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Technical Report

**3rd Generation Partnership Project;
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Further advancements for E-UTRA;
LTE-Advanced feasibility studies in RAN WG4
(Release 9)**

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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:

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x the first digit:

1 presented to TSG for information;

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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.

1 Scope

The present document is the technical report on "LTE-Advanced Feasibility Studies in 3GPP RAN WG4".

In particular it facilitates within TSG RAN the preparation of the ITU-R submission template with the parameters which are considered as RAN4 responsibility. The ITU-R submission template and its responsibility across the WGs is captured in [3] and discussed in RAN. The ITU-R submission template has been copied in Annex A.1.

This document is intended to gather the relevant background information in order to address critical UE and BS RF requirements and draw a conclusion on the feasibility of the identified RF scenarios and parameters.

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] ITU-R recommendation SM.329: "Unwanted emissions in the spurious domain ".

[2] 3GPP TR 21.905: " Vocabulary for 3GPP Specifications".

[3] ITU-R Report M.2135, Guidelines for evaluation of radio interface technologies for IMT-Advanced, 2008-11, http://www.itu.int/publ/R-REP-M.2135-2008/en

[4] 3GPP TR 36.913: "Requirements for Evolved UTRA (E-UTRA) and Evolved UTRAN (E-UTRAN)

[5] 3GPP TR 36.814: "Further Advancements for E-UTRA, Physical Layer Aspects"

[6] 3GPP TS 36.141: "Base Station (BS) conformance testing"

[7] 3GPP TS 36.101: "User Equipment (UE) radio transmission and reception"

[8] 3GPP TS 36.104: "Base Station (BS) radio transmission and reception"

[9] 3GPP TR 25.912:"Feasibility study for evolved UTRA and UTRAN"

[10] 3GPP TR 36.912:"Feasibility study for Further Advancements for E-UTRA (LTE-Advanced)"

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [2] 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 [2].

(void)

3.2 Symbols

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

(void)

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [2] 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 [2].

(void)

4 Introduction

At the 3GPP TSG RAN #39 meeting, the Study Item description on "Further Advancements for E-UTRA (LTE-Advanced)" was approved.

The study item covers technology components to be considered for the evolution of E-UTRA, e.g. to fulfil the requirements on IMT-Advanced. Within 3GPP these requirements are captured in [4].

The physical layer aspects of LTE-Advanced are captured in [5]. *Carrier aggregation*, where two or more *component carriers* are aggregated, is considered for LTE-Advanced in order to support wider bandwidths. The L1 specification shall support carrier aggregation for both contiguous and non-contiguous component carriers with each component carrier limited to a maximum of 110 Resource Blocks using the Release 8 numerology.

It will be possible to aggregate a different number of component carriers of possibly different bandwidths in the UL and the DL. In typical TDD deployments, the number of component carriers and the bandwidth of each component carrier in UL and DL will be the same.

The following carrier aggregation scenarios shall be considered when appraising the feasibility of the RF scenarios and parameters:

- Intra band
  - Contiguous Component Carrier
  - Non contiguous Component Carrier
- Inter band
  - Contiguous Component Carrier
  - Non contiguous Component Carrier

The following additional aspects related to the LTE-Advanced physical layer concept [5] can also be considered when appraising the feasibility of the RF scenarios and parameters:

- Uplink transmission schemes , Uplink spatial multiplexing
- Downlink transmission schemes, Downlink spatial multiplexing
- Coordinated multiple point transmission and reception
  - Downlink coordinated multi-point transmission
  - Uplink coordinated multi-point reception
- Relaying functionality

5 Radio transmission/reception and radio resource management

5.1 RF scenarios

5.1.1 Deployment scenarios for ITU-R submission

This section reviews the 4 operator's deployment scenarios that were considered for initial investigation in order to meet the ITU-R submission timescales. Agreed scenarios are shown in Table 5.1.1-1.

Table 5.1.1-1: Deployment scenarios for ITU-R submission

Scenario	Proposed RAN4 ITU deployment scenario for investigation
#1	Single band contiguous allocation @ 3.5 GHz band for FDD (UL:40 MHz, DL: 80 MHz)
#2	Single band contiguous allocation @ 2.3 GHz band 40 for TDD (100 MHz)
#7	Multi band non-contiguous allocation @ Bands 1, 3 and 7 for FDD (UL:40MHz, DL:40 MHz) *
#10	Multi band non contiguous allocation Bands 34, 39 and 40 for TDD (90 MHz) *
Note *	For some technical aspects for the ITU-R submission this would be done with 2 carrier aggregations

5.1.2 Deployment scenarios for Feasibility study

Based on operator's input RAN4 identified some LTE-Advanced deployment scenarios and priorities for the feasibility study of LTE-Advanced. RAN4 is focusing on these selected deployment scenarios considering the priorities and thereby timely analyses various RF aspects including terminal complexity. Table 5.1.2-1 provides LTE-A deployment scenarios with the highest priority for the feasibility study.

Table 5.1.2-1: Deployment scenarios with the highest priority for the feasibility study

Scenario No.	Deployment Scenario	Transmission BWs of LTE-A carriers	No of LTE-A component carriers	Bands for LTE-A carriers	Duplex modes
1	Single-band contiguous spec. alloc. @ 3.5GHz band for FDD	UL: 40 MHz DL: 80 MHz	UL: Contiguous 2x20 MHz CCs DL: Contiguous 4x20 MHz CCs	3.5 GHz band	FDD
2	Single-band contiguous spec. alloc. @ Band 40 for TDD	100 MHz	Contiguous 5x20 MHz CCs	Band 40 (2.3 GHz)	TDD
3	Single-band contiguous spec. alloc. @ 3.5GHz band for TDD	100 MHz	Contiguous 5x20 MHz CCs	3.5 GHz band	TDD
4	Single-band, non-contiguous spec. alloc. @ 3.5GHz band for FDD	UL: 40 MHz DL: 80 MHz	UL: Non-contiguous 20 + 20 MHz CCs DL: Non-contiguous 2x20 + 2x20 MHz CCs	3.5 GHz band	FDD
5	Single-band non-contiguous spec. alloc. @ Band 8 for FDD	UL: 10 MHz DL: 10 MHz	UL/DL: Non-contiguous 5 MHz + 5 MHz CCs	Band 8 (900 MHz)	FDD
6	Single-band non-contiguous spec. alloc. @ Band 38 for TDD	80 MHz	Non-contiguous 2x20 + 2x20 MHz CCs	Band 38 (2.6 GHz)	TDD
7	Multi-band non-contiguous spec. alloc. @ Band 1, 3 and 7 for FDD	UL: 40 MHz DL: 40 MHz	UL/DL: Non-contiguous 10 MHz CC@Band 1 + 10 MHz CC@Band 3 + 20 MHz CC@Band 7	Band 3 (1.8 GHz) Band 1 (2.1 GHz) Band 7 (2.6 GHz)	FDD
8	Multi-band non-contiguous spec. alloc. @ Band 1 and Band 3 for FDD	30 MHz	Non-contiguous 1x15 + 1x15 MHz CCs	Band 1 (2.1 GHz) Band 3 (1.8GHz)	FDD
9	Multi-band non-contiguous spec. alloc. @ 800 MHz band and Band 8 for FDD	UL: 20 MHz DL: 20 MHz	UL/DL: Non-contiguous 10 MHz CC@UHF + 10 MHz CC@Band 8	800 MHz band Band 8 (900 MHz)	FDD
10	Multi-band non-contiguous spec. alloc. @ Band 39, 34, and 40 for TDD	90 MHz	Non-contiguous 2x20 + 10 + 2x20 MHz CCs	Band 39 (1.8GHz) Band 34 (2.1GHz) Band 40 (2.3GHz)	TDD
11*	Single-band Contiguous spec. alloc @ Band 7 for FDD	UL: 20 MHz DL: 40 MHz	UL: 1x20 MHz CCs DL: 2x20 MHz CCs	Band 7 (2.6 GHz)	FDD
12	Multi-band non-contiguous spec. alloc. @ Band 7 and the 3.5 GHz range for FDD	UL: 20 MHz DL: 60 MHz	UL/DL: 20 MHz CCs @ Band 7 DL : Non- contiguous 20 + 20 MHz CCs @ 3.5 GHz band	Band 7 (2.6 GHz) 3.5 GHz band	FDD

*Note: From cell view, it has 40MHz both in DL and UL: From UE view, it can mostly have 40MHz in DL and 20MHz in UL. It means that the network can allocate maximum bandwidth of 40MHz in DL for one terminal, but just maximum bandwidth of 20MHz in UL for one UE to reduce the complexity of terminal.

5.1.3 Scenario #1 (Single band contiguous allocation @3.5GHz for FDD (UL: 40MHz, DL: 80MHZ)

The 3500 MHz band is currently still under discussion in both 3GPP and ITU-R[1]. Based on current discussion in WP-5D we note the Figure 5.1.3-1 is the recommended frequency arrangement for implementation of IMT in the 3400 – 3600 MHz band

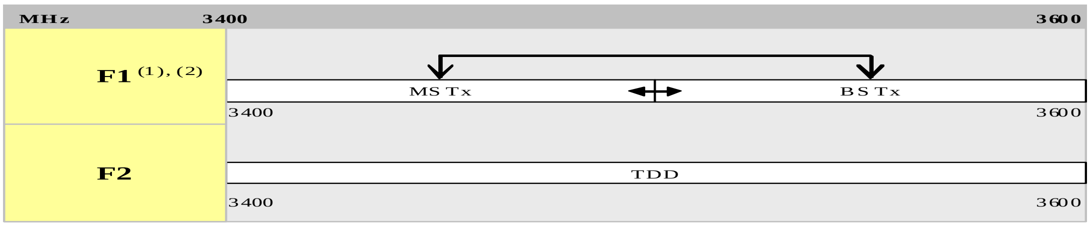

Figure 5.1.3-1: ITU recommended frequency arrangement

In particular, we note the following is still under discussion in ITU;

- the size of the segments for the FDD uplink (MS Tx) and downlink (BS Tx), where one could disappear (i.e. zero width);
- the size of the centre gap and duplex separation;
- the arrangement of the segments (i.e. the FDD uplink and downlink direction)
- the use of the external bands (i.e. combination of any FDD pairing with the bands other than 3 400-3 600 MHz

Based on the UMTS-LTE TR (R4-091019) we note the following band plan as shown in Figure 5.1.3.-2, under discussion for deployment in Europe. In particular practical allocations would start at 3410MHz[2] and this would lead to problems for UE harmonization problems if the frequency position of the duplex gap is different.

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[1] Revision of Recommendation M.1036-3: "Frequency arrangements for implementation of the terrestrial component of International Mobile Telecommunications (IMT) in the bands identified for IMT in the Radio Regulations"

Note: Regarding asymmetric spectrum arrangements see estimates for a mix of traffic described in Report ITU-R M.2023, Report ITU-R M.2078, and Recommendation ITU-R M.1822. Suitable techniques to support asymmetric traffic are described in Report ITU-R M.2038.

Note: The ITU-R Radio Regulations Art. 5. says in footnote 5.130A for the band 3400 – 3600 MHz in Region 1: "Before an administration brings into use a (base or mobile) station of the mobile service in this band, it shall ensure that the power flux-density (pfd) produced at 3 m above ground does not exceed −154.5 dB(W/(m^2 · 4 kHz)) for more than 20% of time at the border of the territory of any other administration. This limit may be exceeded on the territory of any country whose administration has so agreed…."

[2] In Europe the band 3400 MHz – 3410 MHz is allocated to amateur services on a secondary basis

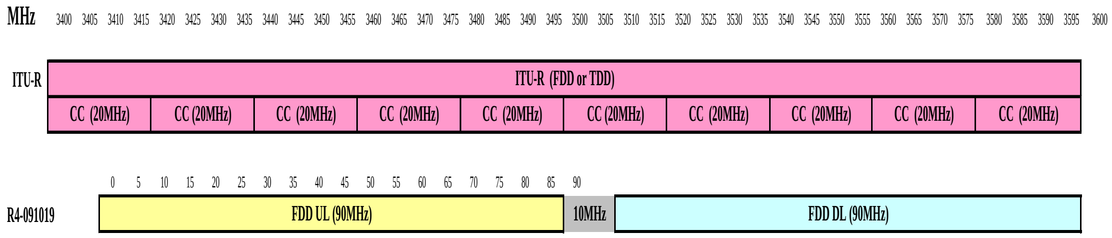


Figure 5.1.3-2: UMTS-LTE 3500MHz TR recommended frequency arrangement

However, as mentioned in TR (R4-091019), it will be difficult to implement a complete 2 x 90MHz FDD arrangement with a single duplexer in the UE based on a 10MHz duplex gap at 3.5GHz and a 2x70MHz is suggested. Assuming frequency scaling based on Band 8, a more reasonable single duplex band arrangement may be in the order of 2x75MHz with a 45MHz duplex (FFS), but such an arrangement would cover a smaller portion of the existing band arrangement and would not be spectrally efficient and, more importantly limit the number of contiguous CC. This is shown below in Figure 5.1.3-3

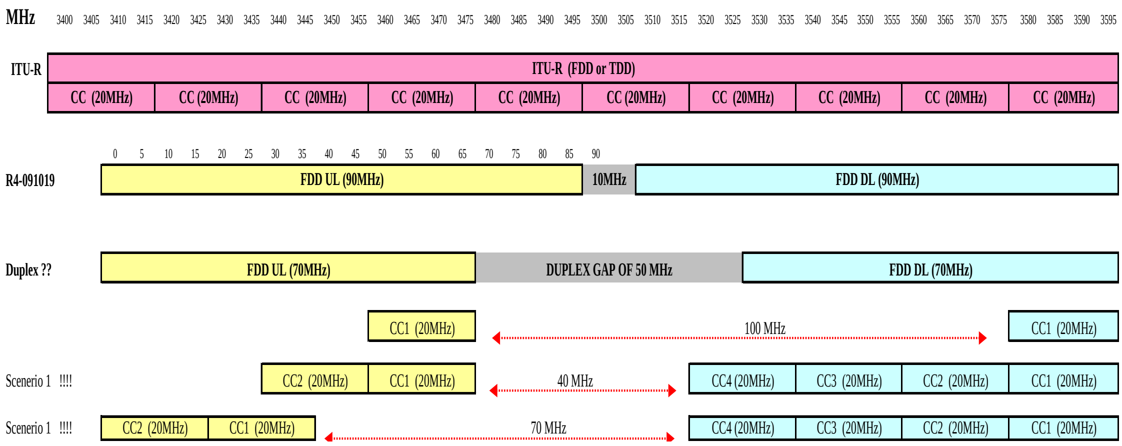


Figure 5.1.3-3: Scenario 1 deployment

One way to avoid the need for a large duplex gap is to sub-divide this band into two operating bands but this would increase the number of operating bands, but more importantly reduce the number of contiguous CC available and also lead to significant UE to UE co-existence issues.

Observations (assuming band plan as per UMTS-LTE TR);

- harmonization with ITU-R on location of duplex gap is paramount for global harmonization
- Duplex gap of 10 MHz is not sufficient to prevent UE self interference when a UE UL is on CC1 and DL at 4 CC4. The Tx to Rx spacing for contiguous CC would be too small
- Duplex gap of 50MHz is better, but not sufficient to prevent UE self interference when a UE UL is on CC1 and DL at 4 CC
- Key issue is if ALCR (Tx leakage component in Rx pass band) is based for multiple CC is assume to scale with number of CC. This has implications on UE architecture and addressed in R4-091366
- Scenario 1 cannot be supported assuming symmetrical UL/DL FDD plan without scheduler assistance to maintain minimum Tx to Rx duplex distance or half duplex type service..Note Tx Rx spacing could be 40 – 100MHz depending on allocation of RB
- Other solutions would be to reduce the number of contiguous CC and/or allow a large reduction in Tx power or an allowed Rx desense value.
- Adjacent inter-band co-existence would need to be addressed. In this case the guard band would be determined by the front end RF or duplex filter

The key problem with FDD deployment of very large bandwidths is the resultant UE self dense if the Tx –Rx spacing is not adequate. Increasing the Tx – Rx spacing would result in a large duplex gap which is counter productive in the case of the 3500MHz band. One alternative in order to address this issue is to allow paring with other bands to increase the effective TX-RX spacing (but creates problems for existing band users due to UE to UE co-existence) or deploy HD-FDD or TDD (assuming synchronized CC operation).

5.1.4 Scenario #2 (Single band contiguous allocation @2.3GHz for TDD (100MHz)

For this scenario the operator's have requested 5 x 20 MHz UL/DL – 5 Component Carrier (CC) of 20MHz

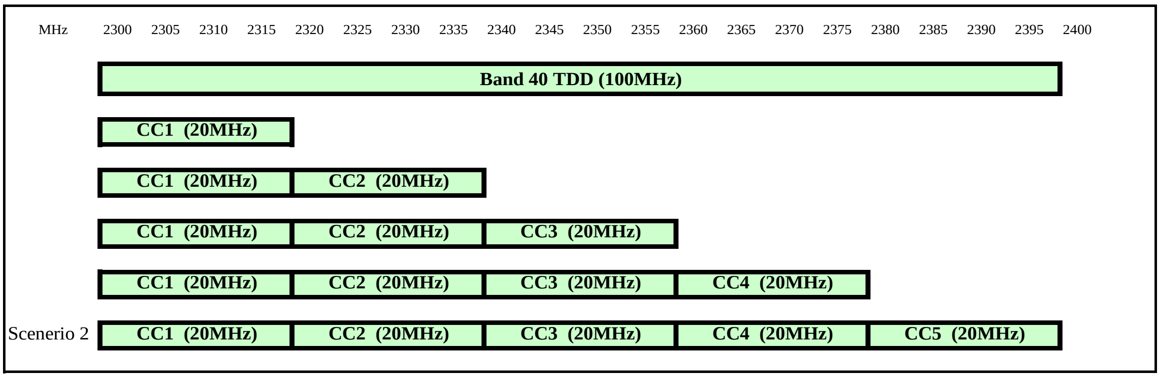


Figure 5.1.2-1: Scenario 2 deployment

One of the main benefits of TDD is the mitigation available for self interference. In this case, if synchronised channel can be supported in the operating band, the impact of UE to UE co-existence within the operating band is avoided. In this case, only adjacent inter-band co-existence would need to be addressed and would be FFS.

Taking account of the operator request for 5 x 20MHz DL we note the following;

- No limitation like the FDD case due to self interference /IP2
- Synchronization of UL/DL needed for all CC to avoid need for guard band between operators in this band
- ALCR (Tx leakage component in Rx pass band) for multiple CC is not an issue due to TDD operation unlike FDD

5.2 Common requirements for UE and BS

5.2.1 Operating bands

E-UTRA is designed to operate in the operating bands as defined in [7, 8]. E-UTRA operating bands are shown in Table 5.2.1-1.

Table 5.2.1-1 E-UTRA operating bands

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit			Downlink (DL) operating band BS transmit UE receive			Duplex Mode
	F_{UL_low}	–	F_{UL_high}	F_{DL_low}	–	F_{DL_high}	
1	1920 MHz	–	1980 MHz	2110 MHz	–	2170 MHz	FDD
2	1850 MHz	–	1910 MHz	1930 MHz	–	1990 MHz	FDD
3	1710 MHz	–	1785 MHz	1805 MHz	–	1880 MHz	FDD
4	1710 MHz	–	1755 MHz	2110 MHz	–	2155 MHz	FDD
5	824 MHz	–	849 MHz	869 MHz	–	894MHz	FDD
6 [Note 1]	830 MHz	–	840 MHz	875 MHz	–	885 MHz	FDD
7	2500 MHz	–	2570 MHz	2620 MHz	–	2690 MHz	FDD
8	880 MHz	–	915 MHz	925 MHz	–	960 MHz	FDD
9	1749.9 MHz	–	1784.9 MHz	1844.9 MHz	–	1879.9 MHz	FDD
10	1710 MHz	–	1770 MHz	2110 MHz	–	2170 MHz	FDD
11	1427.9 MHz	–	[1447.9] MHz	1475.9 MHz	–	[1495.9] MHz	FDD
12	698 MHz	–	716 MHz	728 MHz	–	746 MHz	FDD
13	777 MHz	–	787 MHz	746 MHz	–	756 MHz	FDD
14	788 MHz	–	798 MHz	758 MHz	–	768 MHz	FDD
15	Reserved			Reserved			FDD
16	Reserved			Reserved			FDD
17	704 MHz	–	716 MHz	734 MHz	–	746 MHz	FDD
18	815 MHz	–	830 MHz	860 MHz	–	875 MHz	FDD
19	830 MHz	–	845 MHz	875 MHz	–	890 MHz	FDD
20	832 MHz		862 MHz	791 MHz		821 MHz	FDD
21	1447.9 MHz		1462.9 MHz	1495.9 MHz		1510.9 MHz	FDD
22	[3410] MHz		[3500] MHz	[3510] MHz		[3600] MHz	FDD
...							
33	1900 MHz	–	1920 MHz	1900 MHz	–	1920 MHz	TDD
34	2010 MHz	–	2025 MHz	2010 MHz	–	2025 MHz	TDD
35	1850 MHz	–	1910 MHz	1850 MHz	–	1910 MHz	TDD
36	1930 MHz	–	1990 MHz	1930 MHz	–	1990 MHz	TDD
37	1910 MHz	–	1930 MHz	1910 MHz	–	1930 MHz	TDD
38	2570 MHz	–	2620 MHz	2570 MHz	–	2620 MHz	TDD
39	1880 MHz	–	1920 MHz	1880 MHz	–	1920 MHz	TDD
40	2300 MHz	–	2400 MHz	2300 MHz	–	2400 MHz	TDD
[41]	[3400] MHz		[3600] MHz	[3400] MHz		[3600] MHz	TDD
Note 1: Band 6 is not applicable.							

Possible IMT bands supported by the RIT include the following frequency bands as examples:

(a) Possible frequency bands in 3.4-3.8 GHz band

(b) Possible frequency bands in 3.4-3.6GHz as well as 3.6-4.2GHz

(c) Possible frequency bands in 3.4-3.6 GHz band

(d) Possible frequency bands in 470 - 450–470 MHz band,

(e) Possible frequency bands in 698–862 MHz band

(f) Possible frequency bands in 790–862 MHz ban

(g) Possible frequency bands in 2.3–2.4 GHz band

(h) Possible frequency bands in 4.4-4.99 GHz band

5.2.2 Component Carrier Aggregation

Aspects related to the aggregation component carriers are considered in RAN4. The following subclauses summarize some of the findings.

5.2.2.1 Channel raster

For E-UTRA Rel-8 the channel raster is 100 kHz for all bands, which means that the carrier centre frequency must be an integer multiple of 100 kHz.

The same channel raster is expected for LTE-Advanced.

5.2.2.2 Channel bandwidth

In TS36.101/104 the following terminology and numerology is defined for the Rel-8 E-UTRA channel bandwidth:

> **Channel bandwidth:** The RF bandwidth supporting a single E-UTRA RF carrier with the transmission bandwidth configured in the uplink or downlink of a cell. The channel bandwidth is measured in MHz and is used as a reference for transmitter and receiver RF requirements.
>
> **Transmission bandwidth configuration:** The highest transmission bandwidth allowed for uplink or downlink in a given channel bandwidth, measured in Resource Block units.

Figure 5.2.2.2-1 and Table 5.2.2.2-1 show the relation between the Rel-8 E-UTRA Channel bandwidth ($BW_{Channel}$) and the Transmission bandwidth configuration (N_{RB}). The channel edges are defined as the lowest and highest frequencies of the carrier separated by the channel bandwidth, i.e. at F_C +/- $BW_{Channel}$ /2.

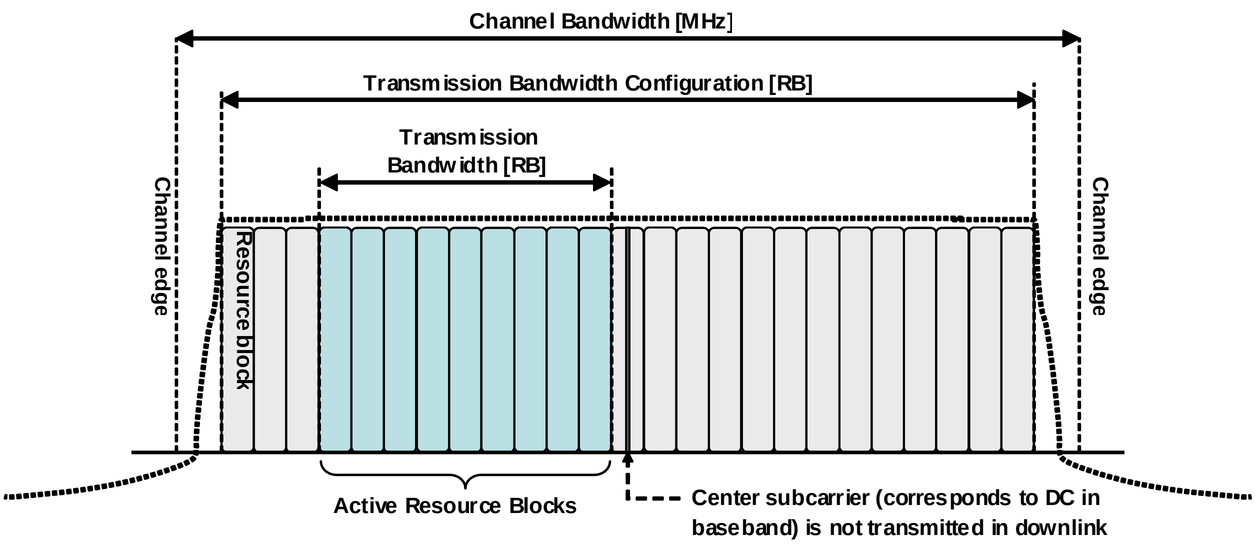


Figure 5.2.2.2-1: Definition of Channel Bandwidth and Transmission Bandwidth Configuration for one Rel-8 E-UTRA carrier

Table 5.2.2.2-1: Transmission bandwidth configuration N_{RB} in Rel-8 E-UTRA channel bandwidths

Channel bandwidth $BW_{Channel}$ [MHz]	**1.4**	**3**	**5**	**10**	**15**	**20**
Transmission bandwidth configuration N_{RB}	6	15	25	50	75	100

The channel bandwidth is measured in MHz and is used as a reference for transmitter and receiver RF requirements

The Rel-8 E-UTRA definitions related to channel edges (i.e. F_C +/- $BW_{Channel}$ /2) can be re-used for LTE-Advanced with respect to the component carriers at the edges of CC aggregation scenarios in order to provide a reference for transmitter and receiver RF requirements. It is also expected that LTE-Advanced component carriers will support the channel configurations of Table 5.2.2.2-1.

5.2.2.3 Additional Transmission bandwidth configurations

Additional transmission bandwidth configurations are not precluded.

The studies in RAN4 have considered usage of component carriers larger than 100 RBs for contiguous carrier aggregation, in particular a 108 RB configuration. From these investigations it is concluded that the transmit spectrum shaping is feasible, at least when the component carriers are spaced such that the distance from the aggregated channel edge to the outermost subcarrier of the edge RB is comparable to what is obtained from the Rel-8 configurations in Table 5.2.2.2-1.

Component carriers that are larger than 100 RBs can be made backwards compatible to Rel-8 UEs as additional RBs are transparent and removed by the RX filtering.

It is noted that the introduction of >100 RB transmission bandwidth configurations for aggregation of 20 MHz component carriers will prevent the efficient re-use of LTE Rel-8/9 RF and performance requirements. This is due to the required increase of the frequency offset from the DC subcarrier of the aggregation edge CC to the nominal aggregated channel edge (at which RF requirements shall apply) as well as the increased # of RBs within a CC. Hence, the introduction of >100 RB transmission bandwidth configurations will require increased efforts in RAN4 (e.g. additional demodulation performance requirements) as well as testing and IoT.

Furthermore no actual operator spectrum use cases for introduction of >100 RB transmission bandwidth configurations have emerged from the studies in RAN4 in order to justify new transmission bandwidth configurations. There remain still large uncertainties to the actual available spectrum allocations for LTE-A. Additionally, the potential gains in optimizing transmission bandwidth configurations for 20 MHz CCs appear to be small. It is thus premature to commit to additional transmission bandwidth configurations for 20 MHz CCs. If such a need arises to support specific deployment cases, this can be then done in subsequent releases of LTE-A

5.2.2.4 Extension Carrier

An extension carrier is not backward compatible with Rel-8 and complies with the Transmission bandwidth configuration of Table 5.2.2.2-1. Some of the common channels, such as PSS/SSS, broadcast channels, paging channels, PRACH, etc may not be present subject to decisions in other RAN WGs.

5.2.2.5 Carrier spacing between contiguously aggregated component carriers

In Rel-8 E-UTRA, the spacing between carriers can depend on the deployment scenario, the size of the frequency block available and the channel bandwidths. The nominal channel spacing between two adjacent Rel-8 E-UTRA carriers is defined as following:

$$\text{Nominal Channel spacing} = (BW_{Channel(1)} + BW_{Channel(2)})/2$$

where $BW_{Channel(1)}$ and $BW_{Channel(2)}$ are the channel bandwidths of the two respective Rel-8 E-UTRA carriers. The channel spacing can be adjusted to optimize performance in a particular deployment scenario. This includes the possibility to reduce the channel spacing in order to support specific spectrum assignments.

Similarly, with LTE-Advanced it shall be possible to aggregate component carriers in a spectrum efficient way for the case of contiguous spectrum. This will, for example, allow two aggregated 100 RB component carriers to be placed with 18.3 MHz center-to-center frequency separation. To facilitate this efficiently, the spacing between centre frequencies of contiguously aggregated component carriers shall be a multiple of 300 kHz. This is in order to be compatible with the 100 kHz frequency raster of LTE Rel-8 and at the same time preserve orthogonality of the subcarriers with 15 kHz spacing.

The carrier spacing between an extension carrier and a component carriers is FFS.

5.3 UE RF requirements

5.3.1 General

5.3.1.1 UE capability classes

(Void)

5.3.2 Transmitter characteristics

Tx characteristic are analysed for 3 generic aggregation scenarios;

- *Intra band contiguous component carrier (CC) aggregation*
- *Intra band non - contiguous component carrier (CC) aggregation*
- *Inter band contiguous component carrier (CC) aggregation*

5.3.2.1 General

Figure 5.3.2.1-1 illustrates various Tx architectures options according to where the component carriers are combined, i.e., at digital baseband, or in analog waveforms before RF mixer, or after mixer but before the PA, or after the PA.

Option A

- In an adjacent *contiguous common carrier* aggregation scenario, the UE very likely has one PA. Connected to the PA can be a single RF chain (a zero-IF mixer, a wideband DAC, and a wideband IFFT)

Option-B

- Combines analog baseband waveforms from component Carrier first (e.g., via a mixer operating at an IF of roughly the bandwidth of the other component carrier in the example of 2-component carrier aggregation). Then the resulting wideband signal is up-converted to RF.

Option-C

- Does ZIF up-conversion of each component carrier before combining and feeding into a single PA.

Option-D

- Employs multiple RF chains and multiple PAs after which the high-power signals are combined and fed into a single antenna. PA coupling at the UE can be challenging for option-D.

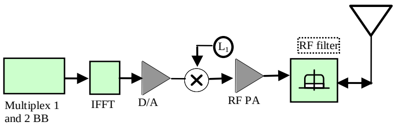
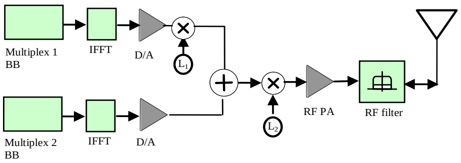
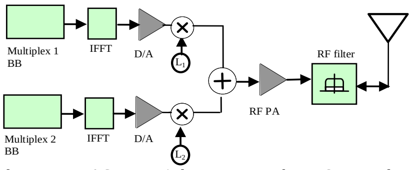
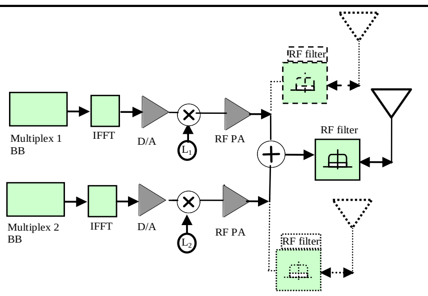
Tx Characteristics				
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 5.3.2.1-1: Possible UE Architectures in three aggregation scenarios

5.3.2.2 Transmit power

5.3.2.2.1 Power Class

In the study item report TR 25.912 for LTE [9] related to UE maximum output power it was indicated; It should be possible to reuse the rel-6 PA in order to allow for a single PA implementation for multi-mode (E-UTRA, UTRA) and multi-band terminals and that the E-UTRA UE power class should be a subset of the current UTRA Rel-6 power classes.

However it is not clear if the same requirements would be applicable in the case of dual Tx antenna (separate or dual PA) or CPE/ Relay products. In the case of case of these scenarios, the conducted transmit power may need to be reduced in order to support these larger bandwidths but then the radiated antenna gain is likely to be higher or the cell size would be smaller due to the larger supported data rate. In this case the transmitter characteristic could be defined for a new power class (Class 4) as proposed in Table 5.3.2.2.1-1

Table 5.3.2.2.1-1: UE maximum conducted power

E-UTRA Band	Class 1 (dBm)	Tolerance (dB)	Class 2 (dBm)	Tolerance (dB)	Class 3 (dBm)	Tolerance (dB)	Class 4 (dBm)	Tolerance (dB)
					23	±2	[20]	[±2]

Open issues for FFS are;

- *Should the UE class be linked to maximum conducted power*
- *Should the UE conducted power be linked to the number of Tx antenna (single or dual antenna)*
- *How should the maximum conducted power be defined ; per RB, per CC*

5.3.2.2.2 MPR /A-MPR

Open issues for FFS are

- *How should MPR/ A-MPR be extended for single and/or multiple CC bandwidths*
- *How should MPR/ A-MPR be extended new power classes and UE classes*

5.3.2.3 Output power dynamics

Currently power control is defined on sub-frame basis for a single component carrier in REL8 in the RAN1 specification. For LTE-A, the architecture of single or multiple PA can have an impact on the power control dynamics. In the case where the PA supports a component carrier, the CM is not a concern since each component carrier will have a fixed maximum transmit power. But a single PA architecture can potentially impact the power control procedure when its power is shared amongst component carriers

Another area for study is whether the multi-CC UL signal is combined digitally (at the baseband) or in analogue (at IF or RF) since the power control accuracy in terms accurate power control ratio amongst different CC will be less precise due to the analog component in the RF chain

For LTE-A power control would need to consider the following scenarios in the case of; OFF power, minimum power and power tolerance; In this case the transmitter characteristic for output power dynamics could be defined;

- *Intra band contiguous component carrier (CC) aggregation*
- *Intra band non - contiguous component carrier (CC) aggregation*
- *Inter band contiguous component carrier (CC) aggregation*
- *Single or multiple segment power control*

5.3.2.4 Transmit signal quality

Currently EVM performance is defined on slot bases for a single component carrier in REL8 in the RAN1 specification. For LTE-A EVM would need to consider the following scenarios;

In this case the transmitter characteristic for EVM could be defined

- *Intra band contiguous component carrier (CC) aggregation*
- *Intra band non - contiguous component carrier (CC) aggregation*
- *Inter band contiguous component carrier (CC) aggregation*

5.3.2.5 Output RF spectrum emissions

Spurious emissions are emissions which are caused by unwanted transmitter effects such as harmonics emission, parasitic emissions, intermodulation products and frequency conversion products, but exclude out of band emissions.

As captured in TR36.803 the spectrum emission mask scales in proportion to the channel bandwidth due to PA non-linearity for a single component carrier. In the case of multiple contiguous CC scenarios should the spectrum mask be proportional to the total number of contiguous channel bandwidth (REL8 approach) or be unchanged and be no different from that of a single CC bandwidth

Spectrum mask which is proportional to the single CC channel bandwidth would require a multi-carrier approach at baseband with a single linear RF PA or multiple PA solution RF combining approach which each PA supporting a single CC channel bandwidth. Both solutions have an impact on Tx architecture.

5.3.2.5.1 Adjacent Channel Leakage ratio

Depending on the adjacent channel bandwidth (single or multiple CC) it may be necessary to investigate the impact of ALCR with different number of CC.

In this case the transmitter characteristic for ACLR could be defined for;

- *Intra band contiguous component carrier (CC) aggregation*
- *Intra band non - contiguous component carrier (CC) aggregation*
- *Inter band contiguous component carrier (CC) aggregation*

5.3.2.5.2 Spurious emission (UE to UE co-existence)

One aspect relating to the emission spectrum would be UE to UE co-existence.

In this case the following aspects would need FFS;

- *UE1 (Tx) and U2 (Rx) configuration for UE to UE co-existence analysis*
- *Should the same limit (-50dBm /1MHz) be applicable or a lower limit of be considered for the case of contiguous CC carrier*
- *In the case of inter band scenario how do we address harmonic requirements*
- *Guard band for TDD non synchronized operation*

5.3.2.6 Transmit intermodulation

The transmit intermodulation performance is a measure of the capability of the transmitter to inhibit the generation of signals in its non linear elements caused by presence of the wanted signal and an interfering signal reaching the transmitter via the antenna.

The current RAN1 assumption assumes in the case of contiguous CC carriers then RB can be freely allocated for the different CC carriers. In this case intermodulation performance could be challenging and may need to be defined in terms; per RB allocation / per CC carrier / all CC.

5.3.3 Receiver characteristics

In this section we have deliberately chosen to align with the UE specification TS36.101 [7] since the impact of Very Large bandwidths would have an impact in many areas of the Tx / Rx characteristics.

A terminal may simultaneously receive one or multiple component carriers depending on its capabilities: We propose to analyse 3 generic aggregation scenarios;

- *Intra band contiguous component carrier (CC) aggregation*
- *Intra band non - contiguous component carrier (CC) aggregation*
- *Inter band contiguous component carrier (CC) aggregation*

Table 5.3.3-1 illustrates various Rx architectures options for the three scenarios

Table 5.3.3-1: Possible UE Architecture for the three aggregation scenarios

Rx Characteristics				
Option	Description (Rx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	Single (RF + FFT + baseband) with BW>20MHz	Yes		
B	Multiple (RF + FFT + baseband) with BW≤20MHz	Yes	Yes	Yes

Option A

- UE may adopt a single wideband-capable (i.e., >20MHz) RF front end (i.e., mixer, AGC, ADC) and a single FFT, or alternatively multiple "legacy" RF front ends (<=20MHz) and FFT engines. The choice between single or multiple transceivers comes down to the comparison of power consumption, cost, size, and flexibility to support other aggregation types.

Option B

- In this case, using a single wideband-capable RF front end is undesirable in the case of Intra band non contiguous CC due to the unknown nature of the signal on the "unusable" portion of the band. In the case non adjacent Inter separate RF front end are necessary

5.3.3.1 General

In order to define the consider the applicable Rx characteristic a number of working assumptions will be needed to ensure the feature is applicable in terms of UE implementation. Current REL8 working assumption has assumed some constraints due to complexity and battery saving

One new form factor that could be consider is Customer Premise Equipment (CPE) which would have the ability to initial these new features such as 2 Tx antenna port and 4 Rx antenna port as a baseline work assumption in order to address the Tx characteristics.

5.3.3.2 Receiver Sensitivity

The current reference sensitivity power level REFSENS is the minimum mean power applied to both the UE antenna ports at which the throughput shall meet or exceed the requirements for the specified reference measurement channel

For LTE-A

- *Should this be applicable to all ports*
- *Sensitivity defined per single CC or multiple CC.*

5.3.3.2.1 MSD (Maximum sensitivity reduction)

For LTE-A

- *For intra and inter CC operation.*
- *TX should be single RB, full allocation (single or multiple CC)?*

5.3.3.3 Selectivity

ACS is the ratio of the receive filter attenuation on the assigned channel frequency to the receive filter attenuation on the adjacent channel(s).

For LTE-A

- *Based on single and/or multiple CC channel bandwidths*
- *Need to define power allocation and distribution for RB single and/or multiple CC*

  Channel bandwidths due to UE Rx operating point (AGC)

5.3.3.4 Blocking performance

The blocking characteristic is a measure of the receiver's ability to receive a wanted signal at its assigned channel frequency in the presence of an unwanted interferer on frequencies other than those of the spurious response or the adjacent channels, without this unwanted input signal causing a degradation of the performance of the receiver beyond a specified limit.

- In-band blocking
- Out of -band blocking
- Narrow band blocking

For *LTE-A*

- *Based on single and/or multiple CC channel bandwidths*
- *Power allocation for RB single and/or multiple CC channel bandwidths*
- *Per Rx antenna ports or across all antenna ports*
- *Need to define power allocation and distribution for RB single and/or multiple CC Channel bandwidths due to UE Rx operating point (AGC)*

5.3.3.5 Spurious response

Spurious response is a measure of the receiver's ability to receive a wanted signal on its assigned channel frequency without exceeding a given degradation due to the presence of an unwanted CW interfering signal at any other frequency at which a response is obtained i.e. for which the out of band blocking limit is not met.

5.3.3.6 Intermodulation performance

Intermodulation response rejection is a measure of the capability of the receiver to receiver a wanted signal on its assigned channel frequency in the presence of two or more interfering signals which have a specific frequency relationship to the wanted signal.

For LTE-A

- *Based on single and/or multiple CC channel bandwidths*
- *Power allocation for RB single and/or multiple CC channel bandwidths*
- *Per Rx antenna ports or across all antenna ports*

5.3.3.7 Spurious emission

The spurious emissions power is the power of emissions generated or amplified in a receiver that appear at the UE antenna connector.

5.4 BS RF requirements

5.4.1 General

5.4.1.1 RF scenarios

LTE-Advanced BS RF requirements extend those of LTE Rel-8 considering the following component carrier aggregation scenarios:

- Intra band
  - Contiguous Component Carrier aggregation
  - Non contiguous Component Carrier aggregation
- Inter band
  - Non contiguous Component Carrier aggregation

Intra band, contiguous carrier aggregation is specified for DC-HSDPA on the DL and DC-HSUPA on the UL. The DC-HSDPA specification supports both, carrier aggregation with a single PA (antenna connector) as well as two PAs (antenna connectors); for both cases the RF requirements are defined on a per antenna connector basis. The need for a similar flexibility is also foreseen for CA within the LTE-Advanced specifications. One important parameter to define within the WI phase is the # of aggregated carriers and/or the maximum aggregated bandwidth.

Intra band, non-contiguous carrier aggregation is a new concept for RAN4 BS specifications and requires appropriate extension of the transmit (e.g. unwanted emissions, ACLR) and receive (e.g. ACS, blocking, ...) RF requirements across the "gaps" between CCs in order to facilitate co-existence between uncoordinated systems. In case this scenario is elected for the WI phase, the LTE-Advanced specifications would need be flexible and support implementations using one or multiple antenna connectors.

Inter band, non-contiguous carrier aggregation is specified for DB-DC-HSDPA on the DL. Following the rationale provided in RAN4 the corresponding DB-DC-HSDPA transmit requirements are based on single band transmission and apply separately to each antenna connector (pertaining to an aggregated band), with the other one(s) terminated. This specification concept can be extended to aggregation on the UL. The concept of per-band requirements shall also be considered for LTE-Advanced when defining the relevant unwanted emissions limits and receiver RF requirements.

LTE-Advanced RF requirements shall be considered for WA Base Stations. Introduction of other base station classes than WA is not precluded. The requirements for these may be different than for the WA base station class and may require some co-existence studies.

Some of the LTE-Advanced RF requirements may only apply in certain regions either as optional requirements or set by local and regional regulation as mandatory requirements. It is normally not stated in the 3GPP specifications under what exact circumstances that the requirements apply, since this is defined by local or regional regulation.

5.4.1.2 Re-use of existing LTE Rel-8 requirements

Whenever appropriate, LTE-Advanced RF requirements shall be based on the re-use of existing LTE Rel-8 requirements in a "building block" manner. This facilitates faster introduction of LTE-Advanced from the view point of specification development, compliance with regulatory requirements as well as the development of conformance test cases.

This "building block" approach is already used in TS 36.104, Annex F for the some of the LTE Rel-8 multi-carrier scenarios. It is also used for carrier aggregation on DL for DC-HSDPA and DB-DC-HSDPA as well as on UL for DC-HSUPA. It is also used within the MSR specifications on DL and UL for multi-carrier and multi-/RAT TX/RX scenarios. From these cases it can be observed that carrier aggregation can be introduced with minimal impact on existing specifications as long as the "numerology" of the component carriers remains the same; in case of LTE-Advanced this corresponds maintaining the Channel and Transmission bandwidth configurations of Rel-8 E-UTRA.

5.4.2 Transmitter characteristics

5.4.2.1 General

In LTE Rel-8 transmitter requirements are expressed for a single transmitter antenna connector. In case of transmit diversity or MIMO transmission; the requirements apply for each transmitter antenna connector.

In DB-DC-HSDPA separate antenna connectors per active band are assumed. In DC-HSDPA, aggregated carriers can go through the same or separate antenna connectors (PAs). In all these cases the transmitter requirements apply for each transmitter antenna connector. In current BS specifications no RF combining network across multiple antenna connectors is stipulated in order to accumulate unwanted emissions originating from multiple carriers and/or MIMO branches.

To maintain consistency with the existing specifications, LTE-Advanced shall follow the same principles for carrier aggregation. The following transmit antenna configurations are expected to be supported by the LTE-Advanced specifications in order to facilitate relevant implementations related to component carrier aggregation:

- Multiple CCs can be aggregated at one antenna connector for intra-band contiguous carrier aggregation. Additionally,
- > 1 antenna connector can be used for intra-band contiguous carrier aggregation of multiple CCs. This may be required in scenarios with large aggregated bandwidth due to the limited PA bandwidth available and/or the need to aggregate high powers from multiple PAs. Similarly,
- In case of intra-band non-contiguous carrier aggregation, > 1 antenna connector can be used for the CCs (or groups of contiguous CCs). This will be necessary if the CCs are widely separated in frequency and don't fit within the PA bandwidth.
- in case of inter-band non-contiguous carrier aggregation, one or multiple bands may be available on the antenna connector. The latter case is possible in case diplexers would be integrated within the BS (FFS). However, transmit requirements and tests shall apply for only one active band at a time, with the emissions within other transmit bands switched off (terminated). This is necessary in order to obtain consistent per-band requirements, e.g. the measurements of spurious emissions on one DL operating band must not be interfered by the carrier power transmitted on another DL operating band.

5.4.2.2 Base Station output power

In LTE Rel-8 the base station maximum output power is defined as the mean power level per carrier measured at the antenna connector during the transmitter ON period in a specified reference condition. There exist requirements for the base station maximum output power to remain within +/- x dB of the rated output power declared by the manufacturer.

This can be extended in LTE-Advanced for a component carrier. The output power of multiple component carriers can be aggregated and it is FFS if nominal aggregated power per band shall also be declared by the manufacturer.

Base Stations intended for general-purpose applications do not have limits on the maximum output power. However, there exist regional regulatory requirements which limit the maximum output power in some instances. Base Stations other than those belonging to the WA class do have limits on the per-carrier maximum output power and it needs to be checked if the currently specified per-carrier limits are also applicable for CA.

The specifications related to the associated conformance tests in TS 36.141 [6] with regard to the E-TMs can also be re-used provided the transmission bandwidth configurations of Rel-8 E-UTRA are maintained for LTE-Advanced.

5.4.2.3 Transmitted signal quality

In LTE Rel-8 requirements for transmitted signal quality are defined for:

- Frequency error; a measure of the difference between the actual BS transmit frequency and the assigned frequency of a carrier. The same source is used for RF frequency and data clock generation.
- Error Vector Magnitude; a measure of the difference between the ideal symbols and the measured symbols after the equalization.

- In case of Tx Diversity and spatial multiplexing, the time alignment between transmitter branches, i.e. the delay between the signals from two antennas at the antenna ports

These requirements can be extended in LTE-Advanced on the basis of component carriers.

Additionally, in LTE-Advanced the time alignment error between component carriers shall be considered, for both intra- and inter-band scenarios. Some relaxations need to be considered (ref. time alignment error requirements for UTRA DB-DC-HSDPA and DC-HSDPA + MIMO).

The specifications related to the associated conformance tests in TS 36.141 [6] with regard to the E-TMs can also be re-used provided the transmission bandwidth configurations of Rel-8 E-UTRA are maintained for LTE-Advanced.

5.4.2.4 Unwanted emissions

In LTE Rel-8 requirements for unwanted emissions are defined in form of operating band unwanted emission limits and transmitter spurious emissions. These requirements apply, for each transmit antenna connector, whatever the type of transmitter considered (single carrier or multi-carrier) and for all transmission modes foreseen by the manufacturer's specification.

With the exception of multi-carrier (-RAT) transmissions on a single transmit antenna connector, the current UTRA, E-UTRA and MSR specifications do *not* contain any limits for the following aggregated unwanted emissions:

- across MIMO (or transmit diversity) branches
- across multi-carrier (-RAT) transmissions using multiple antenna connectors
- across *aggregated* multi-carrier transmissions using multiple antenna connectors (for DC-HSDPA)
- across multiple bands (for DB-DC-HSDPA)

The same approach shall be considered for LTE-A.

Additionally there exist aggregate emission limits stipulated by regulation on the basis of license blocks (e.g. EIRP BEM) which are, however, outside the scope of the LTE-Advanced specifications.

5.4.2.4.1 Operating band Unwanted emissions

For each antenna connector, operating band unwanted emission limits are defined from 10 MHz below the lowest frequency of the downlink operating band up to 10 MHz above the highest frequency of the downlink operating band. They apply below the lower edge of the carrier transmitted at the lowest carrier frequency and above the higher edge of the carrier transmitted at the highest carrier frequency. The unwanted emission limits in the part of the downlink operating band that fall into the spurious domain are consistent with ITU-R Recommendation SM.329 [1].

The concept of the LTE Rel-9 operating band unwanted emission limits can also be considered in LTE-Advanced on the basis of component carriers.

In case the intra-band non-contiguous carrier aggregation scenario is elected for the CA WI, the limits across the "gaps" between CCs need to be defined, for the cases of a single, respectively multiple antenna connectors. In case of multiple antenna connectors (each transmitting one or more contiguous CCs), it is recommended not to define aggregated unwanted emission limits, but instead define limits per antenna connector, with the other one(s) terminated.

5.4.2.4.2 Transmitter spurious emissions

The spurious domain covers frequencies, which are separated from the carrier centre frequency by more than 250% of the necessary bandwidth, as recommended in ITU-R SM.329. These transmitter spurious emission limits apply, for each antenna connector, from 9 kHz to 12.75 GHz.

The transmitter spurious emission limits of LTE-Advanced shall comply with ITU-R SM.329 [1]. These requirements shall apply whatever the type of transmitter considered (single carrier, multi-carrier, aggregated CCs) for each antenna connector.

5.4.3 Receiver characteristics

5.4.3.1 Reference sensitivity level

In LTE Rel-8, the reference sensitivity power level $P_{REFSENS}$ is the minimum mean power of a carrier received at the antenna connector at which a throughput requirement shall be met for a specified reference measurement channel.

In LTE Rel-8, reference sensitivity levels are defined on the basis of transmission bandwidth configurations of 6 (1.4MHz channel bandwidth), 15 (3MHz channel bandwidth) and 25 resource blocks (channel bandwidths ≥5MHz) of the wanted signal. Rel-8 requirements can be applied on a component carrier basis, provided the Rel-8 E-UTRA transmission bandwidth configurations are maintained for LTE-Advanced. For component carriers with N_{RB} >100 additional reference sensitivity level requirements would be needed, requiring the introduction of new Fixed Reference Channels together with their corresponding performance requirements which require additional link level simulation results.

5.4.3.2 Dynamic range

In LTE Rel-8, the dynamic range is specified as a measure of the capability of the receiver to receive a wanted signal in the presence of an interfering signal inside the received channel bandwidth. In this condition a throughput requirement shall be met for a specified reference measurement channel. The interfering signal for the dynamic range requirement is an AWGN signal.

In LTE Rel-8, dynamic range requirements are defined on the basis of transmission bandwidth configurations of 6 (1.4MHz channel bandwidth), 15 (3MHz channel bandwidth) and 25 resource blocks (channel bandwidths ≥5MHz) of the wanted signal. Rel-8 requirements can be applied on a component carrier basis, provided the Rel-8 E-UTRA transmission bandwidth configurations are maintained for LTE-Advanced. For component carriers with N_{RB} >100 additional dynamic range requirements would be needed, requiring the introduction of new Fixed Reference Channels together with their corresponding performance requirements which require additional link level simulation results.

5.4.3.3 In-channel selectivity

In LTE Rel-8, the in-channel selectivity is a measure of the receiver ability to receive a wanted signal at its assigned resource block locations in the presence of an interfering signal received at a larger power spectral density. In this condition a throughput requirement shall be met for a specified reference measurement channel.

In LTE Rel-8, reference sensitivity levels are defined on the basis of transmission bandwidth configurations of 3 (1.4MHz channel bandwidth), 9 (3MHz channel bandwidth), 15 (5MHz channel bandwidth) and 25 resource blocks (channel bandwidths ≥10MHz) of the wanted signal. Rel-8 requirements can be applied on a component carrier basis, provided the Rel-8 E-UTRA transmission bandwidth configurations are maintained for LTE-Advanced. For component carriers with N_{RB} >100 additional reference sensitivity level requirements would be needed, requiring the introduction of new Fixed Reference Channels together with their corresponding performance requirements which require additional link level simulation results.

5.4.3.4 Adjacent Channel Selectivity (ACS), narrow-band blocking, Blocking, Receiver intermodulation

In LTE Rel-8 the following receiver RF requirements are defined:

- Adjacent channel selectivity (ACS); a measure of the receiver ability to receive a wanted signal at its assigned channel frequency in the presence of an adjacent channel signal with a specified centre frequency offset.
- Blocking characteristics; a measure of the receiver ability to receive a wanted signal at its assigned channel in the presence of an unwanted interferer (specified for in-band blocking and out-of-band blocking)
- Intermodulation response rejection; a measure of the capability of the receiver to receive a wanted signal on its assigned channel frequency in the presence of two interfering signals which have a specific frequency relationship to the wanted signal.

In LTE Rel-8, these requirements are defined on the basis of transmission bandwidth configurations of 6 (1.4MHz channel bandwidth), 15 (3MHz channel bandwidth) and 25 resource blocks (channel bandwidths ≥5MHz) of the wanted signal and by considering an appropriate desensitisation relative to the reference sensitivity level requirement.

For LTE-Advanced Rel-8 requirements can be considered on a component carrier basis, provided the Rel-8 E-UTRA transmission bandwidth configurations are maintained.

For component carriers with N_{RB} >100 additional requirements would be needed due to the different structure of the wanted and interfering signals (e.g. 27 resource blocks of the wanted and interfering signals in case of component carrier of 108 resource blocks). Also the required increase of the frequency offset from the DC subcarrier of the aggregation edge CC to the nominal aggregated channel edge (relative to which interfering signal offsets shall apply) will require additional considerations. Furthermore, for any given N_{RB} >100, these increased frequency offsets are expected to differ for the various aggregation cases but would need to be reflected in the specifications.

Extensions to cater for the case of intra-band non-contiguous Component Carrier aggregation need to be considered keeping in mind the co-existence issues between uncoordinated systems.

5.4.3.5 Performance requirements

In LTE Rel-8, demodulation performance requirements for the BS are specified for defined fixed reference channels and propagation conditions.

For UL carrier aggregation within DC-HSUPA demodulation performance requirements are derived from existing HSUPA requirements on a per-carrier basis, without the need to introduce additional Fixed Reference Channels. If the same approach is also utilized for CC aggregation in LTE-Advanced, Rel-8 demodulation performance requirements can be re-used, provided the Rel-8 E-UTRA transmission bandwidth configurations are maintained. For component carriers with N_{RB} >100 additional performance requirements would be needed, requiring the introduction of new Fixed Reference Channels together with their corresponding performance requirements which require additional link level simulation results.

Additional requirements to support further features of LTE-Advanced, e.g. uplink single-user spatial multiplexing, need to be considered.

5.4.4 Implementation feasibility of carrier aggregation scenarios

This Subclause discusses aspects related to the implementation feasibility of the carrier aggregation scenarios in clause 5.1.2. The discussion is limited to FDD and to the wide area BS class.

5.4.2.5.1 Intra-band contiguous carrier aggregation

One important aspect for Intra-band contiguous carrier aggregation is the maximum bandwidth which can be expected for transmit and receive across a single antenna connector. The BS transmit direction is understood to be more limiting than BS receive, due to the required high power linear PAs. A typical DAPD PAs optimized for Rel-8 LTE may have a usable bandwidth of 20 MHz. Extending the usable bandwidth to > 20 MHz while maintaining the same output power spectrum density level leads to the following design challenges:

- increasing the bandwidth will make linearization more challenging (DAPD, clipping,…), leading potentially to lower PA output power and reduced efficiency.
- LTE-Advanced would need to evolve from the transmit powers per CC (or per MHz) used on existing Rel-8 LTE sites. This would require higher PA output power.
- TX IMD products may fall into the own receive channels for operating bands with narrow duplex gap.
- offset of the own RX channels to the edge of the used TX band decreases, which makes it more difficult to achieve the necessary attenuation of spurious emissions to protect the own receiver.

While there is potential to evolve the usable bandwidth of current PA technologies beyond 20 MHz, performance degradations, e.g., reduced output power per CC compared to 20 MHz Rel-8 LTE need to be considered. At the same time the combining of CCs going through separate PAs based on "air-combining" will either require multiple transmit antennas or lossy wideband combiners as diplexers are not feasible for contiguous CCs. Therefore, in order to facilitate also > 20 MHz CA with a RF performance per CC aligned with that of a Rel-8 LTE 20 MHz CC, the specifications should also support CA with a PA BW ≤ 20 MHz..

These aspects are relevant for the contiguous carrier aggregation scenarios with DL aggregation bandwidths of > 20 MHz i.e. FDD Scenarios # 1, #4 and #11.

The remaining FDD scenarios, have a maximum contiguous aggregated DL bandwidth of ≤ 20 MHz per band (or are intra-band non- contiguous CA) and are not impacted by PA BW limitations.

5.4.2.5.2 Intra-band non-contiguous carrier aggregation

The limitations in the usable PA bandwidth discussed in Subclause 5.4.2.5.1 apply also for Intra-band non-contiguous carrier aggregation with a single PA. When the resulting frequency range from the lowest CC to the highest CC exceeds the PA bandwidth, transmission using multiple PAs needs to be considered, together with either "air-combining" using multiple transmit antennas or, alternatively, some RF combining approach. These remarks are relevant for Scenarios #4, #5 and #12.

5.4.2.5.3 Inter-band non-contiguous carrier aggregation

Inter-band non-contiguous carrier aggregation requires the use of multiple PAs. The relationship between the number of operating bands and antenna connectors has already been discussed in Subclauses 5.4.2.1. Naturally, the same issues regarding the per-band CA mentioned in Subclauses 5.4.2.5.1 and 5.4.2.5.2 apply here as well. However, in addition to the possible need for separate antenna connectors (and larger BS configurations) on a per-band basis, Inter-band CA is not seen to pose specific implementation issues.

5.4.2.5.4 Aspects related to MIMO multi-TX

As shown the previous subclauses, CA might require the use of more than one transmit antenna (PA). If in addition MIMO is used, the number of required transmit antennas (PA) is to be multiplied accordingly. As an example, Scenario #1 using 8x8 MIMO leads to very large BS configurations when compared to typical 3G (or Rel-8 LTE) sites of today.

5.5 TS 36.133 requirements enhancements

As already in LTE Rel-8 and also in LTE-Advanced robust general minimum RRM requirements ensure good mobility performance across the cellular network for various mobile speeds and different network deployments. The minimum RRM requirements are defined both in idle mode and in active mode. In Active mode the requirements are defined both without DRX and with DRX in order to ensure that good mobility performance in all cases. Different network controlled parameter values for cell reselection in idle mode and for handover in active mode can be utilised for optimising mobility performance in different scenarios, which also include low mobility and high mobility scenarios.

6 Conclusions

This TR contains the outcomes of the RAN WG4 related studies on the technical feasibility of LTE-Advanced.

The studies related to carrier aggregation used LTE-Advanced deployment scenarios which were based on operator's input.

It is concluded that with LTE-Advanced it will be possible to contiguously aggregate component carriers in a spectrum efficient way, provided, the spacing between centre frequencies of component carriers is a multiple of 300 kHz.

UE architectures options to support the carrier aggregation scenarios were identified and feasible BS configurations to support the selected aggregation scenarios were found.

The impact of the carrier aggregation scenarios on the UE and BS RF requirements was also investigated. It was found that the LTE-Advanced RF requirements can be based on the re-use of existing structure of LTE Rel-8 requirements in a "building block" manner.

Annex A: ITU Template response

A.1 ITU Description template – characteristics template

The description template – characteristics (4.2.3.2) is found in Annex C.1 in TR 36.912 [10].

A.2 ITU Description template – characteristics response (RAN4)

The description template – characteristics response is found in Annex C.1 in TR 36.912 [10].

Annex B: Change history

Change history							
Date	**TSG #**	**TSG Doc.**	**CR**	**Rev**	**Subject/Comment**	**Old**	**New**
2009-03	R4#50bis	R4-091444			Skeleton Technical Report / LTE-Advanced feasibility studies in RAN4		0.0.1
2009-05	R4#51	R4-091673			Agreed Text Proposals in RAN4#50bis: **R4-091480**, " TP: Prioritized Deployment Scenarios for ITU-R submission" **R4-091481**, " TP for operating bands"	0.0.1	0.1.0
2009-06	R4#51bis	R4-092123			Agreed Text Proposals in RAN4#51: **R4-091674**, " TP for LTE-Advanced deployment scenarios" **R4-091802**, " TP:LTE- Advanced; Deployment scenarios" **R4-091803**, " TP: LTE- Advanced; UE Tx characteristics" **R4-091804**, " TP: LTE- Advanced; UE Rx characteristics" **R4-092105**, " RAN4 LTE-Advanced ITU-R response for June submission"	0.1.0	0.2.0
2009-10	R4#52bis	R4-093646			Agreed Text Proposals in RAN4#52: **R4-092698**, " TP for LTE-Advanced frequency arrangements" **R4-092945**, " Text proposal on clarification for asymmetric LTE-A deployment scenarios" **R4-093435**, " Final version of characteristics template"	0.2.0	0.3.0
2009-11	R4#53	R4-094984			Agreed Text Proposals in RAN4#53: **R4-094888**, " TP for LTE-A RAN4 feasibility studies TR 36.815: Component Carrier Aggregation"	0.3.0	0.4.0
2010-02	R4#54	R4-100868			Agreed Text Proposals in RAN4-AH#2010-01: **R4-100014**, " TP for LTE-A RAN4 feasibility studies TR 36.815: Subclause 5.4.3 Receiver characteristics" **R4-100071**, " TP for LTE-A RAN4 feasibility studies TR 36.815: Subclause 5.4.1 General" **R4-100073**, " TP for LTE-A RAN4 feasibility studies TR 36.815: Subclause 5.4.2.1 General" **R4-100074**, " TP for LTE-A RAN4 feasibility studies TR 36.815: Subclause 5.4.2.2 Base Station output power" **R4-100075**, " TP for LTE-A RAN4 feasibility studies TR 36.815: Subclause 5.4.2.3 Transmitted signal quality" **R4-100076**, " TP for LTE-A RAN4 feasibility studies TR 36.815: Subclause 5.4.2.4 Unwanted emissions"	0.4.0	0.5.0
2010-02	R4#54	R4-100966			Agreed Text Proposals in RAN4#54: **R4-100281**, " TP for LTE-A RAN4 feasibility studies TR 36.815: Subclause 5.4.4 Implementation feasibility of carrier aggregation scenarios" **R4-100403**, " TP for TR 36.815: RRM aspect" **R4-100952**, " TP for LTE-A RAN4 feasibility studies TR 36.815: Subclause 5.4.2.1 General" **R4-100985**, " Concluding remarks for TR36.815"	0.5.0	0.6.0
2010-02	R4#54	R4-101068			Agreed Text Proposals in RAN4#54: **R4-100281 re-submission**, " TP for LTE-A RAN4 feasibility studies TR 36.815: Subclause 5.4.4 Implementation feasibility of carrier aggregation scenarios"	0.6.0	0.7.0
2010-03	R#47	RP-100113			Presentation of TR 36.815 to TSG RAN#47 for approval.	0.7.0	2.0.0
2010-03	R#47	RP-100113			Approved by RAN	2.0.0	9.0.0
2010-06	RP-48	RP-100634	001		Removing the Contents of Annex A in TR 36.815	9.0.0	9.1.0
2010-06	RP-48	RP-100634	002		Reference corrections to LTE-A TR 36.815	9.0.0	9.1.0