands (dB)8** | |
| **Component band in order of bands in configuration9**  **Proposed values by company A / B / C** | |
| CA\_n28-n105 | 1.0 / 0.4 / 0.2 | 1.0 / 0.4 / 0.2 |
| NOTE 8: “-” denotes ΔRIB,c = 0.  NOTE 9: The component band order in the configuration should be listed by the order of NR bands, such as for CA\_n1-n77 the band order from left to right is n1 and n77. | | |

#### 5.5.3.5 REFSENS evaluation

For CA\_n28-n105, the 2 antennas implementation n28 and n105 MSDs related to cross band isolation described in Table 5.5.3.3-4 must be evaluated.

Three companies provided their evaluation for both cross band MSDs.

For n28 MSD due to n105 UL, one company suggested that no MSD was needed while the two other companies’ input can be found in Table 5.5.3.5-1a and b respectively.

Table 5.5.3.5-1a n28 MSD due to cross band isolation for CA\_n28-n105 with n105 UL (company A)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n105 | n28 | 693 | 20 | 15 | 20 (RBstart=86) | 760.5 | 5 | 3.7 | >ACLR2 |

Table 5.5.3.5-1b n28 MSD due to cross band isolation for CA\_n28-n105 with n105 UL (company B)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n105 | n28 | 693 | 20 | 15 | 20 (RBstart=86) | 760.5 | 5 | 10.8 | >ACLR2 |

Similarly, for n105 MSD due to n28 UL, the three companies’ input can be found in Table 5.5.3.5-1a, b and c.

Table 5.5.3.5-2a n105 MSD due to cross band isolation for CA\_n28-n105 with n28 UL (company A)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n28 | n105 | 718 | 30 | 15 | 25 (RBstart=0) | 649.5 | 5 | 17 | ACLR2 |

Table 5.5.3.5-2b n105 MSD due to cross band isolation for CA\_n28-n105 with n28 UL (company B)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n28 | n105 | 718 | 30 | 15 | 25 (RBstart=0) | 649.5 | 5 | 12.7 | ACLR2 |

Table 5.5.3.5-2c n105 MSD due to cross band isolation for CA\_n28-n105 with n28 UL (company C)

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n28 | n105 | 718 | 30 | 15 | 25 (RBstart=0) | 649.5 | 5 | 10.1 | ACLR2 |

### 5.5.4 Specific for 2 bands UL of fallback CA\_n28-n105

#### 5.5.4.1 Maximum output power for inter-band CA

Power class 3 was assumed for UL CA\_n28-n105, but as discussed in the next clauses, it was decided that the two UL configuration will not be supported due to significant IMD3 MSD and potential co-existence issues with DTV channels.

#### 5.5.4.2 UE co-existence studies

Table 5.5.4.2-1 lists Band n28 + Band n105 2UL bands CA 2nd, 3rd, 4th and 5th order IMD for the UE-to-UE coexistence analysis.

**Table 5.5.4.2-1 IMD interference analysis for CA\_n28-n105 with 2 ULs**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **UE UL carriers** | **fx\_low** | **fx\_high** | **fy\_low** | **fy\_high** |
| UL frequency (MHz) | 663 | 703 | 703 | 748 |
| 2nd harmonics frequency limits | 2\*fx\_low | 2\*fx\_high | 2\*fy\_low | 2\*fy\_high |
| 2nd harmonics frequency limits (MHz) | 1326 | 1406 | 1406 | 1496 |
| 3rd harmonics frequency limits | 3\*fx\_low | 3\*fx\_high | 3\* fy\_low | 3\* fy\_high |
| 3rd harmonics frequency limits (MHz) | 1989 | 2109 | 2109 | 2244 |
| 4th harmonics frequency limits | 4\*fx\_low | 4\*fx\_high | 4\* fy\_low | 4\* fy\_high |
| 4th harmonics frequency limits (MHz) | 2652 | 2812 | 2812 | 2992 |
| 5th harmonics frequency limits | 5\*fx\_low | 5\*fx\_high | 5\* fy\_low | 5\* fy\_high |
| 5th harmonics frequency limits (MHz) | 3315 | 3515 | 3515 | 3740 |
| 6th harmonics frequency limits | 6\*fx\_low | 6\*fx\_high | 6\* fy\_low | 6\* fy\_high |
| 6th harmonics frequency limits (MHz) | 3978 | 4218 | 4218 | 4488 |
| 7th harmonics frequency limits | 7\*fx\_low | 7\*fx\_high | 7\* fy\_low | 7\* fy\_high |
| 7th harmonics frequency limits (MHz) | 4641 | 4921 | 4921 | 5236 |
| 2nd order IMD products | |fy\_high – fx\_low| | |fy\_low – fx\_high| | |fy\_low + fx\_low| | |fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 85 | 0 | 1366 | 1451 |
| 3rd order IMD products | |fy\_high – 2\*fx\_low| | |fy\_low – 2\*fx\_high| | |2\*fy\_low – fx\_high| | |2\*fy\_high – fx\_low| |
| IMD frequency limits (MHz) | 578 | 703 | 703 | 833 |
| 3rd order IMD products | |2\*fx\_low + fy\_low| | |2\*fx\_high + fy\_high| | |2\*fy\_low + fx\_low| | |2\*fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 2029 | 2154 | 2069 | 2199 |
| Two-tone 4th order IMD products | |2\*fx\_low –2\* fy\_high| | |2\*fx\_high – 2\*fy\_low| | |2\*fx\_low +2\* fy\_low| | |2\*fx\_high +2\* fy\_high| |
| IMD frequency limits (MHz) | 170 | 0 | 2732 | 2902 |
| Two-tone 4th order IMD products | |3\*fx\_low –1\* fy\_high| | |3\*fx\_high – 1\*fy\_low| | |3\*fy\_low – 1\*fx\_high| | |3\*fy\_high – 1\*fx\_low| |
| IMD frequency limits (MHz) | 1241 | 1406 | 1406 | 1581 |
| Two-tone 4th order IMD products | |3\*fx\_low +1\* fy\_low| | |3\*fx\_high +1\* fy\_high| | |3\*fy\_low + 1\*fx\_low| | |3\*fy\_high + 1\*fx\_high| |
| IMD frequency limits (MHz) | 2692 | 2857 | 2772 | 2947 |
| Two-tone 5th order IMD products | |fx\_low – 4\*fy\_high| | |fx\_high – 4\*fy\_low| | |fy\_low – 4\*fx\_high| | |fy\_high – 4\*fx\_low| |
| IMD frequency limits (MHz) | 2329 | 2109 | 2109 | 1904 |
| Two-tone 5th order IMD products | |fx\_low + 4\*fy\_low| | |fx\_high + 4\*fy\_high| | |fy\_low + 4\*fx\_low| | |fy\_high + 4\*fx\_high| |
| IMD frequency limits (MHz) | 3475 | 3695 | 3355 | 3560 |
| Two-tone 5th order IMD products | |2\*fx\_low – 3\*fy\_high| | |2\*fx\_high – 3\*fy\_low| | |2\*fy\_low – 3\*fx\_high| | |2\*fy\_high – 3\*fx\_low| |
| IMD frequency limits (MHz) | 918 | 703 | 703 | 493 |
| Two-tone 5th order IMD products | |2\*fx\_low + 3\*fy\_low| | |2\*fx\_high + 3\*fy\_high| | |2\*fy\_low + 3\*fx\_low| | |2\*fy\_high + 3\*fx\_high| |
| IMD frequency limits (MHz) | 3435 | 3650 | 3395 | 3605 |

From the above table, it can be found that both n28 DL and n105 DL are subject to MSD due to dual-uplink IMD3 and IMD5 of 2UL CA\_n28-n105 configuration. Furthermore, the DTV channels below 608 MHz are also victims of the CA\_n28-n105 IMD3 and higher orders and thus the coexistence between UL CA\_n28-n105 and DTV channels may be compromised.

#### 5.5.4.3 REFSENS evaluation

Based on the above IMD analysis, the IMD3 and IMD5 MSD test points in Table 5.5.4.2-1 were discussed. Some estimations of the IMD3 MSD ranged between 25 dB and 44dB depending on the performance of the filters and antenna coupling assumptions. Based on this large MSD and the potential coexistence issue with (US) DTV channels, it was agreed together with the band combination proponent, that 2UL configuration will not be supported. This agreement is captured in way forward [14].

**Table 5.5.4.3-1 potential MSD test points due to IMD3 and IMD5 if 2UL configuration would be specified.**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Band / Channel bandwidth / NRB / Duplex mode | | | | | | | | Source of IMD |
| NR CA band combination | NR band | UL Fc  (MHz) | UL/DL BW  (MHz) | UL  CLRB | DL Fc (MHz) | MSD  (dB) | Duplex mode |
| CA\_n28-n105 | n28 | 745.5 | 5 | 25 | 800.5 | 2UL not specified | FDD | IMD3 |
| n105 | 690.5 | 5 | 25 | 639.5 | N/A | FDD | N/A |
| n28 | 745.5 | 5 | 25 | 800.5 | N/A | FDD | IMD3 |
| n105 | 694.5 | 5 | 25 | 643.5 | 2UL not specified | FDD | N/A |
| n28 | 715 | 5 | 25 | 770 | 2UL not specified | FDD | IMD5 |
| n105 | 687.5 | 5 | 25 | 636.5 | N/A | FDD | N/A |
| n28 | 715.5 | 5 | 25 | 770.5 | N/A | FDD | IMD5 |
| n105 | 690 | 5 | 25 | 639 | 2UL not specified | FDD | N/A |

## 5.6 CA\_n26-n28

### 5.6.1 General

In this configuration the uplink is also CA\_n26A-n28A, but there are two fall back options:

DL\_n26A-n28A\_UL\_n28A\_BCS0 (already completed)

UL\_n26A-n28A\_UL\_n26A\_BCS0

The implementation of the band n28 of CA\_n26\_n28 has been discussed, and the pros and cons of the following two cases can be further traded-off, whether and/or how to do the down-selection in the future is for further study.

Case 1: lower 30MHz of n28 (UL: 703~733MHz, DL: 758~788MHz) is supported.

Case 2: entire n28 frequency range (UL: 703~748MHz, DL: 758~803MHz) is supported.

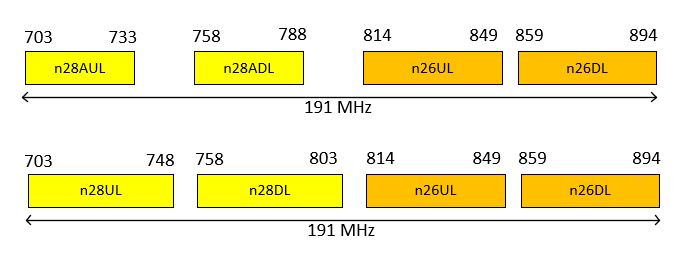


Figure 5.6.1-1 CA\_n26-n28 frequency ranges

Besides, as a reference for further study, proponent operator provided some related information about the allocated spectrum in the 700MHz and extended 850 MHz bands as sketched in the following figure and table.

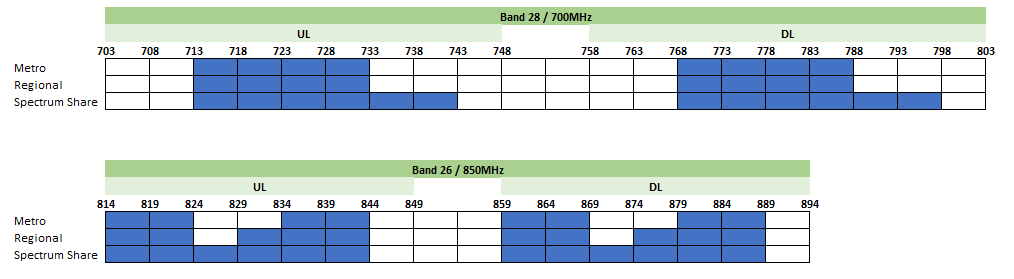


Figure 5.6.1-2 n26 and n28 spectrum allocation

Table 5.6.1-1 n26 and n28 spectrum allocation

|  |  |  |
| --- | --- | --- |
|  | Uplink | Downlink |
| n28 (national) | 713 MHz – 733 MHz | 768 MHz – 788 MHz |
| n26 (Metropolitan) | 814 MHz – 824 MHz  835 MHz – 845 MHz | 859 MHz – 869 MHz  880 MHz – 890 MHz |
| n26 (Regional) | 814 MHz – 824 MHz  830 MHz – 845 MHz | 859 MHz – 869 MHz  875 MHz – 890 MHz |

### 5.6.2 UE RF architecture assumption

The potential UE RF architectures for CA\_n26A-n28A case 1 and case 2 can be considered as shown below. Baseline architecture for UE RF requirements development will be further discussed. As the performance of band n26 is similar to band n28, after the development of CA\_n5-n28, some architectures could be used as a reference to CA\_n26-n28.

#### 5.6.2.1 UE RF architecture with lower 30MHz of n28 supporting

Architecture of case 1 (lower 30MHz of n28 (UL: 703~733MHz, DL: 758~788MHz) is supported) is listed as below. Entire n28 presents a greater challenge to filter implementation, so further research on feasibility and applicable filtering techniques should be considered.

The topology for architecture 1 with 2 antenna, as shown in Figure 5.6.2.1-1:

1) antenna 1 with quadplexer supporting n26DL+n26UL+n28AUL+n28ADL

2) antenna 2 with duplexer supporting n26DL+n28ADL

The topology for architecture 2 with 2 antenna, as shown in Figure 5.6.2.1-2:

1) antenna 1 with triplexer supporting n26DL+n28AUL+n28ADL

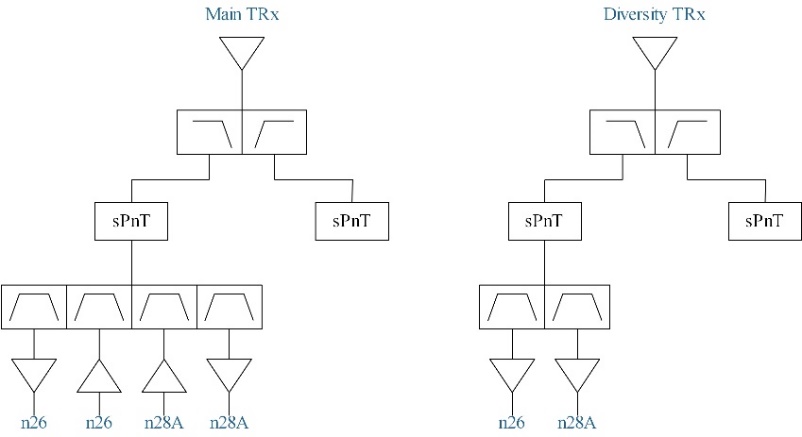
2) antenna 2 with triplexer supporting n26DL+n26UL+n28ADL

The topology for architecture 3 with 3 antenna, as shown in Figure 5.6.2.1-3:

1) antenna 1 with duplexer supporting n28AUL+n28ADL

2) antenna 2 with duplexer supporting n26UL+n26DL

3) antenna 3 with duplexer supporting n26DL+n28ADL



**Figure 5.6.2.1-1 Architecture 1: Quadplexer solution for CA\_n26-n28 with two antennas**

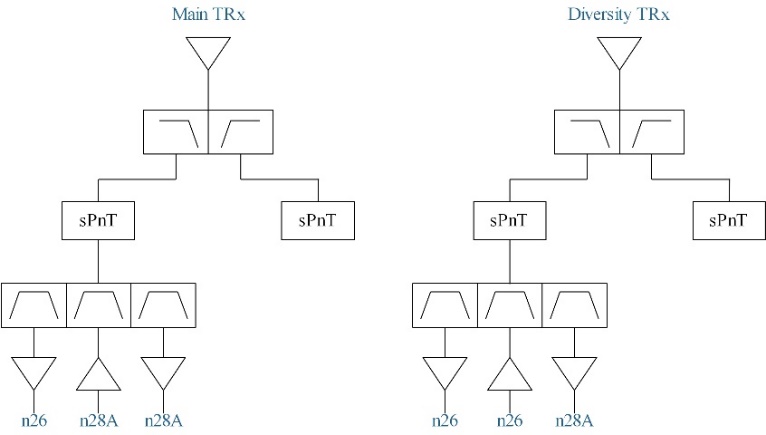


Figure 5.6.2.1-2 Architecture 2: Triplexer solution for CA\_n26-n28 with two antennas

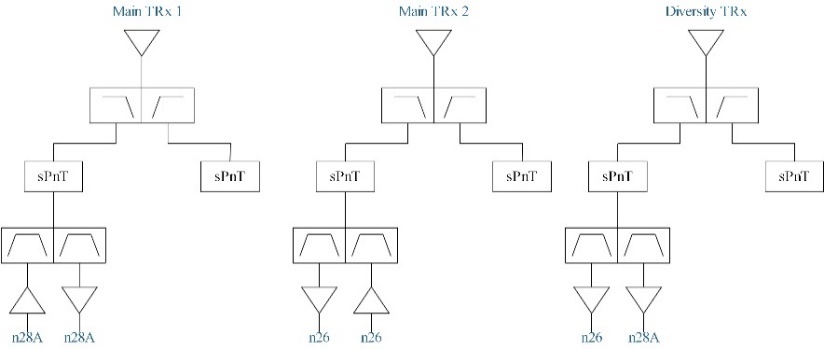


Figure 5.6.2.1-3 Architecture 3: Three-antenna solution for CA\_n26-n28

#### 5.6.2.2 UE RF architecture with entire n28 frequency range supporting

Architecture of case 2 (entire n28 frequency range (UL: 703~748MHz, DL: 758~803MHz) is supported) is listed as below.

The topology for architecture 4 with 2 antenna, as shown in Figure 5.6.2.2-1:

1) antenna 1 with dual-quadplexer supporting n26UL+ n26DL+ n28AUL+ n28ADL\_ n26UL+ n26DL+ n28BUL+ n28BDL

2) antenna 2 with duplexer supporting n26DL+n28DL

The topology for architecture 5 with 2 antenna, as shown in Figure 5.6.2.2-2:

1) antenna 1 with dual-triplexer supporting n26DL+ n28AUL+n28ADL\_ n26DL+ n28BUL+n28BDL

2) antenna 2 with triplexer supporting n26DL+n26UL+n28UL

The topology for architecture 6 with 3 antenna, as shown in Figure 5.6.2.2-3:

1) antenna 1 with dual-duplexer supporting n28AUL+n28ADL\_ n28BUL+n28BDL

2) antenna 2 with duplexer supporting n26UL+n26DL

3) antenna 3 with duplexer supporting n26DL+n28ADL

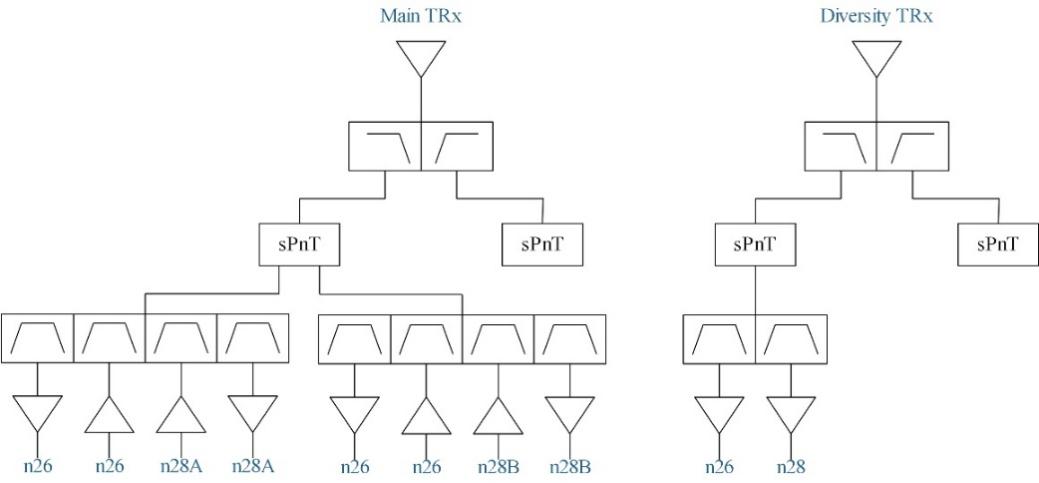


Figure 5.6.2.2-1 Architecture 4: Dual-quadplexer solution for CA\_n26-n28 with two antennas

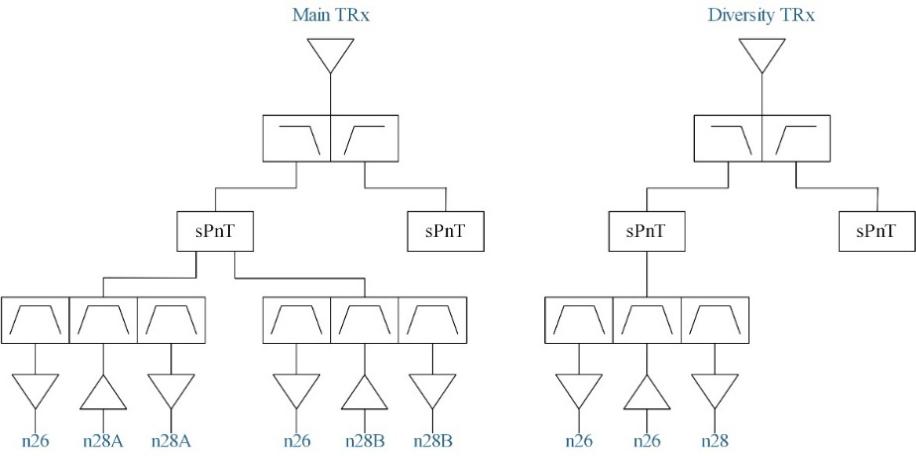
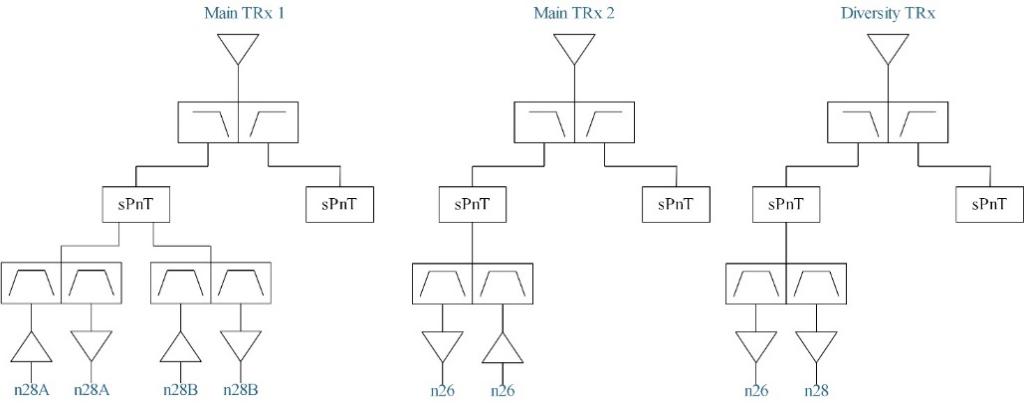


Figure 5.6.2.2-2 Architecture 5: Dual-triplexer solution for CA\_n26-n28 with two antennas



**Figure 5.6.2.2-3 Architecture 6: Three-antenna solution for CA\_n26-n28**

For architecture 4 with 2 antenna, there are some potential implementation challenges:

- The main antenna should simultaneously cover the whole band from n28UL to n26DL with the length of 191MHz, the bandwidth ratio is as high as 23.9%, it would far exceed the bandwidth ratio for a typical planar antenna design in a smartphone, therefore the radiative performance for CA\_n26A-n28A is expected to be compromised.

- The performance requirements of quadplexer such as filter isolation and insertion loss are strict, posing challenge to the implementation and cost of the UE front-end, and the feasibility of two quadplexers may need further study.

For architecture 5 with 2 antenna, there are some advantages and potential implementation challenges:

- A two-antenna architecture with three triplexers can be easier to design with proper delta T and delta R, so architecture 2 seems to be more feasible.

- The difficulties of triplexer implementation still remain with two gaps of 10MHz, n26 BW of 35MHz and n28DL of 45MHz.

For architecture 6 with 3 antenna, there are some advantages and potential implementation challenges:

- For the 3-antenna architecture, there are two antennas on the main signal path, which eases the difficulty of multiplexer design and implement. The frequency range for each main antenna is narrower compared with 2-antenna architecture, and the antenna BW ratios of the two antennas would be close to the current devices.

- 3 LB antennas present a greater challenge to the dimension of the mobile phone than 2-amtenna architecture.

### 5.6.3 Common for 1 band UL and 2 bands UL of CA\_n26-n28

#### 5.6.3.1 Operating bands for CA

Table 5.6.3.1-1: CA band combination of band n26+n28

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR Band | Uplink (UL) band | | | Downlink (DL) band | | | Duplex  mode |
| BS receive / UE transmit | | | BS transmit / UE receive | | |
| FUL\_low – FUL\_high | | | FDL\_low – FDL\_high | | |
| n26 | 814 MHz | – | 849 MHz | 859 MHz | – | 894 MHz | FDD |
| n28 | 703 MHz | – | 748 MHz | 758 MHz | – | 803 MHz | FDD |

A note may be needed if case 1 is considered for CA\_n26-n28, e.g. band n28 is restricted at lower 30MHz (UL: 703~733MHz, DL: 758~788MHz).

In addition, referring to the contribution [10], the following options about different frequency range restrictions are listed to trade-off the pros and cons. From a high level perspective, based on the proponent operator’s feedback, one possibility is that RAN4 move forward with option 4 (i.e. both options 1 and 3 being captured in the specification) which would allow maximum implementation flexibility.

Option 1 Keep current CA\_n26A-n28A with entire n28 frequency range and specify n26 UL and UL CA support for entire frequency range

Option 2 Modify current CA\_n26A-n28A to include only lower 30MHz of n28 and specify n26 UL and UL CA support for lower 30MHz frequency range

Option 3 Keep current CA\_n26A-n28A with entire n28 frequency range and specify n26 UL and UL CA support for lower 30MHz frequency range

Option 4 Combination of options 1 and 3

#### 5.6.3.2 Channel bandwidths per operating band for CA

Referring to table 5.5A.3.1-1h of TS 38.101-1, DL\_n26A-n28A\_BCS0 and BCS1 has been specified

#### 5.6.3.3 Identify the potential MSD issues due to harmonic/harmonic mixing/cross band isolation

There is no need to specify harmonics and harmonics mixing exception for CA\_n26-n28 as we didn’t specify them in current spec.

For cross band isolation issue:

Case 1: The 2nd adjacent channel leakage from band n26 may fall into band DL frequency range (774~788) when 20MHz UL CBW is assumed for band n26.

Case 2: the 1st adjacent channel leakage from band n26 may fall into n28 DL frequency range (796~803) when 20MHz UL CBW is assumed for band n26.

#### 5.6.3.4 ∆TIB,c and ∆RIB,c values

Option 1 is proposed based on the agreed ΔTIB,c and ΔRIB,c values for CA\_n5-n28 in WF [11] which can be reused for CA\_n26-n28.

Option 2 is proposed in the contribution [10].

Table 5.6.3.4-1: ΔTIB,c

|  |  |  |  |
| --- | --- | --- | --- |
| Inter-band CA Configuration | NR Band | ΔTIB,c [dB] option 1 | ΔTIB,c [dB] option 2 |
| CA\_n26A-n28A | n26 | 0.7 | 0.5 |
|  | n28 | 0.7 | 0.5 |

Table 5.6.3.4-2: ΔRIB,c

|  |  |  |  |
| --- | --- | --- | --- |
| Inter-band CA Configuration | NR Band | ΔRIB,c [dB] option 1 | ΔRIB,c [dB] option 2 |
| CA\_n26A-n28A | n26 | 0.2 | 0.3 |
|  | n28 | 0.2 | 0.3 |

#### 5.6.3.5 REFSENS exception evaluation for one UL band

1) Referring to the contribution [12], the following band n28A MSD evaluations, assuming 35dB and 45dB Tx filter rejection of band n26.

Table 5.6.3.5-1: band n28A MSD evaluations due to cross band isolation for CA\_n26-n28

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n26 | n28A | 824 | 20 | 15 | 25 (RBstart=0) | 785.5 | 5 | 25.6 | ACLR2 |
| n26 | n28A | 824 | 20 | 15 | 25 (RBstart=0) | 785.5 | 5 | 15.9 | ACLR2 |

Referring to the contribution [12], we have the following band n28B MSD evaluations, assuming filter performance with set 1 and set 2 in Table 5.6.3.5-3.

Table 5.6.3.5-2: band n28B MSD evaluations due to cross band isolation for CA\_n26-n28

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference  source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n26 | n28B | 824 | 20 | 15 | 25 (RBstart=0) | 801.5 | 5 | 45.9 (Set 1) | ACLR1 |
| n26 | n28B | 824 | 20 | 15 | 25 (RBstart=0) | 801.5 | 5 | 28.5 (Set 2) | ACLR1 |

Table 5.6.3.5-3: Filter performance assumption

|  |  |  |
| --- | --- | --- |
|  | Set 1 | Set 2 |
| n28B Rx filter rejection at 814~849MHz | 12 dB | 33 dB |
| n26 Tx filter rejection at 773~803MHz | 35 dB | 45 dB |

2) Referring to the contribution [13], the following analysis were provided.

To evaluate the potential 1UL and 2UL for CA\_n26-n28 with band n28 full (n28F) or the lower 30MHz (n28A), it is useful to compare existing cases for CA\_n5-n28F and CA\_n18-n28F and CA\_n18-n28A. This can be done by observing the IMD landscape provided in Figure 5.6.3.5-1, and the related wanted UL RB allocation and its image IMDs overlaps for 5MHz and 30MHz n28DL for n28F or n28A scenarios that are collected in Table 5.6.3.5-4.

In addition, 1UL cross band MSD for n28F and n28A were proposed in 1UL cross band MSD for n28F and n28A.

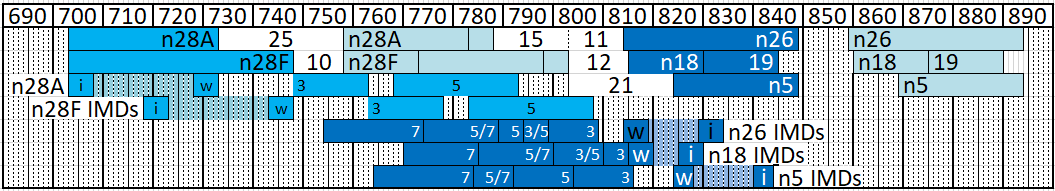


Figure 5.6.3.5-1: IMD landscape of n5, n18, n26 and n28 for n28F and n28A cases.

Table 5.6.3.5-4: Distance to n28 victim DL and IMD overlap for different UL and DL scenarios

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Band | Max UL BW | #RB | Distance to (MHz) | | IMD overlap | | | |
| n28A | n28F | n28A 5MHz | n28F 5MHz | n28A 30MHz | n28F 30MHz |
| n26 | 20MHz | 25 | 26 | 11 | IMD5/7 | IMD3 | IMD5/7 | IMD3/5/7 |
| n5 | 20MHz | 20 | 21 | 36 | IMD5/7 | IMD5 | IMD5/7 | IMD5/7 |
| n18 | 15MHz | 25 | 17 | 12 | IMD5/7 | IMD3/5 | IMD5/7 | IMD3/5/7 |
| n28A | 30MHz | 25 | 25 | na | na | na | IMD3/5 | na |
| n28F | 30MHz | 25 | na | 10 | na | na | na | IMD3/5 |

Table 5.6.3.5-5: 1UL cross band MSD for n28F and n28A

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n26 | n28 | 822.5 | 20 | 15 | 25 (RBstart=0) | 800.5 | 5 | [>30] | ACLR1 |
| n26 | n28 | 822.5 | 20 | 15 | 25 (RBstart=0) | 785.5 | 5 | [18] | ACLR2 |

3) Referring to the contribution [10], the technical analysis for two cases (case 1: n28 Cross-band MSD for lower 30MHz of n28 / case 2: n28 Cross-band MSD for entire n28) are shown below.

Table 5.6.3.5-6: Cross-band MSD for lower 30MHz of n28



Table 5.6.3.5-7: n28 Cross-band MSD for entire n28



It’s observed that MSD is about 15-20dB higher if the entire n28 must be supported, compared to case when only lower 30MHz of n28 is supported.

Table 5.6.3.5-8: n28 Cross-band MSD test point for lower 30MHz of n28 and entire n28

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **UL band** | **DL band** | **UL Fc** | **UL BW** | **SCS of UL band** | **UL RB Allocation** | **DL Fc** | **DL BW** | **MSD** | **Cross-band**  **Interference**  **source** |
| **(MHz)** | **(MHz)** | **(kHz)** | **LCRB** | **(MHz)** | **(MHz)** | **(dB)** |
| n26 | n28 | 824 | 20 | 15 | 25 (RBstart=0) | 785.5 | 5 | 17.0 | ACLR2 |
| n26 | n28 | 824 | 20 | 15 | 25 (RBstart=0) | 800.5 | 5 | 33.7 | ACLR |

### 5.6.4 Specific for 2 bands UL of CA\_n26-n28

#### 5.6.4.1 Maximum output power for inter-band CA

Power class 3 is assumed for UL CA\_n26-n28

#### 5.6.4.2 UE co-existence studies

Table 5.6.4.2-1 lists Band n26 + Band n28 2UL bands CA 2nd, 3rd, 4th and 5th order IMD for the UE-to-UE coexistence analysis.

Table 5.6.4.2-1: Band n26 and Band n28 UL IMD products

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| UE UL carriers | fx\_low | fx\_high | fy\_low | fy\_high |
| UL frequency (MHz) | 814 | 849 | 703 | 748 |
| 2nd order IMD products | |fy\_low – fx\_high| | |fy\_high – fx\_low| | |fy\_low + fx\_low| | |fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 146 | 66 | 1517 | 1597 |
| Two-tone 3rd order IMD products | |2\*fx\_low – fy\_high| | |2\*fx\_high – fy\_low| | |2\*fy\_low – fx\_high| | |2\*fy\_high – fx\_low| |
| IMD frequency limits (MHz) | 880 | 995 | 557 | 682 |
| Two-tone 3rd order IMD products | |2\*fx\_low + fy\_low| | |2\*fx\_high + fy\_high| | |2\*fy\_low + fx\_low| | |2\*fy\_high + fx\_high| |
| IMD frequency limits (MHz) | 2331 | 2446 | 2220 | 2345 |
| Two-tone 4th order IMD products | |3\*fx\_low –1\* fy\_high| | |3\*fx\_high – 1\*fy\_low| | |3\*fy\_low – 1\*fx\_high| | |3\*fy\_high – 1\*fx\_low| |
| IMD frequency limits (MHz) | 1694 | 1844 | 1260 | 1430 |
| Two-tone 4th order IMD products | |3\*fx\_low +1\* fy\_low| | |3\*fx\_high + 1\*fy\_high| | |3\*fy\_low + 1\*fx\_low| | |3\*fy\_high + 1\*fx\_high| |
| IMD frequency limits (MHz) | 3145 | 3295 | 2923 | 3093 |
| Two-tone 4th order IMD products | |2\*fx\_low –2\* fy\_high| | |2\*fx\_high –2\* fy\_low| | |2\*fx\_low +2\* fy\_low| | |2\*fx\_high +2\* fy\_high| |
| IMD frequency limits (MHz) | 132 | 292 | 3034 | 3194 |
| Two-tone 5th order IMD products | |fx\_low – 4\*fy\_high| | |fx\_high – 4\*fy\_low| | |fy\_low – 4\*fx\_high| | |fy\_high – 4\*fx\_low| |
| IMD frequency limits (MHz) | 2178 | 1963 | 2693 | 2508 |
| Two-tone 5th order IMD products | |2\*fx\_low - 3\*fy\_high| | |2\*fx\_high - 3\*fy\_low| | |2\*fy\_low - 3\*fx\_high| | |2\*fy\_high -3\*fx\_low| |
| IMD frequency limits (MHz) | 616 | 411 | 1141 | 946 |
| Two-tone 5th order IMD products | |fx\_low + 4\*fy\_low| | |fx\_high + 4\*fy\_high| | |fy\_low + 4\*fx\_low| | |fy\_high + 4\*fx\_high| |
| IMD frequency limits (MHz) | 3626 | 3841 | 3959 | 4144 |
| Two-tone 5th order IMD products | |2\*fx\_low + 3\*fy\_low| | |2\*fx\_high + 3\*fy\_high| | |2\*fy\_low + 3\*fx\_low| | |2\*fy\_high + 3\*fx\_high| |
| IMD frequency limits (MHz) | 3737 | 3942 | 3848 | 4043 |

3rd order IMD may also fall into Rx frequencies of bands n26 when both Band n26 and Band n28 transmit the UL signals.

Table 5.6.4.2-2: Protected bands for the 2UL bands CA configuration

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NR CA Configuration | Spurious emission | | | | | | |
| Protected band | Frequency range (MHz) | | | Maximum Level (dBm) | MBW (MHz) | NOTE |
| CA\_n26-n28 | E-UTRA Band 2, 3, 5, 18, 19, 25, 26, 31, 34, 40, 73  NR Band n79 | FDL\_low | - | FDL\_high | -50 |  |  |
| E-UTRA Band 4, 41, 42, 43, 50, 51, 52, 65, 66, 74 NR Band n77, n78, n79 | FDL\_low | - | FDL\_high | -50 | 1 | 2 |
| E-UTRA Band 1 | FDL\_low | - | FDL\_high | -50 | 1 | 2, 11, 15 |
| E-UTRA Band 11, 21 | FDL\_low | - | FDL\_high | -50 | 1 | 2, 11, 12 |
| Frequency range | 1884.5 | - | 1915.7 | -41 | 0.3 | 3, 11 |
| Frequency range | 470 | - | 694 | -42 | 8 | 4, 14 |
| Frequency range | 470 | - | 710 | -26.2 | 6 | 13 |
| Frequency range | 662 | - | 694 | -26.2 | 6 | 4 |
| Frequency range | 758 | - | 773 | -32 | 1 | 4 |
| Frequency range | 773 | - | 799 | -50 | 1 |  |
| Frequency range | 799 | - | 803 | -40 | 1 | 4 |
| Frequency range | 945 | - | 960 | -50 | 1 |  |
| NOTE 2: As exceptions, measurements with a level up to the applicable requirements defined in Table 6.5.3.1-2 are permitted for each assigned NR carrier used in the measurement due to 2nd, 3rd, 4th or 5th harmonic spurious emissions. Due to spreading of the harmonic emission the exception is also allowed for the first 1 MHz frequency range immediately outside the harmonic emission on both sides of the harmonic emission. This results in an overall exception interval centred at the harmonic emission of (2 MHz + N x LCRB x 180kHz), where N is 2, 3, 4, 5 for the 2nd, 3rd, 4th or 5th harmonic respectively. The exception is allowed if the measurement bandwidth (MBW) totally or partially overlaps the overall exception interval.  NOTE 3: Applicable when co-existence with PHS system operating in 1884.5 -1915.7 MHz  NOTE 4: These requirements also apply for the frequency ranges that are less than FOOB (MHz) in Table 6.5.3.1-1 from the edge of the channel bandwidth.  NOTE 11:Applicable when the assigned NR carrier is confined within 718 MHz and 748 MHz and when the channel bandwidth used is 5 or 10 MHz.  NOTE 12: As exceptions, measurements with a level up to the applicable requirement of -38 dBm/MHz is permitted for each assigned NR carrier used in the measurement due to 2nd harmonic spurious emissions. An exception is allowed if there is at least one individual RB within the transmission bandwidth (see Figure 5.3.1-1) for which the 2nd harmonic totally or partially overlaps the measurement bandwidth (MBW).  NOTE 13: This requirement is applicable for 5 and 10 MHz NR channel bandwidth allocated within 718 - 728 MHz. For carriers of 10 MHz bandwidth, this requirement applies for an uplink transmission bandwidth less than or equal to 30 RB with RBstart > 1 and Rbstart < 48.  NOTE 14: This requirement is applicable in the case of a 10 MHz NR carrier confined within 703 MHz and 733 MHz, otherwise the requirement of -25 dBm with a measurement bandwidth of 8 MHz applies.  NOTE 15: As exceptions, measurements with a level up to the applicable requirement of -36 dBm/MHz is permitted for each assigned E-UTRA carrier used in the measurement due to 3rd harmonic spurious emissions. An exception is allowed if there is at least one individual RB within the transmission bandwidth (see Figure 5.6-1) for which the 3rd harmonic totally or partially overlaps the measurement bandwidth (MBW). | | | | | | | |

#### 5.6.4.3 REFSENS exception evaluation for two UL band

1) MSD due to IMD

If the following test frequency range was assumed, we can calculate the frequency range which is hit by IMD3 from UL CA\_n26-n28 as 880~895 MHz. It can be observed the IMD3 missed the DL channel of band n26 by 5MHz.

n26: UL 814~819 DL 859~864

n28: UL 743~748 DL 798~803

IMD3 range is 880~895 MHz

That means there is no direct test frequency point which can be found for IMD3 MSD definition.

2) MSD due to two UL cross band isolation

Even if the performance of duplexer/filter’s isolation can be guaranteed by one UL cross band isolation MSD, two PA linearity performance should be guaranteed simultaneously by two UL cross band isolation MSD requirements especially for the case that two 1st / 2nd adjacent channel interferences from two different UL aggressor bands hit the DL part of victim band. The following test points were proposed in contribution R4-2307477 for further discussion.

Table 5.6.4.3-1: 2UL cross band MSD for n28F and n28A

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| UL band | DL band | UL Fc | UL BW | SCS of UL band | UL RB Allocation | DL Fc | DL BW | MSD | Cross-band  Interference source |
| (MHz) | (MHz) | (kHz) | LCRB | (MHz) | (MHz) | (dB) |
| n26 | n28 | 824 | 20 | 15 | 25 (RBstart=0) | 788 | 30 | [>6] | ACLR1 from n26 UL band and ACLR1+ACLR2 from n28 UL band |
| n28 | 733 | 30 | 15 | 25 (RBstart=135) |
| n26 | n28 | 824 | 20 | 15 | 25 (RBstart=0) | 773 | 30 | [3] | ACLR2 from n26 UL band and ACLR1+ACLR2 from n28 UL band |
| n28 | 718 | 30 | 15 | 25 (RBstart=135) |

## [5.7 CA\_n5-n28-n105]

*Editor’s note: Check at RAN4#107 whether CA\_n5A-n28A-n105A could be included in the SI based on study progress for the fall back combinations.*

Annex A:  
Change history

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Change history** | | | | | | | |
| **Date** | **Meeting** | **TDoc** | **CR** | **Rev** | **Cat** | **Subject/Comment** | **New version** |
| 2022-10 | RAN4#104be | R4-2217712 |  |  |  | TR skeleton | 0.1.0 |
| 2022-10 | RAN4#104be | R4-2217713 |  |  |  | TP and discussion on CA\_n5-n28 | 0.2.0 |
| 2022-10 | RAN4#104be | R4-2217714 |  |  |  | TP and discussion on CA\_n8-n20-n28 | 0.2.0 |
| 2022-10 | RAN4#104be | R4-2217715 |  |  |  | TP and discussion on CA\_n5-n8 | 0.2.0 |
| 2022-11 | RAN4#105 | R4-2220504 |  |  |  | TP for TR 38.872 on CA\_n5-n8 architectures | 0.3.0 |
| 2022-11 | RAN4#105 | R4-2220505 |  |  |  | TP on CA\_n5-n28 | 0.3.0 |
| 2022-11 | RAN4#105 | R4-2220506 |  |  |  | TP for TR 38.872 to capture the RF architecture assumption and IMD evaluation for CA\_n8-n20-n28 | 0.3.0 |
| 2023-03 | RAN4#106 | R4-2300560 |  |  |  | TP for TR 38.872: scope and references | 0.4.0 |
| 2023-03 | RAN4#106 | R4-2303544 |  |  |  | TP for TR 38.872 to complete the open issues for CA\_n5-n8 | 0.4.0 |
| 2023-03 | RAN4#106 | R4-2303545 |  |  |  | TP for TR 38.872 to complete the open issues for CA\_n5-n28 | 0.4.0 |
| 2023-03 | RAN4#106 | R4-2303546 |  |  |  | TP for TR 38.872 to complete the open issues for CA\_n8-n20-n28 | 0.4.0 |
| 2023-03 | RAN#99 | RP-230425 |  |  |  | Editorial update for 1.0.0 version | 1.0.0 |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **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 |
| 2023-06 | RAN#100 | RP-231366 | 0001 |  | B | Big CR for TR 38.872 to introduce outcomes of CA\_n5-n105 CA\_n28-n105 CA\_n26-n28 in sub-1GHz SI | 18.1.0 |