3GPP TR 38.831 V16.1.0 (2020-12)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
NR;
User Equipment (UE) Radio Frequency (RF) requirements for Frequency Range 2 (FR2)
(Release 16)

3GPP

Postal address

3GPP support office address

650 Route des Lucioles - Sophia Antipolis
Valbonne - FRANCE
Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Internet

http://www.3gpp.org

Contents

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:

Version x.y.z

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 technical report for NR RF Requirement Enhancements for FR2 WI.

2 References

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

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

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

[2] 3GPP TS 38.101-2: "User Equipment (UE) radio transmission and reception; Part 2: Range 2 Standalone".

[3] 3GPP TS 38.307: "Requirements on User Equipments (UEs) supporting a release-independent frequency band".

3 Definitions of terms, symbols and abbreviations

3.1 Terms

For the purposes of the present document, the terms given in 3GPP TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in 3GPP TR 21.905 [1].

3.2 Symbols

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

Fs	Frequency separation class
Fsd	Frequency separation class for DL-only spectrum
$\Delta MB_{P,n}$	Reference sensitivity relaxation parameter
$\Delta MB_{S,n}$,	EIS spherical coverage relaxation parameter

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in 3GPP TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in 3GPP TR 21.905 [1].

ADC	Analog to digital converter
AoA	Angle of arrival
BC	Beam correspondence
CA	Carrier aggregation
CBW	Channel bandwidth
CC	Component carrier

CSI-RS	Channel State Information Reference Signal
DL	Downlink
EIRP	Effective Isotropic Radiated Power
EIS	Effective Isotropic sensitivity
EVM	Error vector magnitude
FR2	Frequency range 2
LO	Local oscillator
MBR	Multiband relaxation
MOP	Maximum output power
NZP CSI RS	Non zero power CSI-RS
OBW	Occupied bandwidth
PBCH	Physical Broadcast Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Data Shared Channel
PRB	Physical resource block
PSD	Power spectral density
RRM	Radio resource management
RSRP	Reference signal received power
SCS	Sub-carrier spacing
SMTC	SSB-based RRM Measurement Timing Configuration
SNR	Signal to noise ratio
SSB	Synchronization Signal Block
UE	User equipment
UL	Uplink
QCL	Quasi co-located

4 Topics

4.1 Void

4.2 FR2 UE Beam Correspondence requirements

4.2.1 Beam correspondence based on SSB

4.2.1.1 Feasibility

A requirement on beam correspondence based on SSB verifies the UE's ability to select its uplink beam based on measurements of SSB. SSB is a mandatory signal with various repetition rates (5ms, 10ms, 20ms, 40ms, 80ms, and 160ms periodicity). As a reliable, repetitive resource, it can serve as a standard candle for the UE to evaluate its beams for best directional gain. It follows that SSB can indeed serve as a reference signal for beam correspondence.

SSB-based beam correspondence is very important because it is the basis of initial acquisition. It also potentially allows faster roll-out of networks, because it requires a simpler set of signals from the gNB. These considerations generally imply both motivation and feasibility to use SSB as the sole reference signal for the UE to achieve beam correspondence.

A requirement on beam correspondence based on SSB, provided the side conditions can be guaranteed, presents a problem due to two sets of MOP: MOP requirements for SSB based BC and CSI-RS based BC. Two sets of MOP indicated not only MOP test will be doubled, but also other TX test cases will be affected. Two sets of MOP test may produce two different beam peak direction, however, most of other TX test cases are based on unique beam peak direction. Two different beam peak direction will make other TX test cases ambiguous. It is not reasonable and not affordable to test all TX test cases two times based on the two beam peak direction respectively. Not only beam peak direction, but also side condition will be used for other TX test case. According to TS 38.101-2, beam correspondence side conditions for SSB and CSI-RS will be used for other test cases. Based on above observations, it can be concluded that SSB based BC is not feasible, unless side condition can be guaranteed and two sets of MOP issue can be addressed. One possible approach is that SSB based BC will be set as an optional feature, if UE supports SSB based BC, then

MOP based on SSB based BC will be considered as the unique MOP, and CSI-RS based BC test shall be skipped; if UE does not support SSB based BC, MOP will be based on CSI-RS based BC.

Cell-level mobility is based on L3 SSB measurements. For a UE that supports SSB-based beam correspondence, beam-level mobility is based on L1 SSB measurements. The SSBs used for L1 and L3 measurements may not be the same, but the UE possesses knowledge of which SSB is associated with each measurement category. The UE that supports SSB-based beam correspondence can opportunistically use its L1 measurement opportunities to perform beam refinement.

SSB-based RRM requirements upper-bound the number of Rx beams to 8, in context of a specific cell search and measurement timeline, see table 9.5.4.1-1 of TS38.133. The standard however does not mandate that the SSB codebook consist exclusively of rough beams. A simple algorithm for a UE to implement SSB-based beam correspondence is below:

1. To search non-serving cells/SSBs, use rough beams on non-serving cell SSB bursts in SMTC windows
2. For serving-cell SSB measurements, use progressively refined beams when conditions allow. Opportunistic beam refinement detail is below:
   a. At time-1, UE receives 8 SSB bursts
      i. UE obtains 8 sets of data pairs, e.g. (rough beam-1, RSRP-1), (rough beam-2, RSRP-2), …, (rough beam-8, RSRP-8).
      ii. UE finds the data set corresponding to the max RSRP out of 8 sets, for example, (rough beam-2, RSRP-2)
   b. At time-2, UE receives 8 SSB bursts.
      iii. UE measures RSRP with rough beam-2 first.
      iv. UE compares the measured RSRP to RSRP-2 that was measured in the previous occasion Time-1.
      v. If the difference is marginal, then UE can tell it doesn't need to repeat RSRP measurement for all hypotheses. (UE doesn't need to perform neighbor cell search because those resources will be provided separately, e.g. measurement gap and/or SMTC configuration in measurement object)
      vi. UE can attempt to refine Rx beam during 7 remaining SSB bursts.
   c. At time-3, UE receives 8 SSB bursts.
      vii. UE measures RSRP with rough beam-2 first.
      viii UE compares the measured RSRP to RSRP-2 that was measured in the previous occasion Time-2.
      ix. Again, UE can tell it doesn't further need to measure RSRP.
      x. UE performs beam refinement starting from the refined beam at Time-2.
      xii. UE can tell the first tried refine beam quality is still as good as Time-2.
      xiii. UE can skip 6 remaining SSB burst reception for power saving.
   d. At time-4, repeats the same procedure of Time-3
      xiv. If measured RSRP is different from the previous one by some threshold value, UE sweeps its Rx beam for the rest of the 7 SSB bursts, and follows time-1 procedure.

This algorithm was implemented in a UE for experimental verification in a UE compliance test context. The example UE was chosen for its superior spherical coverage, a detail that helps later for this exercise. In Fig. 4.2.1.1-1, the EIS CCDF is presented on a reversed (1 dB/ x division) EIS scale to allow for shape comparison with EIRP CDF. The close similarity in shapes confirms that the same set of beams is used in both DL and UL, in high path loss conditions.

Further considerations are required to confirm that the common beam set does indeed comprise refined (high-gain beams):

1. The peak EIRP value obtained from the CDF of SSB based BC is compared to the best EIRP obtained by manually characterizing each refined beam. The agreement (0.3 dB difference) between the 'head' of the CDF

and the manually determined peak EIRP value confirms that EIRP in this CDF is indeed generated from refined beams. By shape similarity, the conclusion can be extended to sensitivity condition also.

2. A second consideration is the shape of the CDF. RRM requirements assume 7dB lower gain with rough beams. While the gain difference can be smaller in PC3 devices, it is still close to 10log(4). In context of this example UE's CDF, one can conclude that no rough beams are used in the top 50% directions, which have less than 6dB gain drop from peak. It is therefore possible to confirm from measurements that refined beams have indeed been used for all directions used to confirm spherical coverage compliance in this example UE. Note that the example UE's superior spherical coverage merely helped illustrate the dependence on refined beams to establish spherical coverage.

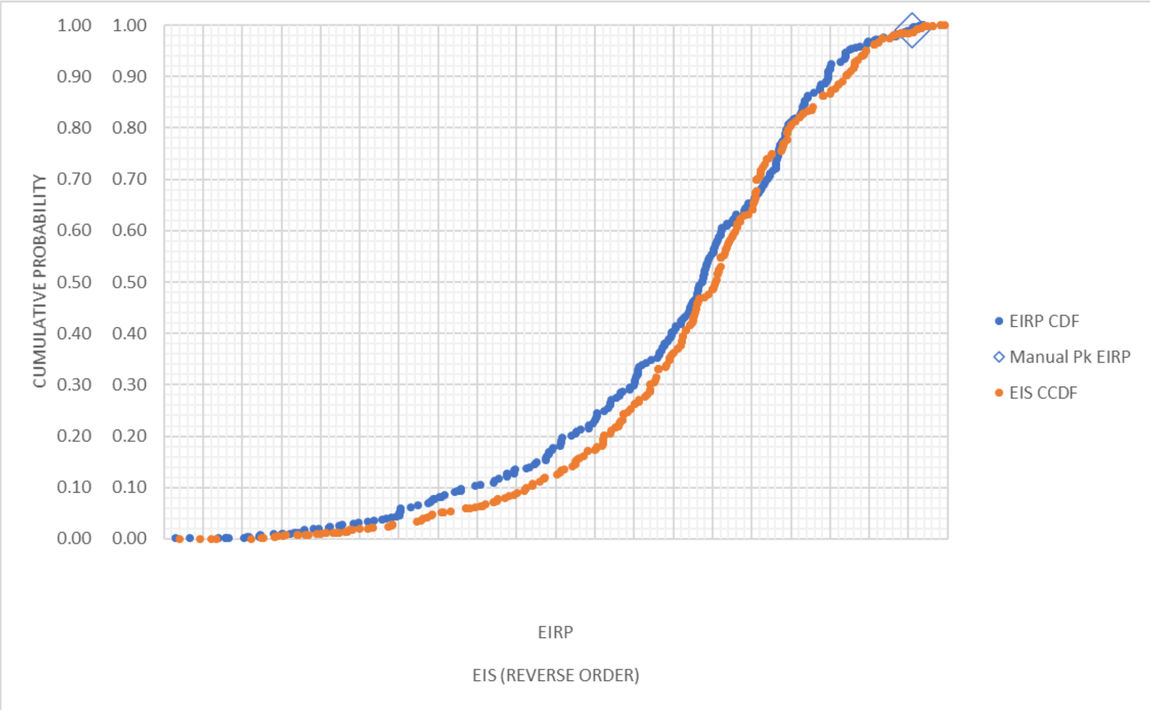


Figure 4.2.1.1-1: EIRP and EIS statistics for UE with SSB-based beam correspondence

Not all companies have agreed that the algorithm above and supporting results are proof of feasibility. One view is based on an interpretation of RRM rules that limits the UE to the same 8 beams for all L1-RSRP measurements:

Even though BC is based on L1-RSRP, the Rx codebook size for SSB and CSI-RS can still be significant different. For SSB based L1-RSRP, total 8Rx beams are assumed, i.e. N=8 for the measurement period $T_{L1\text{-}RSRP\_Measurement\_Period\_SSB}$ defined in Table 9.5.4.1-1, TS38.133. Since the UE cannot assume QCL between SSB used for L3 measurement and SSB for L1 measurement, Rx refinement for SSB cannot be easily assumed. Meanwhile, SSB based L3 measurement is critical to comply with in order to guarantee UE's mobility performance. Due to this reason, it has been specified in TS38.133 that up to 24 SMTC can be used for cell detection and measurement, respectively. Based on this analysis, all UE designs cannot be assumed to implement more than 8 Rx beams, since further increasing the number of Rx beam for SSB measurements including L1-RSRP and L3 can lead to a trade-off in measurement accuracy and/or delay.

The situation for CSI-RS based measurement is quite different. CSI-RS based Rx refinement for L1-RSRP can be realized by P1/P2/P3 CSI-RS configurations. Even for L3 measurement, it is noted that there is no CSI-RS L3 measurement/reporting requirements in Rel-15. Therefore, UE has the flexibility to implement large codebook for Rx beamforming. It is also reasonable to assume the restriction on Rx beam sweeping can be largely relaxed for CSI-RS measurement since UE's mobility performance can be maintained by SSB based L3 measurement. Rel-15 UE can take advantage this by configuring denser Rx beam sweeping for CSI-RS than SSB.

An analysis of the performance degradation with SSB only based beam correspondence, when compared to SSB+CSI-RS based beam correspondence, has been performed based on the following simulation assumptions:

- SSB SNR level is specified as per antenna elements. Depending on Rx antenna array configuration, additional Rx beamforming gain should be considered to derive the baseband SNR for RSRP measurement.

- Additional RSRP measurement inaccuracy margin due to implementation is also considered. In the simulations, implementation margin is uniformly distributed within [-X dB, +X dB], where X=2 or 4.

- P3 CSI-RS is not considered in the evalatuion of SSB-only based BC performance.

- Different antenna array configurations are evaluated.

- The evaluation matric are defined as the CDF of 50-percentile EIRP differences between SSB based and SSB+CSI-RS based BC.

- Different size of Rx beam codebooks are assumed for SSB and CSI-RS measurement. More specifically, codebook size of 4 and 8 are considered for SSB related Rx beam sweeping and codebook size of 16 and 32 are assumed for CSI-RS related Rx beam sweeping

The detailed simulation procedure can be described as follows:

For ue_cnt = 1 To num_UE

For sample = 1 To num_sample_in_a_sphere

Measure RSRP_SSB over Rx beams in SSB_CODEBOOK

Find SSB_rx_beam by maximizing RSRP_SSB

Find SSB_tx_beam by adding UL mismatch to SSB_rx_beam

Measure EIRP_SSB(sample)

Measure RSRP_CSIRS over Rx beams in CSIRS_CODEBOOK

Find CSIRS_rx_beam by maximizing RSRP_CSIRS

Find CSIRS_tx_beam by adding UL mismatch to CSIRS_rx_beam

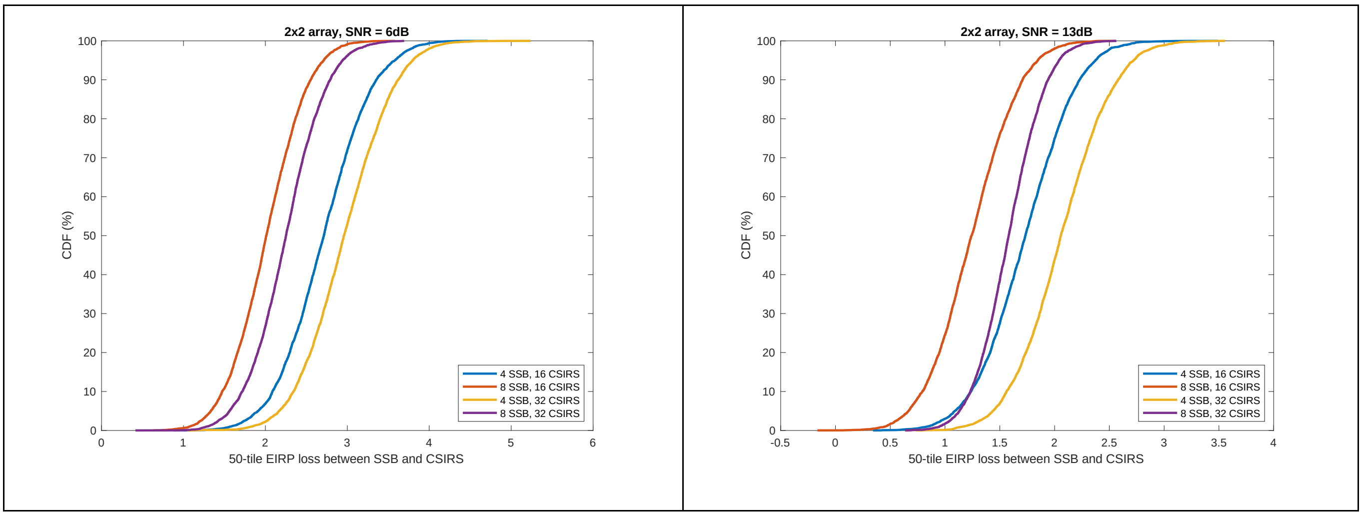
Measure EIRP_CSIRS(sample)

END

50-percentile_EIRP_loss_SSB_wrt_CSIRS(ue_cnt) = 50-percentile (EIRP_CSIRS) - 50-percentile(EIRP_SSB)

END

The simulation results are illustrated in Figures 4.2.1.1-2 and 4.2.1.1-3 below.



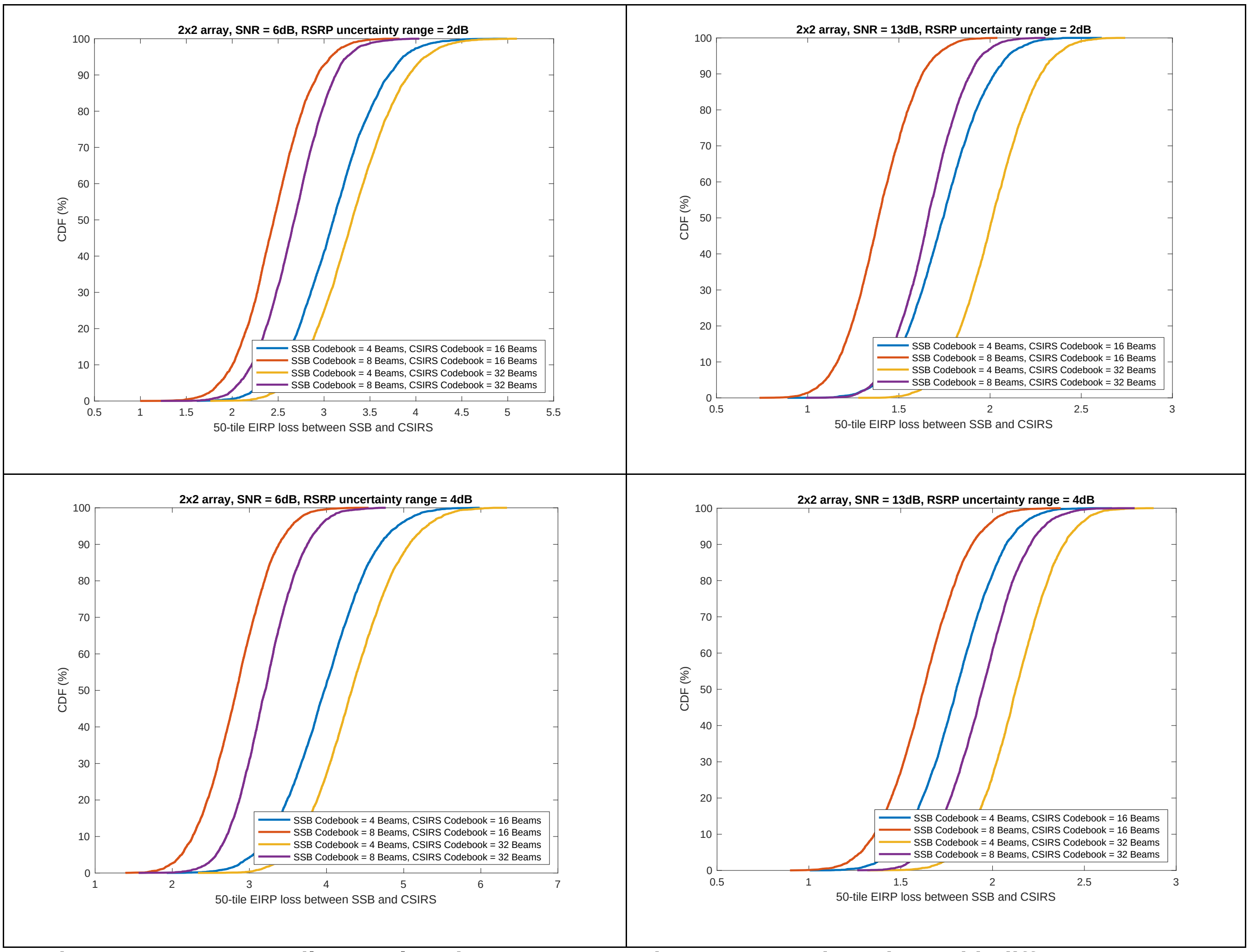
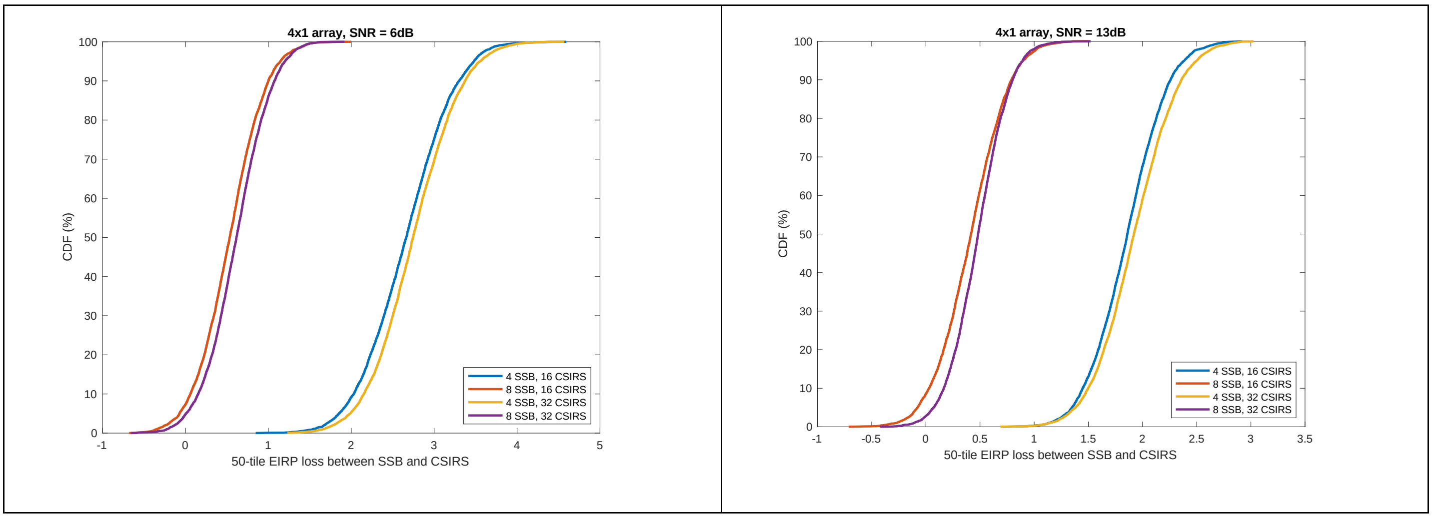


Figure 4.2.1.1-2: 50%-tile EIRP loss between SSB and SSB+CSI-RS based BC with different RSRP implementation margin, 2x2 antenna array aonfiguration



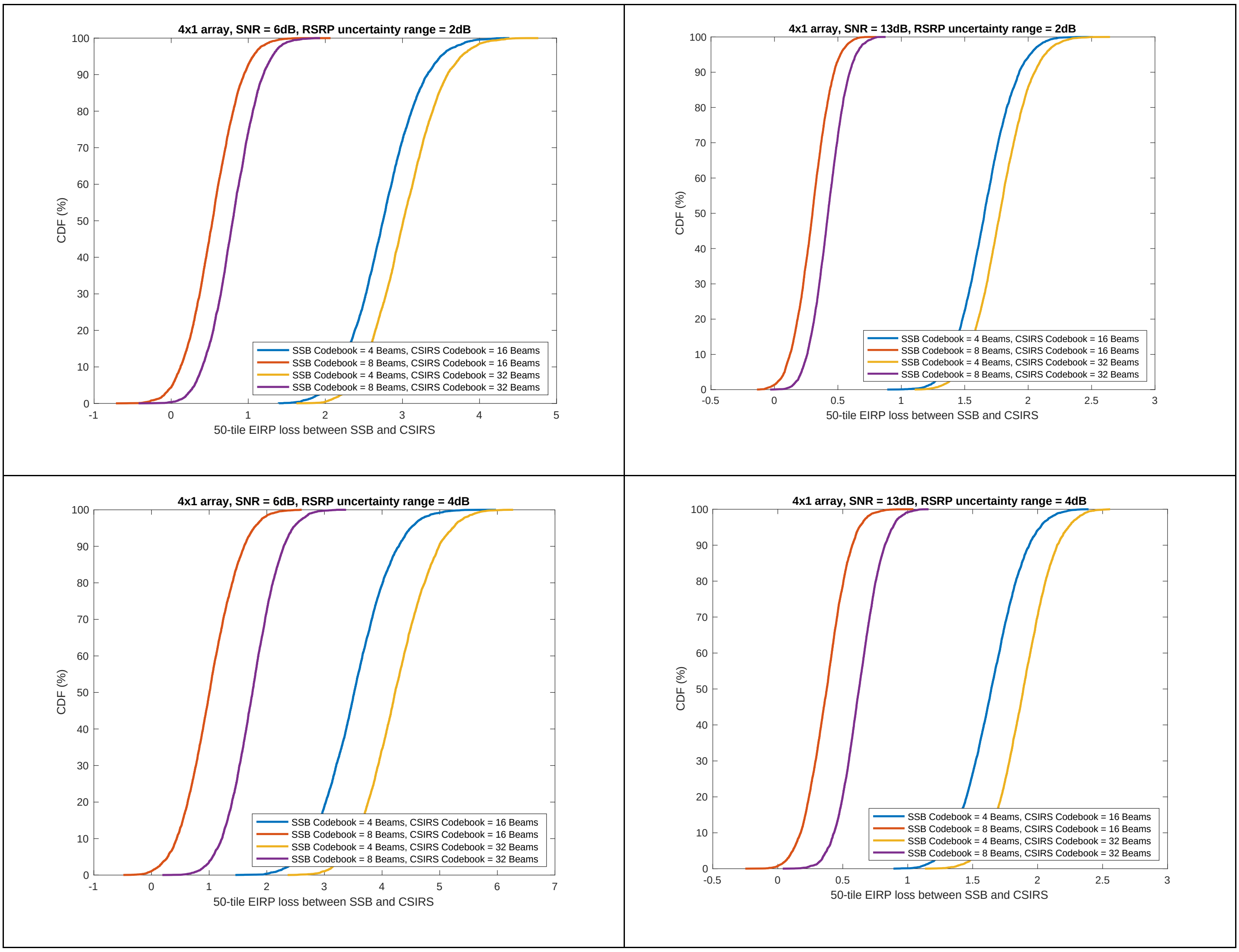


Figure 4.2.1.1-3: 50%-tile EIRP performance loss between SSB and SSB+CSI-RS based BC with different RSRP implementation margin, 4x1 Antenna Array Configuration

The simulation results can be summarized as follows:

Table 4.2.1.1-1: 50th percentile EIRP Loss at 90th percentile

	Num beams per array for SSB	Num beams per array for CSI-RS	SSB SNR Level (dB)	EIRP Loss (dB) with zero RSRP margin	EIRP Loss (dB) with Implementation Margin of 2dB for RSRP	EIRP Loss (dB) with Implementation Margin of 4dB for RSRP
Antenna array with 2x2 Dual-Pol elements	4	16	6	3.4	4.7	4.5
			13	2.2	2.1	2.0
	8	16	6	2.5	2.9	3.3
			13	1.7	1.6	1.8
	4	32	6	3.6	4.0	5.1
			13	2.6	2.2	2.4
	8	32	6	2.8	3.1	3.6
			13	1.9	1.8	2.2
Antenna array with 4x1 Dual-Pol elements	4	16	6	3.3	3.1	4.0
			13	2.2	1.9	1.8
	8	16	6	1	1	1.6
			13	0.8	0.5	0.6
	4	32	6	3.4	3.5	5.0
			13	2.4	2.1	2.1

	8	32	6	1	1.2	2.3
			13	0.8	0.6	0.7

On the feasibility of beam correspondence based on SSB, RAN4 concluded the following:

- $\Delta p = 0$ dB, an optional capability
- If a Rel-16 UE indicates it doesn't support beam correspondence based on SSB, then the network can expect the UE to fulfill beam correspondence based on Rel-15 beam correspondence requirements.
- Rel-16 will continue to have *beamCorrespondenceWithoutUL-BeamSweeping* = 0 and *beamCorrespondenceWithoutUL-BeamSweeping* = 1 UEs

4.2.1.2 Side conditions

The side conditions for the requirement are summarized in Table 4.2.1.2-1 below.

Table 4.2.1.2-1: Side conditions for beam correspondence based on SSB

Parameter	Value
SSB min SNR level	6 dB
SSB periodicity	20 ms
P1 CSI-RS configuration	Not used
P3 CSI-RS configuration	Not used
Use tracking CSI-RS configuration?	Yes
Tracking CSI-RS QCL info	qcl-TypeD=SSB
Tracking CSI-RS min SNR level	6 dB
PDCCH/PDSCH DM-RS QCL info	qcl-TypeD=TRS
NOTE 1: RAN4 didn't assume more than [1] SSB indices should be transmitted NOTE 2: SSB use configuration for Rel-15 which is specified in 38.508 per agreed in RAN4 #92bis meeting	

RAN4 discussed the applicability rule for peak direction for beam correspondence based on SSB with the following outcome: if a UE supports beam correspondence based on SSB, then the network can expect the UE to also fulfill Rel-15 beam correspondence requirements. An additional applicability rule is needed when the UE supports both SSB based beam correspondence and CSI-RS based beam correspondence in Rel-16 (see Clause 4.2.2).

For UEs which support both beam correspondence based on SSB and beam correspondence based on CSI-RS:

- The UE RF core requirements for both side conditions specified in sublause 6.6.4.3.1 of TS38.101-2 apply
- All UL RF requirements are verified with the side condition sets listed in sublause 6.6.4.3.2 of TS38.101-2
- If UE meets beam correspondence requirements based on SSB using side condition sets listed in subclause 6.6.4.3.2 of TS38.101-2, and meets minimum peak EIRP requirement by additonal representative test using the side condition sets listed in subclause 6.6.4.3.3 of TS38.101-2, where the link direction is determined in the SSB based beam correspondence test, then it is considered that the UE has met both the SSB based and CSI-RS based beam correspondence requirements

4.2.2 Beam correspondence based on CSI-RS

4.2.2.1 Feasibility

RAN4 has discussed four potential methods to achieve a test condition where the UE can be expected to perform beam correspondence based on the CSI-RS signal only:

- Method 1: DUT is configured with an active BWP containing no SSB
- Method 2: SSB in wide beam and CSI-RS in fine beam from test equipment

- Method 3: SSB and CSI-RS are present, but SSB's PSD is backed-off by XdB from CSI-RS
- Method 4: Decrease SSB power until UE SSB based SS-SINR measurement reporting is ≤ [-3] dB

RAN4 has ruled out Method 1 due to incompatibility with CBW=400 MHz and the potential for the UE to switch BWPs to continue measuring SSB. RAN4 has also ruled out Method 2 due to testability concerns, since beam width characteristics are not varied by test equipment in the RF test setup.

Some companies have indicated that the CSI-RS only condition may not be typically observed a network and have requested further study to identify the deployment scenario that this test is going to verify before agreeing the requirement.

The UE RF front end architecture has to be designed with the assumption that both SSB and CSI-RS signals are present, and the UE receiver has to accommodate any PSD difference between CSI-RS and SSB so that the baseband can demodulate both signals. Thus, a test case side condition which introduces a PSD level difference between SSB and CSI-RS introduces a requirement on the receiver which may or may not be well aligned with real deployment conditions. Some companies have raised concerns that in a real network deployment, the UE performs scans of SSB to identify neighbor cells and, in the situation of a large imbalance between SSB and CSI-RS signals arriving from one cell, is likely to find a different cell where the imbalance is lower and the SSB signal strength is greater. Since RRM requirements for cell selection and reporting are based on SSB, it is not likely a large PSD imbalance between the SSB and CSI-RS signals is "typical."

On the feasibility of beam correspondence based on CSI-RS, RAN4 concluded the following:

- SSB and CSI-RS are present, but SSB's PSD is backed-off by XdB from CSI-RS
- The value of X is TBD in the range of [3 – 9] dB, and is selected to be X = 5 dB

4.2.2.2 Side conditions

The side conditions for beam correspondence based on CSI-RS are listed in Table 4.2.2.2-1 below.

Table 4.2.2.2-1: Side conditions for beam correspondence based on CSI-RS

Parameter	Value
P1 CSI-RS configuration	Not used
P2 CSI-RS configuration	Not used
P3 CSI-RS configuration	Is configured
P3 CSI-RS QCL info	qcl-TypeD to P1 CSI-RS
P3 CSI-RS repetitions per resource set	According to *maxNumberRxBeam* UE capability IE of MIMO-ParametersPerBand repetitions per resource set
P3 CSI-RS configuration repetition	on
P3 CSI-RS min SNR level	6 dB
P3 CSI-RS trigger	[Slot80(120kHz)]
Tracking CSI-RS periodicity	reuse Rel-15 60 kHz SCS: 40 slots for CSI-RS resources 1 and 2 120 kHz SCS: 80 slots for CSI-RS resources 1 and 2
NOTE 1: One company has proposed to define the P1 CSI-RS QCL info as qcl-TypeD='none' and the following P3 CSI-RS configuration: maxNumberRxBeam in UE capability IE of MIMO-ParametersPerBand repetitions per resource set QCL Type D to P1 CSI-RS	

RAN4 discussed the applicability rule for peak direction for beam correspondence based on CSI-RS with the following outcome: if a UE supports beam correspondence based on CSI-RS, then the network can expect the UE to also fulfill Rel-15 beam correspondence requirements. An additional applicability rule is needed when the UE supports both SSB based beam correspondence (see Clause 4.2.1) and CSI-RS based beam correspondence in Rel-16.

Further elaborating on NOTE 1 in Table 4.2.2.2-1, an examination of the RAN1 design and associated signaling is provided below.

In TS 38.214 and TS 38.331, CSI-RS can be configured as beam management usage with periodic and aperiodic, which are also defined as repetition on and off in TS 38.331. Where repetition is configured in CSI-RS resource set as below:

***NZP-CSI-RS-ResourceSet* information element**

```
-- ASN1START
-- TAG-NZP-CSI-RS-RESOURCESET-START
NZP-CSI-RS-ResourceSet ::=          SEQUENCE {
    nzp-CSI-ResourceSetId               NZP-CSI-RS-ResourceSetId,
    nzp-CSI-RS-Resources                SEQUENCE (SIZE (1..maxNrofNZP-CSI-RS-ResourcesPerSet)) OF NZP-CSI-RS-ResourceId,
    repetition                          ENUMERATED { on, off }                                    OPTIONAL,   -- Need S
    aperiodicTriggeringOffset           INTEGER(0..6)                                             OPTIONAL,   -- Need S
    trs-Info                            ENUMERATED {true}                                         OPTIONAL,   -- Need R
    ...
}
```

For periodic CSI-RS configuration, we copy the configuration IE as below:

***NZP-CSI-RS-Resource* information element**

```
-- ASN1START
-- TAG-NZP-CSI-RS-RESOURCE-START

NZP-CSI-RS-Resource ::=             SEQUENCE {
    nzp-CSI-RS-ResourceId               NZP-CSI-RS-ResourceId,
    resourceMapping                     CSI-RS-ResourceMapping,
    powerControlOffset                  INTEGER (-8..15),
    powerControlOffsetSS                ENUMERATED{db-3, db0, db3, db6}     OPTIONAL,   -- Need R

    scramblingID                        ScramblingId,
    periodicityAndOffset                CSI-ResourcePeriodicityAndOffset    OPTIONAL,   -- Cond PeriodicOrSemiPersistent
    qcl-InfoPeriodicCSI-RS              TCI-StateId                         OPTIONAL,   -- Cond Periodic
    ...
}
```

Conditional Presence	Explanation
Periodic	The field is optionally present, Need M, for periodic *NZP-CSI-RS-Resources* (as indicated in *CSI-ResourceConfig*). The field is absent otherwise.

For *QCL-info* configuration, it is specified as optional present, which means the gNB/TE is allowed configure this QCL-Info as 'none'.

Meanwhile, in TS 38.214, QCL configuration for *NZP-CSI-RS-ResourceSet* with higher layer parameter repetition is specified as below:

For a CSI-RS resource in a NZP-CSI-RS-ResourceSet configured with higher layer parameter repetition, the UE shall expect that a TCI-State indicates one of the following quasi co-location type(s):

- *'QCL-TypeA' with a CSI-RS resource in a NZP-CSI-RS-ResourceSet configured with higher layer parameter trs-Info and, when applicable, 'QCL-TypeD' with the same CSI-RS resource, or*
- *'QCL-TypeA' with a CSI-RS resource in a NZP-CSI-RS-ResourceSet configured with higher layer parameter trs-Info and, when applicable, 'QCL-TypeD' with a CSI-RS resource in a NZP-CSI-RS-ResourceSet configured with higher layer parameter repetition, or*
- *'QCL-TypeC' with an SS/PBCH block and, when applicable, 'QCL-TypeD' with the same SS/PBCH block.*

From TS 38.214, we can see that 'QCL-TypeD' is not always provided by gNB reflecting with the word "when applicable". Based on the above, periodic CSI-RS beam management can be configured as QCL-info='none' which is justified with RAN1/2 specification.

If a configuration is defined with periodic CSI-RS(P1 CSI-RS), which is QCL-ed with SSB for CSI-RS only test case, then from the perspective of beam management, the proposed configuration actually means UE can skip P1 CSI-RS measurement and just use the maintenance on SSB measurement as the P1 measurement result, even if there is XdB PSD difference between SSB and CSI-RS. Combining with aperiodic CSI-RS configuration (P3 CSI-RS), it actually a test case with both SSB and CSI-RS, which violates the objective in the WID.

Given these considerations, the motivation to define the side conditions as shown in Table 4.2.2.2-1 is based on the observation that configuring CSI-RS with '*qcl-TypeD = none'* in FR2 is not fully supported by the current specification. As background, in order to resolve issues that may arise when such an unexpected configuration is provided by network, it proposed in RAN1 to add default QCL assumption so that a subsequent UE behavior can be clearly defined. This, however, was not accepted by RAN1. As an outcome, even in RAN1, where CSI-RS configurations and pertinent UE behavior should be defined, there was no clear assumption on default QCL and subsequent UE behavior when *qcl-TypeD* of periodic CSI-RS is absent. Therefore, all test cases requiring periodic CSI-RS should avoid configuring *qcl-typeD = 'none'*.

There may also be technical implementation issues which can be caused by P1 CSI-RS configuration with *qcl-typeD = 'none'*. An initial UE Rx beam for P1 CSI-RS would not be optimized because UE cannot use the Rx beam obtained from SSB, which makes UE consume more time and energy to train its Rx beam based on P1 CSI-RS.

If there is no explicit QCL relation between SSB and P1 CSI-RS, UE would have to conduct two independent beam managements which may end up with conflict with each other. When P1 CSI-RS based beam tracking fails, UE cannot fallback to SSB-based Rx beam without going through RLF.

4.3 Void

4.4 FR2 UE requirements for non-contiguous intra-DL CA for Frequency separation classes larger than 1400 MHz

4.4.1 General

Enhanced DL CA aggregated BW is gated by:

- DL data pipe size in the digital domain
- Signal-handling bandwidth of the 'front end', which include RF electronics, ADCs, filters, etc. This parameter is identical to frequency separation, which is defined as the frequency span between the lower edge of the lowest component carrier and the upper edge of the highest component carrier that a UE can support simultaneously.

DL data pipe size enhancement is left to UE implementation. UE frequency separation enhancement is addressed in the UE architecture study in the next clause. The following assumptions apply:

- The UE's UL electronics (frequency separation ability) and data handling capacity ('data pipe') are left untouched while the DL CA capability is enhanced
- The UE's DL CA frequency spectrum coverage, i.e the band where a UE can support placing DL CCs is contiguous. This assumption does not mean DL CA must also be contiguous.
- All DL CCs have the same AoA

The UE can convey sufficient information about its RF CA capabilities to the network by signaling the following three aspects:

- Support for specific band combinations
- The frequency separation class
- A restriction on the allocation of DL carriers relative to the UL carriers

Based on this information, the network can configure the UE with CCs from the set of UE supported combinations and according to the applicable restrictions. We can envision the following potential allocation cases.

4.4.2 UE Architecture Choices

4.4.2.1 Single receive chain with expanded capability

The receiver design comprises a single chain with enhanced capability relative to rel. 15.

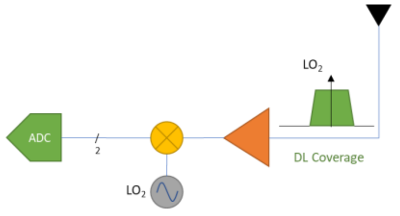


Figure 4.4.2.1-1: Single enhanced receiver to support wider frequency separation

The UL architecture in a UE with independent T/R LOs allows UL coverage to match DL coverage with retuning of TxLO. In the topology with common LOs, the enhanced DL coverage will extend past the UL coverage equally on both sides, unless the UL coverage is enhanced as well.

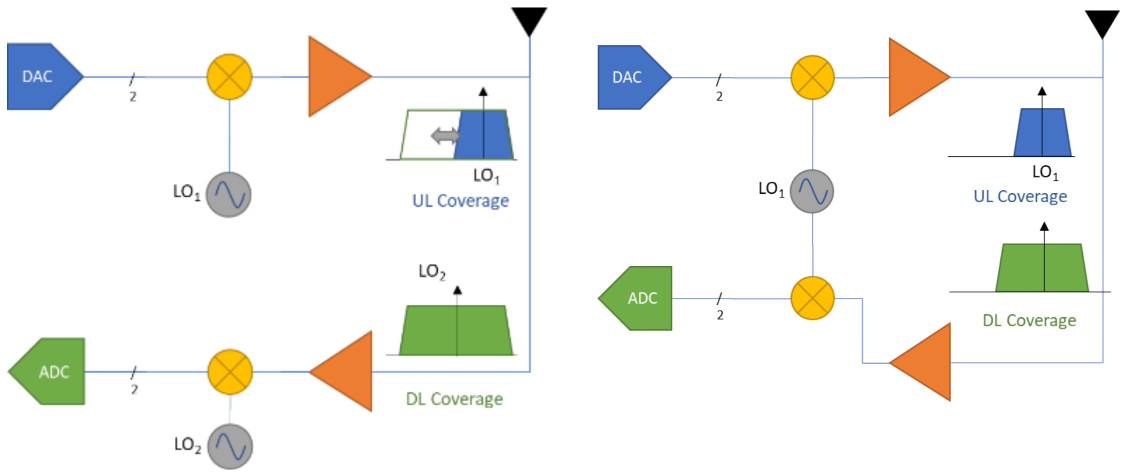


Figure 4.4.2.1-2: UL options for UE with single enhanced receiver chain

4.4.2.2 Multiple parallel receive chains

This implementation arranges multiple receiver chains to work in parallel to deliver CA BW enhancement.

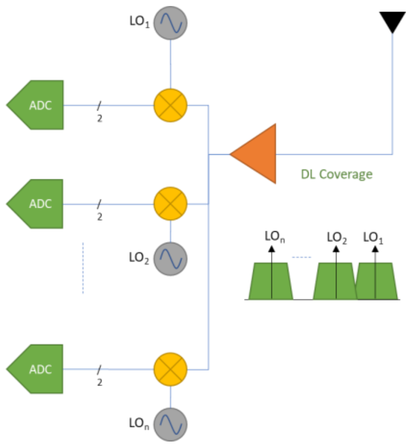


Figure 4.4.2.2-1: Multiple receiver chains to support wider frequency separation

For UEs with independent Rx and Tx LOs, the UE's UL coverage can be made to match it with retuning of TxLO. For UEs that utilize a common LO, the UL coverage must be closely related to DL coverage of one of the receivers.

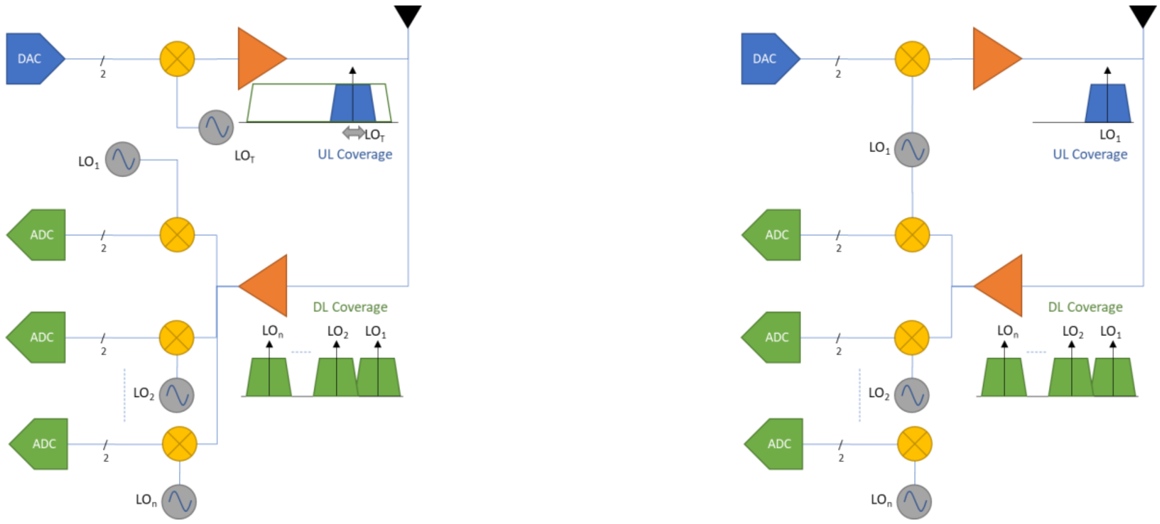


Figure 4.4.2.2-2: UL options for UE with multiple receiver chains

4.4.2.3 UE architecture summary

The UE topologies above exhibit differing UL and DL coverage, summarized in table 4.4.2.3-1.

Table 4.4.2.3-1: UL and DL coverage comparison for UEs

	UL Coverage in Relation to enhanced DL coverage type	
	Independent R/T LOs	**Common R/T LOs**
Single Enhanced receiver	Matches DL coverage	DL coverage extends past UL coverage equally on both sides
Multiple Rel. 15 receivers	Matches DL coverage	DL coverage extends past UL coverage on one side. Additional DL-only spectrum is configurable to be on higher-frequency side or lower-frequency side of UL spectrum.

4.4.3 Feature Definition

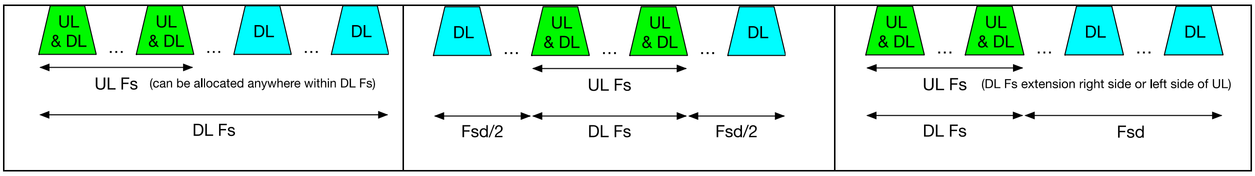
For Rel-16, the DL intra-band CA BW enhancement feature is the definition of UE capability to support DL-only coverage spectrum. This enhancement is in addition to the common UL+DL coverage spectrum of UE carried over from Rel-15.

4.4.4 UE DL-only spectrum extension cases

The assumption for the DL-only spectrum extension cases assumes that DL Fs $\geq$ 1400 MHz as an enhancement over Rel-15 UE capability. Based on this assumption the network should be constrained by two factors:

- Frequency separation class for UL and DL
- UL coverage spectrum contained within the DL coverage spectrum

Case 1: No restriction	Case 2: Symmetric extension	Case 3: One-sided extension



In Case 1 the UE supports different UL & DL coverage spectrum with no restriction and represents the most flexible frequency separation class enhancement in Rel-16. As illustrated in Case 1 the IF bandwidth of the UL and DL can be as wide as 1400 MHz for the UL and 2400 MHz for the DL. The UE implementation in this case may need a dedicated UL LO which increases complexity.

In Case 2 the UE supports symmetric extension of bidirectional coverage spectrum for DL only. These UEs need to further restrict the allocation of DL carriers such that the UL coverage spectrum is centered within the DL coverage spectrum. The UE implementation in this case may reduce the RF architecture complexity by sharing the LO between UL and DL, but it may increase the network's difficulty in exploiting available DL spectrum in the general case.

In Case 3 the UE supports one-sided extension of bidirectional coverage spectrum for DL only. The UE implementation in this case provides a tradeoff between full flexibility/high complexity in case 1 and high restrictive allocation/large DL captured spectrum in case 2.

4.4.4.1 Frequency separation classes for DL-only spectrum

For Rel-16, extend the frequency separation class definition to include the following values for frequency separation 'Fs': {800, 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400} MHz, where Fs values larger 1400 MHz apply to downlink frequency separation only. The DL-only frequency spectrum is the width of UE frequency spectrum available to network to configure DL CCs only, and it extends on one-side of the bidirectional spectrum in contiguous manner with no frequency gap between the two.. The frequency separation classes for DL only spectrum are specified in Table 4.4.2-1, which indicates the maximum DL-only frequency separation span of DL CCs that UE can support per band. The frequency separation class for DL-only spectrum (Fsd) can be equal but not larger than the frequency separation (DL Fs). The combined downlink spectrum (DL Fs + Fsd) cannot exceed 2400 MHz, A UE may configure DL-only spectrum only if the combined downlink spectrum (DL Fs + Fsd) exceeds 1400 MHz.

Table 4.4.2-1: Frequency separation classes for DL-only spectrum

Frequency separation class	Max. DL-only Frequency separation (Fsd)
I	200 MHz
II	400 MHz
III	- 600 MHz
IV	800 MHz
V	1000 MHz
VI	1200 MHz

4.5 Void

4.6 FR2 UE requirements for non-contiguous intra-band UL CA

4.6.1 Emissions requirements for non-contiguous UL CA

The MPR requirements for intra-band non-contiguous UL CA operation are governed by the following requirements, captured as TPs to the respective clauses in TS38.101-2 v16.0.0.

< start of changes intended for TS38.101-2 >

6.4A.2.0 General

For intra-band contiguous and non-contiguous carrier aggregation, the requirements in clauses 6.4A.2.1, 6.4A.2.2, and 6.4A.2.3.

All the parameters defined in clause 6.4A.2 are defined using the measurement methodology specified in Annex F.

All the requirements in 6.4A.2 are defined as directional requirement. The requirements are verified in beam locked mode on beam peak direction, with both UL polarizations active.

6.4A.2.1 Error Vector magnitude

The requirements in this clause apply to UEs of all power classes. For intra-band contiguous and non-contiguous carrier aggregation, the Error Vector Magnitude requirement of clause 6.4.2.2 is defined for each component carrier. Requirements only apply with PRB allocation in one of the component carriers. Similar transmitter impairment removal procedures are applied for CA waveform before EVM calculation as is specified for non-CA waveform.

6.4A.2.2 Carrier leakage

6.4A.2.2.1 General

Carrier leakage is an additive sinusoid waveform. The carrier leakage requirement is defined for each component carrier and is measured on the component carrier with PRBs allocated. The measurement interval is one slot in the time domain.

Note: When UE has DL configured for non-contiguous CA, carrier leakage may land outside the spectrum occupied by all configured UL and DL CC.

The relative carrier leakage power is a power ratio of the additive sinusoid waveform and the modulated waveform. The requirement is verified with the test metric of Carrier Leakage (Link=TX beam peak direction, Meas=Link angle).

6.4A.2.2.2 Carrier leakage for power class 1

When carrier leakage is contained inside the spectrum occupied by all configured UL and DL CCs, the relative carrier leakage power shall not exceed the values specified in Table 6.4A.2.2.2-1 for power class 1 UEs.

Table 6.4A.2.2.2-1: Minimum requirements for relative carrier leakage for power class 1

Parameters	Relative Limit (dBc)
EIRP > 17 dBm	-25
4 dBm ≤ EIRP ≤ 17 dBm	-20

6.4A.2.2.3 Carrier leakage for power class 2

When carrier leakage is contained inside the spectrum occupied by all configured UL and DL CCs, the relative carrier leakage power shall not exceed the values specified in Table 6.4A.2.2.3-1 for power class 2.

Table 6.4A.2.2.3-1: Minimum requirements for relative carrier leakage power class 2

Parameters	Relative limit (dBc)
EIRP > 6 dBm	-25
-13 dBm ≤ EIRP ≤ 6 dBm	-20

6.4A.2.2.4 Carrier leakage for power class 3

When carrier leakage is contained inside the spectrum occupied by all configured UL and DL CCs, the relative carrier leakage power shall not exceed the values specified in Table 6.4A.2.2.4-1 for power class 3 UEs.

Table 6.4A.2.2.4-1: Minimum requirements for relative carrier leakage power class 3

Parameters	Relative limit (dBc)
Output power > 0 dBm	-25
-13 dBm ≤ Output power EIRP ≤ 0 dBm	-20

6.4A.2.2.5 Carrier leakage for power class 4

When carrier leakage is contained inside the spectrum occupied by all configured UL and DL CCs, the relative carrier leakage power shall not exceed the values specified in Table 6.4A.2.2.5-1 for power class 4 UEs.

Table 6.4A.2.2.5-1: Minimum requirements for relative carrier leakage power class 4

Parameters	Relative limit (dBc)
Output power > 11 dBm	-25
-13 dBm ≤ Output power EIRP ≤ 11 dBm	-20

6.4A.2.3 Inband emissions

6.4A.2.3.1 General

Inband emission requirement is defined over the spectrum occupied by all configured UL and DL CCs. The measurement interval is as defined in clause 6.4.2.4. The requirement is verified with the test metric of In-band emission (Link=TX beam peak direction, Meas=Link angle).

For intra-band contiguous and non-contiguous carrier aggregation, the requirements in this clause apply with all component carriers active and with one single contiguous PRB allocation in one of uplink component carriers. The inband emission is defined as the interference falling into the non-allocated resource blocks for all component carriers.

6.4A.2.3.2 Inband emissions for power class 1

The relative in-band emission shall not exceed the values specified in Table 6.4A.2.3.2-1 for power class 1 UEs.

Table 6.4A.2.3.2-1: Requirements for in-band emissions for power class 1

Parameter description	Unit	Limit (NOTE 1)		Applicable Frequencies
General	dB	$max\begin{bmatrix} -25-10\cdot\log_{10}\left(\frac{N_{RB}}{L_{CRB}}\right), \\ 20\cdot\log_{10}(EVM)-\ 5\cdot\frac{(\lvert\Delta_{RB}\rvert-1)}{L_{CRB}}, \\ -55.1dBm-P_{RB}\end{bmatrix}$		Any non-allocated RB in allocated component carrier and not allocated component carriers (NOTE 2)
IQ Image	dB	-25	Output power > 27 dBm	Image frequencies (NOTES 2, 3)
		-20	Output power ≤ 27 dBm	
Carrier leakage	dBc	-25	Output power > 17 dBm	Carrier frequency (NOTES 4, 5)
		-20	4 dBm ≤ Output power ≤ 17 dBm	

NOTE 1: An in-band emissions combined limit is evaluated in each non-allocated RB. For each such RB, the minimum requirement is calculated as the higher of (P_{RB} - 25 dB) and the power sum of all limit values (General, IQ Image or Carrier leakage) that apply. P_{RB} is defined in NOTE 9.

NOTE 2: The measurement bandwidth is 1 RB and the limit is expressed as a ratio of measured power in one non-allocated RB to the measured average power per allocated RB, where the averaging is done across all allocated RBs. For Pi/2 BPSK with Spectrum Shaping, the limit is expressed as a ratio of measured power in one non-allocated RB to the measured power in the allocated RB with highest PSD.

NOTE 3: Image frequencies for UL CA are specified in relation to either UL or DL carrier frequency.

NOTE 4: The measurement bandwidth is 1 RB and the limit is expressed as a ratio of measured power in one non-allocated RB to the measured total power in all allocated RBs.

NOTE 5: The applicable frequencies for this limit are those that are enclosed in the RBs containing the DC frequency, or in the two RBs immediately adjacent to the DC frequency but excluding any allocated RB.

NOTE 6: L_{CRB} is the Transmission Bandwidth for kth allocated component carrier (see Figure 5.3.3-1).

NOTE 7: EVM s the limit for the modulation format used in the allocated RBs.

NOTE 8: Δ_{RB} is the starting frequency offset between the allocated RB and the measured non-allocated RB (e.g. Δ_{RB} = 1 or Δ_{RB} = -1 for the first adjacent RB outside of the allocated bandwidth), and may take non-integer values when the carrier spacing between the CCs is not a multiple of RB.

NOTE 9: P_{RB} is the transmitted power per allocated RB, measured in dBm.

NOTE 10: All powers are EIRP in beam peak direction.

6.4A.2.3.3 Inband emissions for power class 2

The relative in-band emission shall not exceed the values specified in Table 6.4A.2.3.3-1 for power class 2.

Table 6.4A.2.3.3-1: Requirements for in-band emissions for power class 2

Parameter description	Unit	Limit (NOTE 1)		Applicable Frequencies
General	dB	$max\begin{bmatrix} -25-10\cdot\log_{10}\left(\frac{N_{RB}}{L_{CRB}}\right), \\ 20\cdot\log_{10}(\text{EVM})-\ 5\cdot\frac{(\lvert\Delta_{RB}\rvert-1)}{L_{CRB}}, \\ -55.1dBm-P_{RB} \end{bmatrix}$		Any non-allocated RB in allocated component carrier and not allocated component carriers (NOTE 2)
IQ Image	dB	-25	Output power > 16 dBm	Image frequencies (NOTES 2, 3)
		-20	Output power ≤ 16 dBm	
Carrier leakage	dBc	-25	Output power > 6 dBm	Carrier frequency (NOTES 4, 5)
		-20	-13 dBm ≤ Output power ≤ 6 dBm	

NOTE 1: An in-band emissions combined limit is evaluated in each non-allocated RB. For each such RB, the minimum requirement is calculated as the higher of (P_{RB} - 25 dB) and the power sum of all limit values (General, IQ Image or Carrier leakage) that apply. P_{RB} is defined in NOTE 9.
NOTE 2: The measurement bandwidth is 1 RB and the limit is expressed as a ratio of measured power in one non-allocated RB to the measured average power per allocated RB, where the averaging is done across all allocated RBs. For Pi/2 BPSK with Spectrum Shaping, the limit is expressed as a ratio of measured power in one non-allocated RB to the measured power in the allocated RB with highest PSD.
NOTE 3: Image frequencies for UL CA are specified in relation to either UL or DL carrier frequency.
NOTE 4: The measurement bandwidth is 1 RB and the limit is expressed as a ratio of measured power in one non-allocated RB to the measured total power in all allocated RBs.
NOTE 5: The applicable frequencies for this limit are those that are enclosed in the RBs containing the DC frequency, or in the two RBs immediately adjacent to the DC frequency but excluding any allocated RB.
NOTE 6: L_{CRB} is the Transmission Bandwidth for kth allocated component carrier (see Figure 5.3.3-1).
NOTE 7: EVM s the limit for the modulation format used in the allocated RBs.
NOTE 8: Δ_{RB} is the starting frequency offset between the allocated RB and the measured non-allocated RB (e.g. Δ_{RB} = 1 or Δ_{RB} = -1 for the first adjacent RB outside of the allocated bandwidth), and may take non-integer values when the carrier spacing between the CCs is not a multiple of RB.
NOTE 9: P_{RB} is the transmitted power per allocated RB, measured in dBm.
NOTE 10: All powers are EIRP in beam peak direction.

6.4A.2.3.4 Inband emissions for power class 3

The relative in-band emission shall not exceed the values specified in Table 6.4A.2.3.4-1 for power class 3 UEs.

Table 6.4A.2.3.4-1: Requirements for in-band emissions for power class 3

Parameter description	Unit	Limit (NOTE 1)		Applicable Frequencies
General	dB	$max\begin{bmatrix} -25 - 10 \cdot \log_{10}\left(\frac{N_{RB}}{L_{CRB}}\right), \\ 20 \cdot \log_{10}(\mathrm{EVM}) - 5 \cdot \frac{(\lvert\Delta_{RB}\rvert - 1)}{L_{CRB}}, \\ -55.1dBm - P_{RB} \end{bmatrix}$		Any non-allocated RB in allocated component carrier and not allocated component carriers (NOTE 2)
IQ Image	dB	-25	Output power > 10 dBm	Image frequencies (NOTES 2, 3)
		-20	Output power ≤ 10 dBm	
Carrier leakage	dBc	-25	Output power > 0 dBm	Carrier frequency (NOTES 4, 5)
		-20	-13 dBm ≤ Output power ≤ 0 dBm	

NOTE 1: An in-band emissions combined limit is evaluated in each non-allocated RB. For each such RB, the minimum requirement is calculated as the higher of (P_{RB} - 25 dB) and the power sum of all limit values (General, IQ Image or Carrier leakage) that apply. P_{RB} is defined in NOTE 9.
NOTE 2: The measurement bandwidth is 1 RB and the limit is expressed as a ratio of measured power in one non-allocated RB to the measured average power per allocated RB, where the averaging is done across all allocated RBs. For Pi/2 BPSK with Spectrum Shaping, the limit is expressed as a ratio of measured power in one non-allocated RB to the measured power in the allocated RB with highest PSD.
NOTE 3: Image frequencies for UL CA are specified in relation to either UL or DL carrier frequency.
NOTE 4: The measurement bandwidth is 1 RB and the limit is expressed as a ratio of measured power in one non-allocated RB to the measured total power in all allocated RBs.
NOTE 5: The applicable frequencies for this limit are those that are enclosed in the RBs containing the DC frequency, or in the two RBs immediately adjacent to the DC frequency but excluding any allocated RB.
NOTE 6: L_{CRB} is the Transmission Bandwidth for kth allocated component carrier (see Figure 5.3.3-1).
NOTE 7: EVM s the limit for the modulation format used in the allocated RBs.
NOTE 8: Δ_{RB} is the starting frequency offset between the allocated RB and the measured non-allocated RB (e.g. Δ_{RB} = 1 or Δ_{RB} = -1 for the first adjacent RB outside of the allocated bandwidth), and may take non-integer values when the carrier spacing between the CCs is not a multiple of RB.
NOTE 9: P_{RB} is the transmitted power per allocated RB, measured in dBm.
NOTE 10: All powers are EIRP in beam peak direction.

6.4A.2.3.5 Inband emissions for power class 4

The relative in-band emission shall not exceed the values specified in Table 6.4A.2.3.5-1 for power class 4 UEs.

Table 6.4A.2.3.5-1: Requirements for in-band emissions for power class 4

Parameter description	Unit	Limit (NOTE 1)		Applicable Frequencies
General	dB	$max\begin{bmatrix} -25-10\cdot\log_{10}\left(\frac{N_{RB}}{L_{CRB}}\right), \\ 20\cdot\log_{10}(EVM)-\ 5\cdot\frac{(\lvert\Delta_{RB}\rvert-1)}{L_{CRB}}, \\ -55.1dBm-P_{RB} \end{bmatrix}$		Any non-allocated RB in allocated component carrier and not allocated component carriers (NOTE 2)
IQ Image	dB	-25	Output power > 21 dBm	Image frequencies (NOTES 2, 3)
		-20	Output power ≤ 21 dBm	
Carrier leakage	dBc	-25	Output power > 11 dBm	Carrier frequency (NOTES 4, 5)
		-20	-13 dBm ≤ Output power ≤ 11 dBm	

NOTE 1: An in-band emissions combined limit is evaluated in each non-allocated RB. For each such RB, the minimum requirement is calculated as the higher of (P_{RB} - 25 dB) and the power sum of all limit values (General, IQ Image or Carrier leakage) that apply. P_{RB} is defined in NOTE 9.
NOTE 2: The measurement bandwidth is 1 RB and the limit is expressed as a ratio of measured power in one non-allocated RB to the measured average power per allocated RB, where the averaging is done across all allocated RBs. For pi/2 BPSK with Spectrum Shaping, the limit is expressed as a ratio of measured power in one non-allocated RB to the measured power in the allocated RB with highest PSD.
NOTE 3: Image frequencies for UL CA are specified in relation to either UL or DL carrier frequency.
NOTE 4: The measurement bandwidth is 1 RB and the limit is expressed as a ratio of measured power in one non-allocated RB to the measured total power in all allocated RBs.
NOTE 5: The applicable frequencies for this limit are those that are enclosed in the RBs containing the DC frequency, or in the two RBs immediately adjacent to the DC frequency but excluding any allocated RB.
NOTE 6: L_{CRB} is the Transmission Bandwidth for kth allocated component carrier (see Figure 5.3.3-1).
NOTE 7: EVM s the limit for the modulation format used in the allocated RBs.
NOTE 8: Δ_{RB} is the starting frequency offset between the allocated RB and the measured non-allocated RB (e.g. Δ_{RB} = 1 or Δ_{RB} = -1 for the first adjacent RB outside of the allocated bandwidth), and may take non-integer values when the carrier spacing between the CCs is not a multiple of RB.
NOTE 9: P_{RB} is the transmitted power per allocated RB, measured in dBm.
NOTE 10: All powers are EIRP in beam peak direction.

< end of changes >

< start of changes intended for TS38.101-2 >

6.5A Output RF spectrum emissions for CA

6.5A.1 Occupied bandwidth for CA

For intra-band contiguous carrier aggregation, the occupied bandwidth is a measure of the bandwidth containing 99 % of the total integrated power of the transmitted spectrum. The occupied bandwidth for CA shall be less than the aggregated channel bandwidth defined in clause 5.3A.

For intra-band non-contiguous carrier aggregation, the OBW requirement is met when the ratio of the transmitted power in all sub-blocks of the uplink CA configuration to the total integrated power of the transmitted spectrum is greater than 99%.

The occupied bandwidth for CA is defined as a directional requirement. The requirement is verified in beam locked mode on beam peak direction.

6.5A.2 Out of band emissions

6.5A.2.1 Spectrum emission mask for CA

The requirement specified in this clause shall apply if the UE has at least one of UL or DL configured for CA or if the UE is configured for single CC operation with different channel bandwidths in UL and DL carriers.

For intra-band contiguous carrier aggregation, the spectrum emission mask of the UE applies to frequencies (Δf_{OOB}) starting from the ± edge of the aggregated channel bandwidth (Table 5.3A.5-1). For any bandwidth class defined in Table 5.3A.5-1, the UE emission shall not exceed the levels specified in Table 6.5A.2.1-1. The requirement is verified in beam locked mode with the test metric of TRP (Link=TX beam peak direction).

Table 6.5A.2.1-1: General NR spectrum emission mask for intra-band contiguous CA in frequency range 2

Δf_{OOB} (MHz)	Any carrier aggregation bandwidth class	Measurement bandwidth
± 0-0.1*$BW_{Channel\_CA}$	-5	1 MHz
± 0.1*$BW_{Channel\_CA}$ - 2*$BW_{Channel\_CA}$	-13	1 MHz
NOTE 1: If carrier leakage or I/Q image lands inside the spectrum occupied by the configured UL and DL CCs, exception to the general spectrum emission mask limit applies. For carrier leakage the requirements specified in clause 6.4A.2.2 shall apply. For I/Q image the requirements specified in clause 6.4A.2.3 shall apply.		

For intra-band non-contiguous carrier aggregation, the spectrum emission mask requirement is defined as a composite spectrum emissions mask. Composite spectrum emission mask applies to frequencies up to ± Δf_{OOB} starting from the edge of each sub-block. Composite spectrum emission mask is defined as follows:

a) Composite spectrum emission mask is a combination of individual spectrum emissions masks defined for each sub-block. If for some frequency, spectrum emission masks from multiple sub-blocks overlap, the spectrum emission mask allowing the highest power spectral density applies for that frequency

b) In case a sub-block comprises of multiple component carriers spectrum emissions mask is defined in clause 6.5A.2.1 or in case of a single component carrier, the sub-block spectrum emission mask is defined in clause 6.5.2.1

c) If for some frequency the spectrum emission mask of one sub-block overlaps another sub-block, the emission mask does not apply for that frequency.

d) If carrier leakage or I/Q image lands inside the spectrum occupied by the configured UL and DL CCs, exception to the general spectrum emission mask limit applies. For carrier leakage the requirements specified in clause 6.4A.2.2 shall apply. For I/Q image the requirements specified in clause 6.4A.2.3 shall apply.

6.5A.2.3 Adjacent channel leakage ratio for CA

For intra-band contiguous carrier aggregation, the carrier aggregation NR adjacent channel leakage power ratio (CA NR_{ACLR}) is the ratio of the filtered mean power centred on the aggregated channel bandwidth to the filtered mean power centred on an adjacent aggregated channel bandwidth at nominal channel spacing. The assigned aggregated channel bandwidth power and adjacent aggregated channel bandwidth power are measured with rectangular filters with measurement bandwidths specified in 6.5A.2.3-1. If the measured adjacent channel power is greater than -35 dBm then the NR_{ACLR} shall be higher than the value specified in Table 6.5A.2.3-1.

Table 6.5A.2.3-1: General requirements for CA NR_{ACLR}

	CA bandwidth class / CA NR_{ACLR} / Measurement bandwidth
	Any CA bandwidth class
CA NR_{ACLR} for band n257, n258, n261	17 dB
CA NR_{ACLR} for band n260	16 dB
NR channel measurement bandwidth[1]	$BW_{Channel\_CA}$ – $GB_{Channel(1)}$ - $GB_{Channel(2)}$
NOTE 1: The $GB_{Channel(i)}$ is the minimum guard band of the component carriers at the lower edge $F_{edge,\ low}$ and the upper edge $F_{edge,high}$ of the sub-block respectively.	

For intra-band non-contiguous carrier aggregation, adjacent channel leakage power ratio is the ratio of the sum of the filtered mean powers centred on each sub-block bandwidth to the filtered mean power centred on an adjacent sub-block frequency at nominal spacing equal to the sub-block bandwidth. No requirement applies in the gap between neighbouring sub-blocks if the frequency span between the lowest edge of the upper sub-block and the highest edge of the lower sub-block is smaller than the bandwidth of either sub-block.

6.5A.3 Spurious emissions for CA

This clause specifies the spurious emission requirements for carrier aggregation.

NOTE: For measurement conditions at the edge of each frequency range, the lowest frequency of the measurement position in each frequency range should be set at the lowest boundary of the frequency range plus MBW/2. The highest frequency of the measurement position in each frequency range should be set at the highest boundary of the frequency range minus MBW/2. MBW denotes the measurement bandwidth defined for the protected band.

For intra-band contiguous carrier aggregation, the spurious emission limits apply for the frequency ranges that are more than F_{OOB} (MHz) from the edge of the aggregated channel bandwidth, where F_{OOB} is defined as the twice the aggregated channel bandwidth. For frequencies Δf_{OOB} greater than F_{OOB}, the spurious emission requirements in Table 6.5.3-2 are applicable. If carrier leakage or I/Q image lands inside the spectrum occupied by the configured UL and DL CCs, exception to the spurious emissions requirement applies. For carrier leakage the requirements specified in clause 6.4A.2.2 shall apply. For I/Q image the requirements specified in clause 6.4A.2.3 shall apply.

For intra-band non-contiguous carrier aggregation, the spurious emission requirement is defined as a composite spurious emission requirement which is a combination of individual spurious emission requirements defined for each sub-block. The limits in Table 6.5.3-2 apply for the frequency ranges that are more than F_{OOB} (MHz) from the edge of each sub-block but excludes frequency ranges that coincide with another sub-block. No spurious emission limit applies in the gap between neighbouring sub-blocks if the frequency span between the lowest edge of the upper sub-block and the highest edge of the lower sub-block is smaller than $F_{OOB\_L} + F_{OOB\_H}$. If carrier leakage or I/Q image lands inside the spectrum occupied by the configured UL and DL CCs, exception to the spurious emissions requirement applies. For carrier leakage the requirements specified in clause 6.4A.2.2 shall apply. For I/Q image the requirements specified in clause 6.4A.2.3 shall apply.

6.5A.3.1 Spurious emission band UE co-existence for CA

This clause specifies the requirements for the specified carrier aggregation configurations for coexistence with protected bands.

NOTE: For measurement conditions at the edge of each frequency range, the lowest frequency of the measurement position in each frequency range should be set at the lowest boundary of the frequency range plus MBW/2. The highest frequency of the measurement position in each frequency range should be set at the highest boundary of the frequency range minus MBW/2. MBW denotes the measurement bandwidth defined for the protected band.

For intra-band contiguous and non-contiguous carrier aggregation, the requirements in Table 6.5A.3-1 apply.

Table 6.5A.3-1: Requirements for CA

UL CA for any CA bandwidth class	Spurious emission						
	Protected band / frequency range	**Frequency range (MHz)**			**Maximum Level (dBm)**	**MBW (MHz)**	**NOTE**
CA_n257	NR Band n260	F_{DL_low}	-	F_{DL_high}	-2	100	
	Frequency range	23600	-	24000	-8	200	2
	Frequency range	57000	-	66000	2	100	
CA_n258	Frequency range	23600	-	24000	-8	200	2
	Frequency range	57000	-	66000	2	100	
CA_n260	NR Band 257	F_{DL_low}	-	F_{DL_high}	-5	100	
	NR Band 261	F_{DL_low}	-	F_{DL_high}	-5	100	
	Frequency range	23600	-	24000	-8	200	2
	Frequency range	57000	-	66000	2	100	
CA_n261	NR Band 260	F_{DL_low}	-	F_{DL_high}	-2	100	
	Frequency range	23600	-	24000	-8	200	2
	Frequency range	57000	-	66000	2	100	
NOTE 1: F_{DL_low} and F_{DL_high} refer to each NR frequency band specified in Table 5.2-1 NOTE 2: The protection of frequency range 23600-2400MHz is meant for protection of satellite passive services.							

6.5A.3.2 Additional spurious emissions

6.5A.3.2.1 General

These requirements are specified in terms of an additional spectrum emission requirement. Additional spurious emission requirements are signalled by the network to indicate that the UE shall meet an additional requirement for a specific deployment scenario as part of the cell handover/broadcast message.

6.5A.3.2.2 Additional spurious emission requirements for CA_NS_201

When "CA_NS_201" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5.3.2.2-1. This requirement also applies for the frequency ranges that are less than F_{OOB} (MHz) as defined in clause 6.5A.3.

6.5A.3.2.3 Additional spurious emission requirements for CA_NS_202

When "CA_NS_202" is indicated in the cell, the power of any UE emission shall not exceed the levels specified in Table 6.5.3.2.3-1.

4.7 FR2 UE requirements for inter-band DL CA

4.7.1 General

For inter-band downlink carrier aggregation of FR2 bands, the independent beam management (IBM) between the band pairs is only introduced in Rel-16. In IBM, Network can assume that IBM UE supports both co-located and non-co-located deployments. The UE shall meet the EIS spherical coverage requirement simultaneously among bands to support the common coverage, required for co-located deployment; further, the receive power imbalance is assumed as specified below in order to compensate the path loss difference among bands.

4.7.2 Reference sensitivity, EIS spherical coverage, and other receiver requirements

< start of proposed new clause for TS38.101-2 >

7.3A.2.3 Inter-band CA

The inter-band requirement applies for all active component carriers. The throughput for each component carrier shall be ≥ 95 % of the maximum throughput of the reference measurement channels as specified in Annexes A.2.3.2 and A.3.3.2 (with one sided dynamic OCNG Pattern OP.1 TDD for the DL-signal as described in Annex A.5.2.1) with peak reference sensitivity for each carrier specified in section 7.3.2, and relaxation $\Delta R_{IB,P,n}$ applied to peak reference sensitivity requirement. $\Delta R_{IB,P,n}$ is specified in Table 7.3A.2.3-1. [The requirement on each component carrier shall be met when the power in the component carrier in the other band is set to its EIS spherical coverage requirement for inter-band CA specified in sub-clause 7.3A.3.3].

For the combination of intra-band and inter-band carrier aggregation, the intra-band CA relaxation, ΔR_{IB}, is also applied according to the clause 7.3A.2.1 and 7.3A.2.2.

Table 7.3A.2.3-1: ΔR_{IB} reference sensitivity relaxation for inter-band CA for power class 3

NR CA bands	NR band	$\Delta R_{IB,P,n}$ (dB)
CA_n260-n261	n260	[3.5]
	n261	[3.5]

7.3A.3 EIS spherical coverage for DL CA

7.3A.3.3 EIS spherical coverage for inter-band CA

The inter-band CA requirement applies per operating band, for all active component carriers with UL assigned to one band and one DL component carrier per band. The requirement on each component carrier shall be met when the power in the component carrier in the other band is set to its EIS spherical coverage requirement for inter-band CA specified in this sub-clause.

The inter-band CA spherical coverage requirement will be satisfied if the intersection set of spherical coverage areas exceeds the requirement. Intersection set of spherical coverage areas is defined as a fraction of area of full sphere measured around the UE where both bands meet their defined individual EIS spherical coverage requirements.

The requirement is verified with the test metric of EIS (Link=Beam peak search grids, Meas=Link angle).

The reference measurement channels and throughput criterion shall be as specified in clause 7.3A.2.3. The requirement shall be met for an uplink transmission using QPSK DFT-s-OFDM waveforms and for uplink transmission bandwidth less than or equal to that specified in clause 7.3.2.

Unless otherwise specified, the minimum requirements for reference sensitivity shall be verified with the network signalling value NS_200 (Table 6.2.3.1-1) configured.

The required spherical coverage EIS for each band is given in clause 7.3.4 and modified by $\Delta R_{IB,S,n}$. The value of $\Delta R_{IB,S,n}$ is defined in Table 7.3A.3.3-1.

Table 7.3A.3.3-1: $\Delta R_{IB,S,n}$ EIS spherical coverage requirement relaxation for inter-band CA for power class 3

NR CA bands	NR band	$\Delta R_{IB,S,n}$ (dB)
CA_n260-n261	n260	[3.5]
	n261	[3.5]

< Next Changes >

7.4A.3 Maximum input level for Inter-band CA

For inter-band carrier aggregation with one component carrier per operating band and the uplink assigned to one NR band, the maximum input level is defined with the uplink active on the band other than the band whose downlink is being tested. The UE shall meet the requirements specified in clause 7.4 for each component carrier while all downlink carriers are active.

7.5A.3 Adjacent channel selectivity for Inter-band CA

For inter-band carrier aggregation with one component carrier per operating band and the uplink assigned to one NR band, the adjacent channel requirements are defined with the uplink active on the band other than the band whose downlink is being tested. The UE shall meet the requirements specified in clause 7.5 for each component carrier while all downlink carriers are active.

< Next Changes >

7.6A.2.3 In-band blocking for Inter-band non-contiguous CA

For inter-band carrier aggregation with one component carrier per operating band and the uplink assigned to one NR band, the in-band blocking requirements are defined with the uplink active on the band other than the band whose downlink is being tested. The UE shall meet the requirements specified in clause 7.6.2 for each component carrier while all downlink carriers are active.

< End of proposed new clause for TS38.101-2 >

4.8 Void

4.9 Void

4.10 FR2 UE MBR Enhancement

The Rel-15 FR2 RF specification [2] defines the multi-band requirement framework as a table (Table 6.2.1.3-4) of total relaxations, $\sum MB_P$ and $\sum MB_S$, allowed for all possible combinations of the four bands which were introduced in Rel-15 (i.e. bands n257, n258, n260, n261). The definition of the multi-band framework in Rel-15 proceeded in two steps: collection of performance data comparing single band and multi-band performance and the definition of $\sum MB_P$, $\Delta MB_{P,n}$, $\sum MB_S$, $\Delta MB_{S,n}$ terms. The eventual agreement on MBR was a compromise involving many companies which also included an agreement on the beam correspondence requirement in Rel-15. The enhancement of MBR in Rel-16 is motivated by the following observations:

- As new FR2 bands are introduced in releases following Rel-15, the framework's scalability can become a concern, since the relaxation factors need to be recalculated for all bands each time a new band is defined.

- MBR value has an impact on testability in RAN5. The maximum MBR value decides how much relaxation to be required for each test case. In MOP (EIRP) analysis, MBR = 1.7 dB (value for UEs supporting n257, n258, n260, n261) is selected as maximum MBR. This means analysis of testability issue needs to be conducted again if maximum MBR is updated in the future. If maximum MBR becomes larger, RAN5 will need to re-evaluate testability issues per test case. Hence RAN5 cannot and does not intend to keep re-opening testability topics considered complete.

These concerns have been addressed by enhancing the MBR framework in the following way:

- In the scope of Rel-15:

  - RAN4 introduces a maximum cap to the per-band relaxation factors, such that $\Delta MB_{P,n} \leq 0.75$ dB and $\Delta MB_{S,n} \leq 0.75$ dB

- This MBR framework is applicable to the bands defined in Rel-15 (i.e. n257, n258, n260, n261) and is defined only in the Rel-15 version of TS38.101-2

- In the scope of Rel-16 and beyond:

  - RAN4 defines fixed per-band relaxation factors, $\Delta MB_{P,n}$ and $\Delta MB_{S,n}$, directly in the specification

  - This MBR framework applies to a Rel-16+ UE supporting any FR2 band(s)

  - This MBR framework also applies to a Rel-15 UE if it supports any FR2 band which is introduced in Rel-16+ (e.g. band n259)

Table 4.10-1 below captures the enhanced MBR framework in Rel-15.

Table 4.10-1: UE multi-band relaxation factors for power class 3 (Rel-15)

Supported bands	$\sum MB_P$ (dB)	$\sum MB_S$ (dB)
n257, n258	≤ 1.3	≤ 1.25
n257, n260 n258, n260	≤ 1.0	≤ 0.75[3]
n257, n261	0.0	0.0
n258, n261	≤ 1.0	≤ 1.25
n260, n261	0.0	≤ 0.75[2]
n257, n258, n260 n257, n258, n261 n257, n258, n260, n261	≤ 1.7	≤ 1.75[3]
n257, n260, n261	≤ 0.5	≤ 1.25[3]
n258, n260, n261	≤ 1.5	≤ 1.25[3]
NOTE 1: The requirements in this table are applicable to UEs which support only the indicated bands NOTE 2: For supported bands n260 + n261, $\Delta MB_{S,n}$ is not applied for band n260 NOTE 3: For n260, maximum applicable $\Delta MB_{S,n}$ is 0.4 dB and $\Delta MB_{P,n}$ is 0.75 dB NOTE 4: For all bands except n260, the maximum applicable $\Delta MB_{P,n}$ and $\Delta MB_{S,n}$ is 0.75 dB		

Table 4.10-2 below captures the enhanced MBR framework in Rel-16.

Table 4.10-2: UE multi-band relaxation factors for power class 3 (Rel-16)

Band	DMBP (dB)	DMBS (dB)
n257	0.7[3]	0.7[3]
n258	0.6	0.7
n260	0.5[1]	0.4[1]
n261	0.5[2,4]	0.7[4]
Note 1: n260 peak and spherical relaxations are 0 dB for UE that exclusively supports n261+n260 Note 2: n261 peak relaxation is 0 dB for UE that exclusively supports n261+n260 Note 3: n257 peak and spherical relaxations are 0 dB for UE that exclusively supports n261+n257 Note 4: n261 peak and spherical relaxations are 0 dB for UE that exclusively supports n261+n257		

In order to specify requirements for release-indepenent features, RAN4 maintains the release independence specification [3]. A clarifying note is added to Table B.4.1-1 in [3], as shown in Table 4.10-3 below.

Table 4.10-3: Common UE RF requirements for a release independent band

Clause / Clause	Description
5.2	Operating bands
5.3	UE Channel bandwidth
5.4	Channel arrangement
6.2	Transmitter power
6.3	Output power dynamics
6.4	Transmit signal quality
6.5	Output RF spectrum emissions
6.6 of [3]	Beam correspondence
7.3	Reference sensitivity
7.4	Maximum input level
7.5	Adjacent Channel Selectivity
7.6	Blocking characteristics
7.7 of [2]	Spurious response
7.8 of [2]	Intermodulation characteristics
7.9	Spurious emissions
NOTE: A UE which supports any FR2 band introduced in release N, where N > 15, shall meet the requirements according to the FR2 UE multi-band relaxation factors defined in Table 6.2.1.3-4 of the release N version of [3] for all FR2 bands which it supports.	

Annex <A> (informative): Change history

Change history							
Date	**Meeting**	**TDoc**	**CR**	**Rev**	**Cat**	**Subject/Comment**	**New version**
2019-08	RAN4#92	R4-1908286				TR Skeleton	0.0.1
2019-08	RAN4#92	R4-1910281				TR Skeleton	0.0.2
2019-08	RAN4#92bis	R4-1913043				TP to TR38.831: Emissions Requirements for FR2 NC UL CA	0.1.0
2020-08	RAN4#95e	R4-2008486				TP to TR38.831: FR2 UE architectures for DL Intra-band CA BW Enhancement	0.2.0
2020-08	RAN4#95e	R4-2006354				TP to TR38.831: multi-band relaxation framework enhancement	0.2.0
2020-08	RAN4#96e	R4-2011737				TP to TR38.831: beam correspondence enhancement	1.0.0
2020-09	RAN#89	RP-201981				Editorial corrections	1.0.1
2020-09	RAN#89					Approved by plenary – Rel-15 spec under change control	16.0.0
2020-12	RAN#90	RP-202443	0001	1	F	CR to TR 38.831 on beam correspondence corrections	16.1.0
2020-12	RAN#90	RP-202443	0002	1	F	CR to TR 38.831 to include DL CA agreement	16.1.0