ATIS 3GPP SPECIFICATION

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3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Coexistence between LTE-MTC and NR
(Release 16)

Approved by
WTSC
Wireless Technologies and Systems Committee

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3GPP Support Office

650 Route des Lucioles -- Sophia Antipolis

Valbonne - FRANCE

tel: +33 4 92 94 42 00   fax: +33 4 93 65 47 16 web: http://www.3gpp.org

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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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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 a technical report for the work item of R16 LTE-M [2]. The scope of the TR is as follows:

- For LTE-MTC in-band operation co-existence with NR, RAN4 will investigate the following:
- 15 kHz, 30 kHz, and 60 kHz numerologies for NR FR1 bands, with higher priority given first to 15 kHz and then to 30 kHz
- Study feasible LTE-MTC placement allocation without RF backward compatibility impact and compatible with Rel-13 LTE-MTC and Rel-15 NR, to operate simultaneously within various NR channel bandwidths
- Channel raster, PRB and subcarrier grid alignment between LTE-MTC and NR
- Synchronization issue between LTE-MTC and NR, including timing advance
- Frequency band support in LTE-MTC and NR
- Testability applicability
- Compatibility for Rel-15 NR and Rel-13/14/15 LTE-MTC

The case of NR configured with 15 kHz SS block SCS and the case of 30 kHz SS block SCS as specified in 38.101-1 are included in the study.The Rel-16 LTE-MTC and NR coexisting feature

2 References

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

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

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

[2] RP-190770, “Revised WID for Additional MTC enhancements for LTE”

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions 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:

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].

4 Background

In R15, LTE coexisting within a NR carrier is a feature enabling the flexible NR deployment targeting to achieve minimal impact the legacy LTE service. As LTE-MTC service is delivered within a LTE carrier, in general LTE-MTC co-existence with NR will follow the generic framework of the co-existence with NR and LTE. The focus of co-existing LTE-MTC and NR is to deploy MTC service within a NR carrier. The main benefit of the deploy MTC service within NR carrier is that the MTC legacy device and service will be migrate to the 5G network smoothly without backward compatibility issue.

5 Frequency band support for coexistence

Up to Rel-15, LTE-MTC can operate in the following LTE bands.

> UE category M1 and M2 is designed to operate in the E-UTRA operating bands 1, 2, 3, 4, 5, 7, 8, 11, 12, 13, 14, 18, 19, 20, 21, 25, 26, 27, 28, 31, 66, 71, 72, 73, 74 and 85 in both half duplex FDD mode and full-duplex FDD mode, and in bands 39, 40 and 41 in TDD mode.

In Rel-15, the NR operating bands in FR1 are specified as below (see note below the table).

Table 5-1: NR *operating bands* in FR1(3GPP TS 38.104)

NR *operating band*	**Uplink (UL) *operating band* BS receive / UE transmit $F_{UL,low}$ – $F_{UL,high}$**	**Downlink (DL) *operating band* BS transmit / UE receive $F_{DL,low}$ – $F_{DL,high}$**	**Duplex Mode**
n1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
n2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
n3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
n5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
n7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
n8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
n12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
n20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
n25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
n28	703 MHz – 748 MHz	758 MHz – 803 MHz	FDD
n34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
n38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
n39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
n40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
n41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
n50	1432 MHz – 1517 MHz	1432 MHz – 1517 MHz	TDD
n51	1427 MHz – 1432 MHz	1427 MHz – 1432 MHz	TDD
n65	1920 MHz – 2010 MHz	2110 MHz – 2200 MHz	FDD
n66	1710 MHz – 1780 MHz	2110 MHz – 2200 MHz	FDD
n70	1695 MHz – 1710 MHz	1995 MHz – 2020 MHz	FDD
n71	663 MHz – 698 MHz	617 MHz – 652 MHz	FDD
n74	1427 MHz – 1470 MHz	1475 MHz – 1518 MHz	FDD
n75	N/A	1432 MHz – 1517 MHz	SDL
n76	N/A	1427 MHz – 1432 MHz	SDL
n77	3300 MHz – 4200 MHz	3300 MHz – 4200 MHz	TDD
n78	3300 MHz – 3800 MHz	3300 MHz – 3800 MHz	TDD
n79	4400 MHz – 5000 MHz	4400 MHz – 5000 MHz	TDD
n80	1710 MHz – 1785 MHz	N/A	SUL
n81	880 MHz – 915 MHz	N/A	SUL
n82	832 MHz – 862 MHz	N/A	SUL
n83	703 MHz – 748 MHz	N/A	SUL
n84	1920 MHz – 1980 MHz	N/A	SUL
n86	1710 MHz – 1780 MHz	N/A	SUL
n90	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD

Note: The TDD operating band n90 is introduced in Rel-16 specifications as release independent band from Rel-15. Therefore, it is also added in Table 5-1 as it supports coexistence with LTE-MTC.

Hence potentially LTE-MTC can be operated in the following NR bands in Rel-15.

Table 5-2: NR operating bands supporting LTE-MTC coexistence in Rel-15.

NR operating band	Duplex Mode	Channel raster(kHz)	Max NR CBW (MHz)	Support of eMTC	Support of 7.5 kHz shift
n1	FDD	100	20	yes	yes
n2	FDD	100	20	yes	yes
n3	FDD	100	30	yes	yes
n5	FDD	100	20	yes	yes
n7	FDD	100	20	yes	yes
n8	FDD	100	20	yes	yes
n12	FDD	100	20	yes	yes
n20	FDD	100	20	yes	yes
n25	FDD	100	20	yes	yes
n28	FDD	100	20	yes	yes
n39	TDD	100	40	yes	
n40	TDD	100	100	yes	
n41	TDD	15/30	100	yes	
n66	FDD	100	40	yes	yes
n71	FDD	100	20	yes	yes
n74	FDD	100	20	yes	yes
n90	TDD	15/30/100	100	yes	yes

6 LTE-MTC in-band deployment configurations

Coexistence with NR is considered for LTE-MTC in-band operation within frequency bands listed in section 5. Different in-band deployment configurations based on FDM and TDM exist, which are considered below for different NR channel bandwidths.

For coexistence between NR and LTE-MTC in-band operation using FDM, the overlapping between static SSB signals occupying 20 RBs and the centre 6 PRBs of the LTE-MTC Narrowband (NB) carrying LTE PSS and NSS as well as PBCH channel needs to be avoided, since these signals are always active and thus generate interference to the coexisting system.

6.1 NR channel bandwidth: 5 MHz

For NR channel bandwidth of 5 MHz and SCS=15 kHz, 25 NR RBs can be allocated. The SSB signal occupies 20 RBs (3,6 MHz) leaving only 5 PRBs (0.9 MHz), which is too small for allocating 6 centre PRBs for LTE using FDM. Thus, for NR channel bandwidth of 5 MHz, only mixed TDM / FDM based co-existence is possible, requiring multiplexing of LTE-MTC and NR static signals in the time domain to avoid collison overlap, whilst other LTE-MTC and NR signals can be scheduled at the same time but on different RBs. This can be done in NR using symbol-level bitmap in the time-domain with repetition pattern in order to reserve resource for LTE-MTC. In LTE-MTC, resource can be reserved (that will be used by NR) using invalid subframe bitmap or MBSFN subframe configuration. Enhancements in Rel-16 are being investigated within the feature enhanced resource reservation. Further detail on mixed TDM / FDM is given in the section 8 on simultaneously operation with LTE-MTC and NR.

Note: For the mixed TDM / FDM based coexistence in this NR channel bandwidth, SCS of 30 kHz is not considered for NR as the guard band on the channel edge is twice as large as for SCS of 15 kHz.

6.2 NR channel bandwidth: 10 MHz

For NR channel bandwidth of 10 MHz and SCS=15 kHz, 52 NR RBs can be allocated. The SSB signal occupies 20 RBs (3.6 MHz) leaving an allocation of at least 16 RBs on one side of the SSB to place the centre 6 LTE PRBs. Taking into account that LTE requires a 5% guard band (single sided), the guard band for LTE-MTC 1.4 MHz equals 160 kHz and hence is less than the NR 10 MHz guard band (312.5 kHz). Thus, no extra guard band towards the channel edge is needed for this LTE-MTC NB allocation. Therefore, the LTE-MTC NB allocation may be placed at the outer NR RBs or closer to the SSB. Hence aside a mixed TDM/FDM based approach, a FDM based approach is possible for this NR channel bandwidth, which allows to place, in addition to the LTE-MTC NB allocation containing synchronization and broadcast channels and DC carrier, an LTE-MTC NB with 6 PRBs without DC carrier (e.g. adjacent to each other) on one side of the NR SSB, thus serving two LTE-MTC NB allocations, leaving room for NR CORESET and NR traffic channel. Further LTE-MTC NB allocations in case of higher LTE-MTC traffic may be possible, depending on the location of the SSB. Figure 6-1 below shows both deployment cases.

Note: the exact number of available PRBs for LTE-M depends on the NR sync raster and the NR carrier frequency. The consideration for SCS = 30 kHz is FFS. For multiple numerologies a guard band between NR and LTE-MTC NB allocations may be needed, see section 8.2.

6.3 NR channel bandwidth: 15 MHz

For NR channel bandwidth of 15 MHz and SCS=15 kHz, 79 RBs, respectively, can be allocated. The SSB signal occupies 20 RBs (3.6 MHz) leaving an allocation of at least 29 RBs, respectively, on one side of the SSB to place the centre 6 LTE PRBs and up to 3 LTE NBs without DC carrier (i.e. adjacent to each other), in total 4 LTE-MTC NB allocations, taking into account that the outer NR RBs again can be used by LTE-MTC NB allocations, similar as for 10 MHz channel bandwidth. Therefore, the LTE-MTC NB allocations may be placed at the outer NR RBs or closer to the SSB. Hence aside a mixed TDM/FDM based approach a FDM based approach is possible for this NR channel bandwidth placing LTE-MTC NB allocations on one side of the NR SSB, leaving room for the NR CORESET and NR traffic channel. Further LTE-MTC NB allocations in case of higher LTE-MTC traffic may be possible, depending on the location of the SSB.

Note: the exact number of available PRBs for LTE-M depends on the NR sync raster and the NR carrier frequency. The consideration for SCS = 30 kHz is FFS. For multiple numerologies a guard band between NR and LTE-MTC NB allocations may be needed, see section 8.2.

This NR channel bandwidth also allows to deploy an LTE-MTC 5 MHz inband allocation on one side of the SSB. Again, the guard band towards NR channel edge for the LTE allocation is lower than for NR (250 kHz vs. 382,5 kHz), hence outer NR RBs can be used as well. Within the LTE-MTC 5 MHz allocation, LTE NB allocations can be assigend to MTC UEs. This inband configuration can be used to also serve Cat M2 and non-BL CE UEs in coexistence scenarios.

Figure 6-1 below shows both deployment cases.

NR channel bandwidths, larger than 15 MHz and ranging up to 100 MHz, are also relevant for coexistence with LTE-MTC, and require similar approaches as depicted above.

Figure 6-1 illustrates the above depicted exemplary LTE-MTC in-band deployment configurations using FDM. For 5 MHz NR channel bandwith, no FDM between NR and LTE-MTC is possible, thus mixed TDM / FDM must be used.

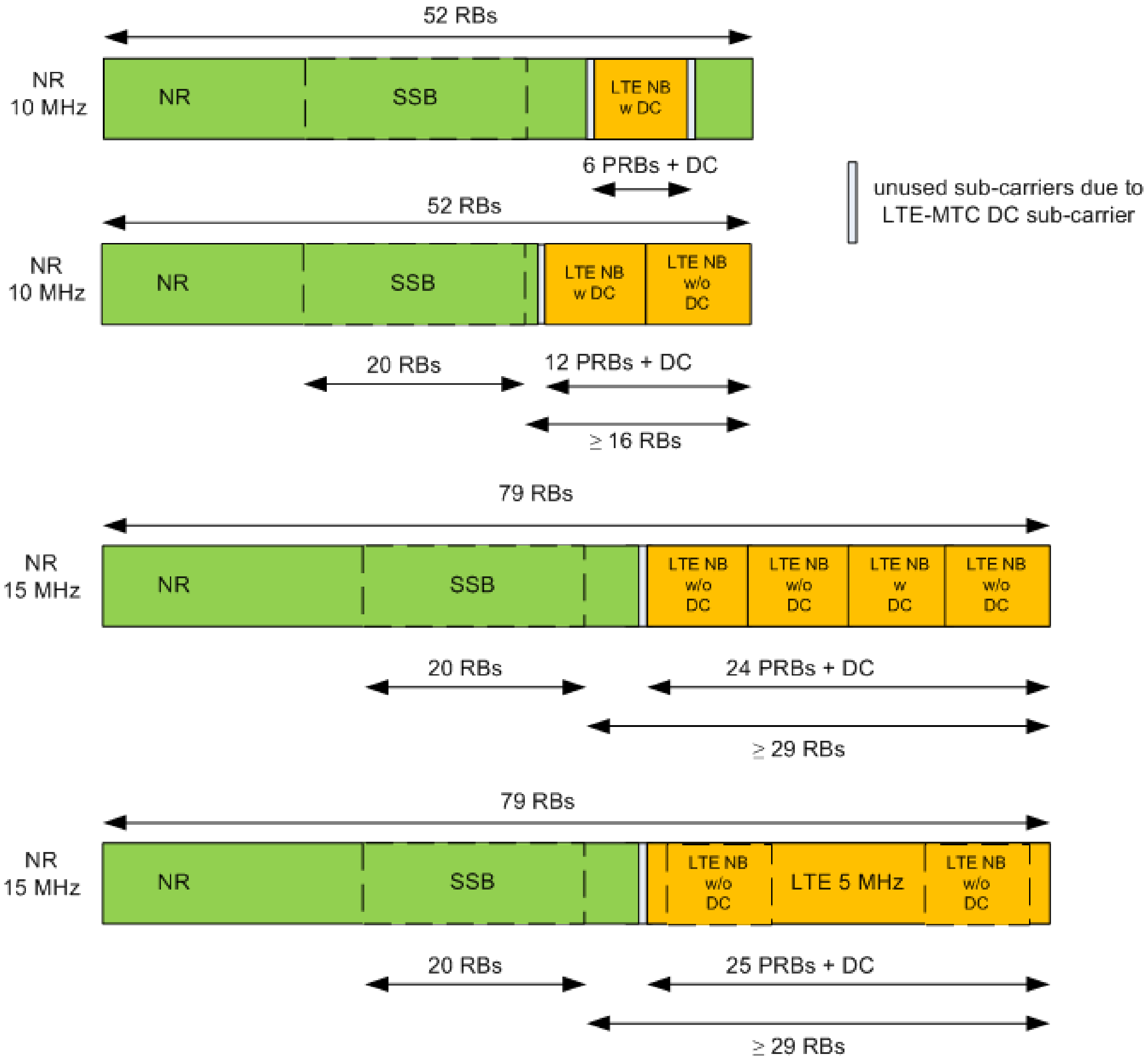


Figure 6-1: Exemplary in-band LTE-MTC deployment configurations including legacy 5 MHz LTE allocation for different NR channel bandwidths using FDM.

7 Channel raster, PRB and subcarrier grid alignment

7.1 Minimal guard band, subcarrier grid alignment for LTE based and SCS based channel rasters

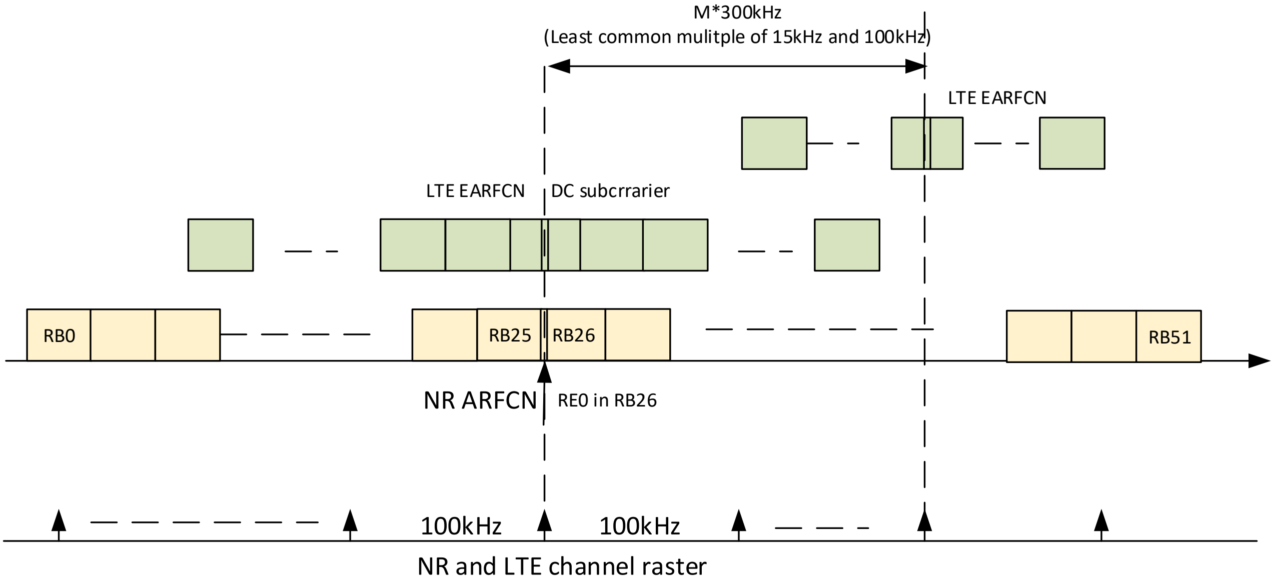


Figure 7.1-1: LTE EARFCN configuration within NR carrier with NR channel raster = 100kHz

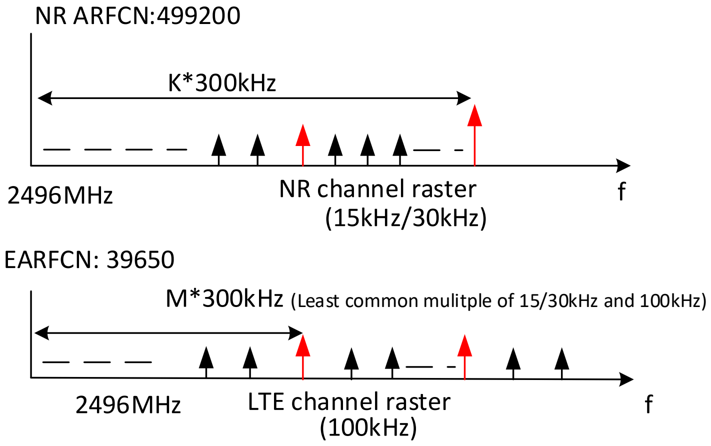


Figure 7.1-2: LTE EARFCN configuration within NR carrier with NR channel raster = 15kHz or 30kHz

In LTE channel raster setting in downlink, there is a DC subcarrier where the LTE EARFCN coincides with the center of this subcarrier. Because the NR channel raster definition considers the co- existence with 100kHz channel raster and subcarrier alignment with LTE, for the NR bands that support the LTE-MTC co-existence with 100kHz channel raster for FDD band, the LTE EARFCN can coincide with NR ARFCN at the same frequency location on the center of NR carrier. This means for downlink the LTE and NR can be aligned in the subcarrier level, but not in PRB level due to the DC subcarrier in LTE**.**

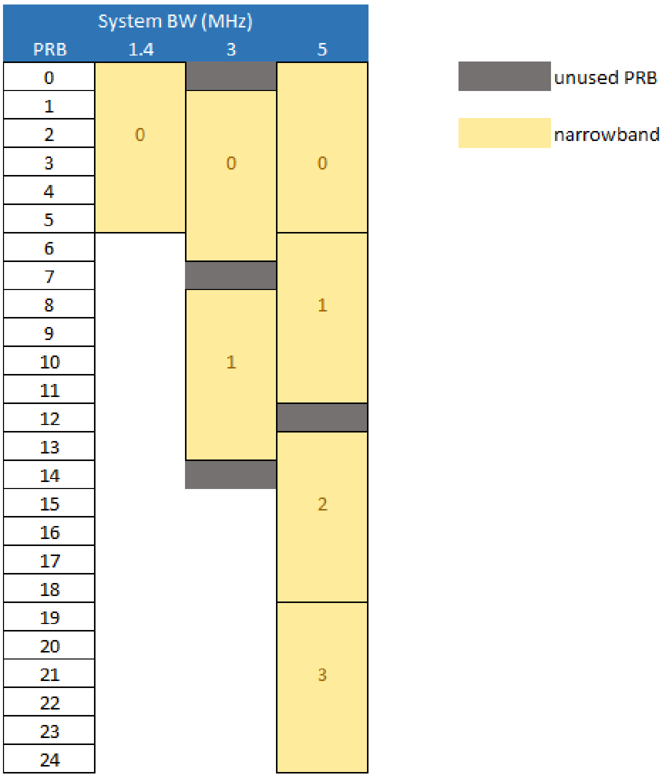
When NR channel raster is 100kHz, as Figure 7.1-1 shows, if LTE carrier is configured with other EARFCN than the center of NR carrier (NR-ARFCN), due to the subcarrier alignment and 100kHz raster, the EARFCN coinciding with NR channel raster will be multiple of 300kHz offset which is the least common multiple of 15kHz and 100kHz. In Figure 7-2, an example is given for a 10MHz NR carrier and a 5 MHz LTE carrier.

When NR channel raster is 15kHz or 30kHz (e.g n41), to have the subcarrier aligned with LTE and NR, the LTE EARFCN need to have multiple 300kHz offset with NR ARFCN as shown in Figure 7.2-2. For example, when K=M, LTE EARFCN will coincide with NR ARFCN, the subcarrier alignment will be achieved. In another case, if K is not equal to M, there will be multiple 300kHz between EARFCN and NR-ARFCN, and the subcarrier alignment will still be achieved.

7.2 PRB alignment

7.2.1 Impact of LTE-MTC Narrowband Operation

LTE-MTC UEs reuse legacy LTE PSS/SSS/PBCH for initial cell selection, which occupies the centre 72 subcarriers in the system BW excluding the DC subcarrier. After MSG1 in the random access procedure, the UE may use only 6 PRBs in a narrowband for transmissions and receptions if no frequency-hopping is configured. Otherwise hopping between multiple narrowbands may be performed. The mapping between the narrowband and the PRB is defined in 3GPP TS 36.211 [3] Section 6.2.7. Figure 7.2-1 illustrates the mapping for system BW up to 5 MHz.



	System BW (MHz)		
PRB	1.4	3	5
0	0	▨	0
1		0	
2			
3			
4			
5			
6			1
7		▨	
8		1	
9			
10			
11			
12			▨
13			2
14		▨	
15			
16			
17			
18			
19			3
20			
21			
22			
23			
24			

▨ unused PRB

🟨 narrowband

Figure 7.2.1-1 Mapping between LTE PRB and Narrowband

For up to at least Rel-15 LTE-MTC operation in NR in-band, the number of NR PRBs reserved for LTE-MTC should be large enough to accommodate all the PRBs within the LTE transmission BW configuration. Particularly, the PUCCH channel in the UL always uses the edge PRBs within the system BW.

7.2.2 Intuitive Analysis

Consider the case of SCS=15 kHz for NR. A total of $N_{\text{RB}}^{\text{DL}}+1$ consecutive NR PRBs in the DL need to be reserved for LTE-MTC owing to the unused DC subcarrier. The set of allowed values for $N_{\text{RB}}^{\text{DL}}$ is given by 3GPP TS 36.104. Depending on the parity of $N_{\text{RB}}^{\text{DL}}$, the DC subcarrier is either in the middle of a LTE PRB or in between two LTE PRBs. It's easily seen that LTE PRBs can be aligned with NR PRBs if the following conditions are satisfied, and at most half of the PRBs in the LTE system BW can be aligned:

1) The LTE DC subcarrier coincides with
   a) the lowest (highest) subcarrier, i.e. subcarrier index 0 (11) of a NR PRB if $N_{\text{RB}}^{\text{DL}}$ is even;
   b) the middle subcarrier, i.e. subcarrier index 6 (5) of a NR PRB if $N_{\text{RB}}^{\text{DL}}$ is odd;
2) The LTE PRB is on the lower (upper) side of the LTE DC subcarrier.

In the UL, the LTE DC subcarrier is a valid subcarrier that belongs to a PRB and a 7.5 kHz frequency shift is employed to mitigate the effect of carrier leakage. Hence, the LTE PRBs may be aligned with the NR PRBs only if the operating NR band also supports 7.5 kHz frequency shift. Furthermore, owing to the restrictions of TX-RX frequency separation as defined in 3GPP TS 36.101, the aforementioned conditions on the DL DC subcarrier should be met so that the LTE DL PRBs on the lower side of the DC subcarrier are aligned with the NR DL PRBs. As a result, all of the LTE UL PRBs can be aligned with the NR UL PRBs.

Figure 7.2-2 illustrates an example of 1.4 MHz LTE carrier inside a NR carrier. In the DL, the LTE DC subcarrier coincides with the subcarrier 0 of an NR PRB. As a result, LTE PRB 0, 1 and 2 are aligned with NR PRBs. In the UL, all LTE PRBs are aligned with NR PRBs after 7.5 kHz shift. Additionally, Figure 7.2-3 illustrates an example of 3 MHz LTE carrier inside a NR carrier. In the DL, the LTE DC subcarrier coincides with the subcarrier 6 of an NR PRB. As a result, LTE PRB 0-6 are aligned with NR PRBs. In the UL, all LTE PRBs are aligned with NR PRBs after 7.5 kHz shift.

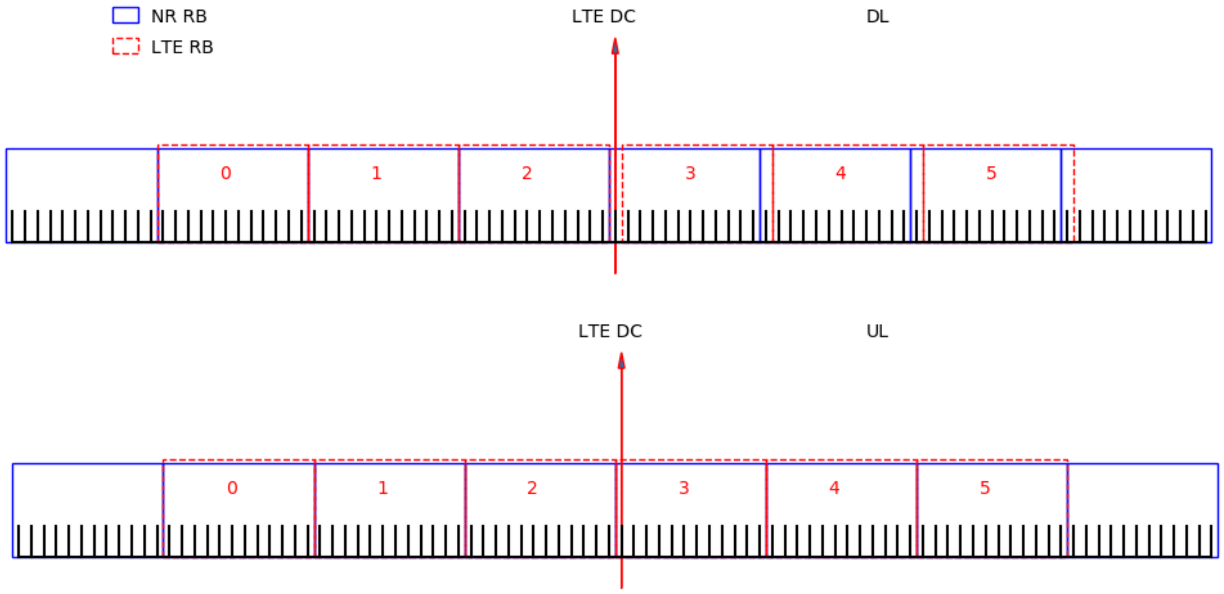


Figure 7.2.2-1: Example PRB alignment for a 1.4 MHz LTE carrier (having one LTE-MTC NB) inside a NR carrier

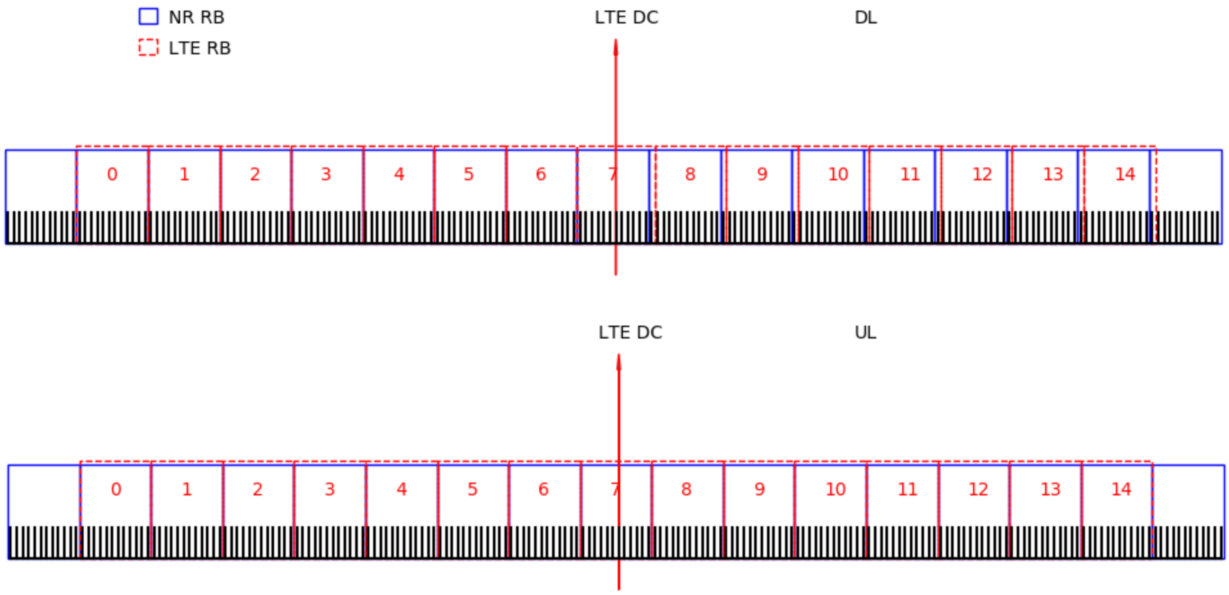


Figure 7.2.2-2: Example PRB alignment for a 3 MHz LTE carrier (having two LTE-MTC NBs) inside a NR carrier

If neither condition #1 nor condition #2 is satisfied, the number of so-called “outlying” subcarriers in the DL LTE carrier would be more than one. The outlying subcarriers are those in the lower/upper edge of the LTE carrier and only partially overlap with a NR RB. Assuming that the LTE DC subcarrier coincides with subcarrier index r

$, (0 \le r \le 11)$ within a NR RB, the number of outlying subcarriers can be derived as:

Table 7.2.2-1: Number of outlying subcarriers in LTE-MTC DL

	Lower edge	Upper edge
LTE $N_{\mathrm{RB}}^{\mathrm{DL}}$ is even	mod(12-r, 12)	mod(r+1, 12)
LTE $N_{\mathrm{RB}}^{\mathrm{DL}}$ is odd	mod(6-r, 12)	mod(r+7, 12)

7.2.3 Quantitative analysis

Let $N_{\mathrm{RB}}^{\mathrm{NR}}$and $N_{\mathrm{RB}}^{\mathrm{LTE}}$ denote the maximum number of RBs in the NR and LTE carrier, respectively. Let $F_{\mathrm{REF}}^{\mathrm{NR}}$ and F_{c}^{LTE} denotes the RF reference frequency for NR and carrier frequency for LTE, respectively. It’s known that:

- NR RF reference frequency $F_{\mathrm{REF}}^{\mathrm{NR}}$ corresponds to subcarrier 0 of RB $\frac{N_{\mathrm{RB}}^{\mathrm{NR}}}{2}$ if $N_{\mathrm{RB}}^{\mathrm{NR}}$ is even, and it corresponds to subcarrier 6 of RB $\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{NR}}}{2} \right\rfloor$ if $N_{\mathrm{RB}}^{\mathrm{NR}}$ is odd;
- LTE carrier frequency F_{c}^{LTE} corresponds to the DC subcarrier with extra 7.5 kHz offset in the UL. In the DL, it locates between two adjacent RBs if $N_{\mathrm{RB}}^{\mathrm{LTE}}$ is even, and it locates in the middle of a RB if $N_{\mathrm{RB}}^{\mathrm{LTE}}$ is odd.

In order to optimize resource utilization, it is desired to align LTE PRBs with NR PRBs (in fact at most half of the PRBs in the DL and all in the UL as described in Section 7.2.2). In the following, we further formulate the conditions described in Section 7.2.2 based on different NR channel raster sizes.

7.2.3.1 NR 100 kHz Channel Raster

For subcarrier alignment (SCS=15 kHz), the NR RF reference frequency and LTE carrier frequency should satisfy the following condition:

$$100m - 100n = 15k \qquad (7.2.3.1\text{-}1)$$

with:

- m being an integer identifying the LTE carrier on the 100 kHz raster, i.e. $F_{\mathrm{c}}^{\mathrm{LTE}} = 100m$ kHz;
- n being an integer identifying the NR carrier on the 100 kHz raster, i.e. $F_{\mathrm{REF}}^{\mathrm{NR}} = 100n$ kHz;
- k being an integer representing the subcarrier offset from the NR RF reference frequency.

Re-write Eq. (7.2.3.1-1) as:

$$100(m - n) = 15k \qquad (7.2.3.1\text{-}2)$$

For the sake of the variable k being an integer, the value of $m - n$ has to be a multiple of 3, i.e., $m - n = 3p$, with p being an integer. Therefore, Eq. (7.2.3.1-2) can be re-written as:

$$k = 20p \text{ , with } p \text{ being an integer} \quad (7.2.3.1\text{-}3).$$

This means that the offset of the LTE carrier from the NR RF reference frequency should be a multiple of 20 subcarriers (i.e., a multiple of 300 kHz). We also have $k > 0$ if the LTE carrier is on the upper side of the NR carrier and $k < 0$ if the LTE carrier is on the lower side. Next we further derive the LTE carrier position in terms of RB offset as well as subcarrier index within a RB.

If $N_{\mathrm{RB}}^{\mathrm{NR}}$ is even, the NR RF reference frequency $F_{\mathrm{REF}}^{\mathrm{NR}}$ corresponds to subcarrier 0 of RB $\frac{N_{\mathrm{RB}}^{\mathrm{NR}}}{2}$. Hence, we have:

- $q \triangleq \left\lfloor \frac{k}{12} \right\rfloor$, the RB offset from the NR RB containing the subcarrier corresponding to $F_{\mathrm{REF}}^{\mathrm{NR}}$
- $r \triangleq \mathrm{mod}(k, 12),\ 0 \le r \le 11,$ the index of the subcarrier corresponding to $F_{\mathrm{c}}^{\mathrm{LTE}}$

With these definitions, we re-write $k = 20p$ as:

$$20p = 12q + r, \qquad (7.2.3.1\text{-}4)$$

$$\text{or } r = 4(5p - 3q) \quad (7.2.3.1\text{-}5).$$

It can be seen that valid values for subcarrier index r are: 0, 4 and 8. Note that the value of RB offset q is limited by the NR channel bandwidth, i.e. $-\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{NR}}}{2} \right\rfloor \le q \le \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{NR}}}{2} \right\rfloor$. For ensuring subcarrier alignment between the LTE-MTC carrier and the NR carrier, the task is to find a suitable solution of (p, q, r) that satisfies Eq. (7.2.3.1-4). Further considering PRB alignment, the condition #1a as described in Section 7.2.2 may be met if additional constraint of $r = 0$ is added. However, the condition #1b as described in Section 7.2.2 can never be met since $r = 6 \text{ or } 5$ is not valid. This is also indicated by the number of LTE outlying subcarriers corresponding to NR subcarrier index $r = 0, 4 \text{ or } 8$ as shown in Table 7.2.3.1-1, which matches the observation in RAN1 [4].

Table 7.2.3.1-1: Number of outlying subcarriers in LTE-MTC DL when the DC subcarrier coincides with NR subcarrier index $r = 0, 4 \text{ or } 8$ ($N_{\mathrm{RB}}^{\mathrm{NR}}$ is even)

	Lower edge	Upper edge
LTE $N_{\mathrm{RB}}^{\mathrm{DL}}$ is even	**0**, 8, 4	**1**, 5, 9
LTE $N_{\mathrm{RB}}^{\mathrm{DL}}$ is odd	6, 2, 10	7, 11, 3

Note: The value shown in bold corresponds to the condition #1a in Section 7.2.2.

On the other hand, if $N_{\mathrm{RB}}^{\mathrm{NR}}$ is odd, the NR RF reference frequency $F_{\mathrm{REF}}^{\mathrm{NR}}$ corresponds to subcarrier 6 of RB $\frac{N_{\mathrm{RB}}^{\mathrm{NR}}}{2}$.

Taking this offset into account, we have $q \triangleq \left\lfloor \frac{k+6}{12} \right\rfloor$ for RB offset and $r \triangleq \mathrm{mod}(k+6, 12)$ for subcarrier index. And Eq. (7.2.3.1-3) can be re-written as:

$$20p + 6 = 12q + r, \qquad (7.2.3.1\text{-}6)$$

$$\text{or } r = 2 * (10p - 3 * (2q - 1)) \quad (7.2.3.1\text{-}7).$$

It can be seen that valid values for subcarrier index r are: 2, 6 and 10. For ensuring subcarrier alignment between the LTE-MTC carrier and the NR carrier, the task is to find a suitable solution of (p, q, r) that satisfies Eq. (7.2.3.1-6). Further considering PRB alignment, the condition #1b as described in Section 7.2.2 may be met if additional constraint of $r = 6$ is added. However, the condition #1a as described in Section 7.2.2 can never be met since $r = 0 \text{ or } 11$ is not valid. This is also indicated by the number of LTE outlying subcarriers corresponding to NR subcarrier index $r = 2, 6 \text{ or } 10$ as shown in Table 7.2.3.1-2, which matches the observation in RAN1 [4].

Table 7.2.3.1-2: Number of outlying subcarriers in LTE-MTC DL when the DC subcarrier coincides with NR subcarrier index $r = 2, 6 \text{ or } 10$ ($N_{\mathrm{RB}}^{\mathrm{NR}}$ is odd)

	Lower edge	Upper edge
LTE $N_{\mathrm{RB}}^{\mathrm{DL}}$ is even	10, 6, 2	3, 7, 11
LTE $N_{\mathrm{RB}}^{\mathrm{DL}}$ is odd	4, **0**, 8	9, **1**, 5

Note: The value shown in bold corresponds to the condition #1b in Section 7.2.2.

7.2.3.2 NR 15 kHz Channel Raster

Corresponding to the E-UTRA bands that support LTE-MTC, most of the NR counterparts use 100 kHz channel raster. So far, only band n41 uses SCS-based channel raster. For the sake of PRB alignment, only SCS=15 kHz is considered. Considering subcarrier alignment, the NR reference frequency and LTE carrier frequency should satisfy the following condition:

$$100m - 15n = 15k, \qquad (7.2.3.2\text{-}1)$$

with:

m being an integer identifying the LTE carrier on the 100 kHz raster, i.e. $F_{\mathrm{c}}^{\mathrm{LTE}} = 100m$ kHz;

n being an integer identifying the NR carrier on the 15 kHz raster, i.e. $F_{\mathrm{REF}}^{\mathrm{NR}} = 15n$ kHz;

k being an integer representing the subcarrier offset from the NR RF reference frequency.

Rewrite Eq. (7.2.3.1-1) as:

$$100m = 15(n + k). \qquad (7.2.3.2\text{-}2)$$

This means that the LTE carrier should be on a raster of 300 kHz, i.e. $m = 3p$, with p being an integer. Together with Eq. (7.2.3.2-2), we have:

$$k = 20p - n. \qquad (7.2.3.2\text{-}3)$$

Reusing the definition of RB offset q and subcarrier index r in Section 7.2.3.1, we have:

$$20p - n = 12q + r, \text{ if } N_{\mathrm{RB}}^{\mathrm{NR}} \text{ is even}, \qquad (7.2.3.2\text{-}4)$$

$$20p - n + 6 = 12q + r, \text{ if } N_{\mathrm{RB}}^{\mathrm{NR}} \text{ is odd}. \qquad (7.2.3.2\text{-}5)$$

Note that the values of p and q are limited by the NR channel bandwidth, e.g. $-\left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{NR}}}{2} \right\rfloor \le q \le \left\lfloor \frac{N_{\mathrm{RB}}^{\mathrm{NR}}}{2} \right\rfloor$. For ensuring subcarrier alignment between the LTE-MTC carrier and the NR carrier, the task is to find a suitable solution of (p, q, r) that satisfies Eq. (7.2.3.2-4) or Eq. (7.2.3.2-5), for a given NR reference frequency, i.e. fixed n. Further considering PRB alignment, the conditions on subcarrier index r as described in Section 7.2.2 should be met as additional constraints. Note that such a solution may not always exist.

7.2.4 Summary

The conditions for PRB alignment between LTE-MTC carrier and NR carrier are discussed. Section 7.2.2 provides an intuitive analysis, which is confirmed by the quantitative analysis in Section 7.2.3. Additionally, more insights are acquired through the numerical analysis, which are summarized in the following tables.

Table 7.2.4-1: Conditions for subcarrier alignment between NR and LTE-MTC

NR Channel Raster Size	Condition	Note
100 kHz	Eq (7.2.3.1-3)	The frequency offset between the LTE-MTC carrier and the NR carrier should be multiple of 300 kHz.
15 kHz	Eq (7.2.3.2-3)	The LTE-MTC carrier frequency should be a multiple of 300 kHz.

Table 7.2.4-2: Constraints on the location of LTE-MTC inside NR in terms of RB offset and subcarrier index

NR Channel Raster Size	$N_{\mathrm{RB}}^{\mathrm{NR}}$ is even	$N_{\mathrm{RB}}^{\mathrm{NR}}$ is odd
100 kHz	Eq (7.2.3.1-4)	Eq (7.2.3.1-6)
15 kHz	Eq (7.2.3.2-4)	Eq (7.2.3.2-5)

Based on the above listed conditions, it is also found that the choice of the NR subcarrier index (within a RB) for placing the LTE-MTC carrier is limited. And different choices result in different number of outlying subcarriers in the LTE-MTC carrier, for which the minimization is usually desired in order to optimize spectrum utilization. Table 7.2.4-3 summarizes the observations for 100 kHz NR channel raster size.

Table 7.2.4-3: Observations on the NR subcarrier index suitable for LTE MTC and the corresponding number of outlying subcarriers (NR channel raster = 100 kHz)

	$N_{\mathrm{RB}}^{\mathrm{NR}}$ is even	$N_{\mathrm{RB}}^{\mathrm{NR}}$ is odd
Subcarrier index within a RB	0, 4, 8	2, 6, 10
Number of outlying subcarriers	Table 7.2.3.1-1	Table 7.2.3.1-2

8 Simultaneous operation with LTE-MTC and NR

8.1 Collision avoidance for static and other NR signals

When an LTE-M service coexists with NR within a NR carrier, the legacy LTE-M device will operate on the carrier configured as a normal LTE carrier without awareness of NR signals. The NR device, however, could be aware of other technology with NR R15 feature of rate-matching the PDSCH around resource elements used by LTE. For the signal sent from LTE which cannot be rate-matched by the NR device, scheduler or configuration coordination is needed to avoid collision between NR and LTE transmissions (or signals). The LTE signals can be classified as static signals and dynamic signals, where the static signals are “always on” signals and shall be always transmitted. The dynamic signals are traffic specific and scheduled in the real time.

An LTE carrier resource grid for FDD band is shown in Figure 8-1.

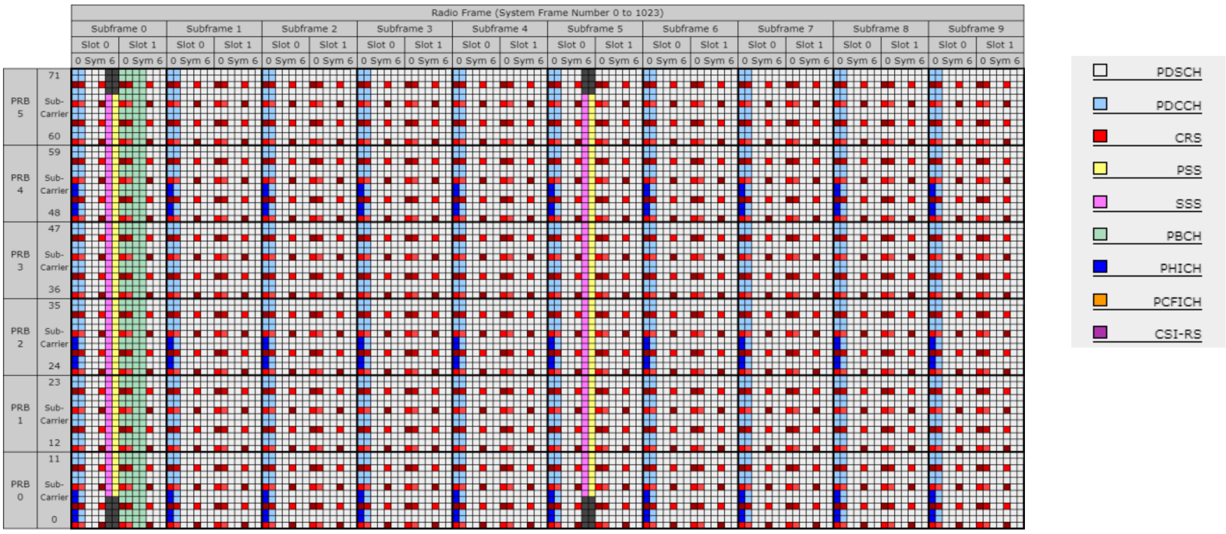


Figure 8-1: Resource grid for downlink signal of the LTE carrier BW=1.4MHz and 4 CRS antenna ports.

As shown in Figure 8-1 for the downlink LTE signal (FDD band) without the scheduled PDSCH,

1) PDCCH in the first 1, 2 or 3 symbols depending on the CFI configuration, minimum is 1 symbol for CFI=1 for every subframe (except in the special case with 1.4 MHz system bandwidth when the number of symbols is 2, 3 or 4),
2) PSS/SSS is configured every 5 ms at symbol 5, 6 in the middle 6 PRBs.
3) PBCH is transmitted at slot 1 every 10ms.
4) CRS (4 ports) signal on symbols 0, 1, 4, 7, 8, 11,
5) The DMRS (4 port), on symbols 5, 6, 12, 13,
6) CSI-RS (4 ports) every 10 ms, on symbols 5, 6, 12, 13.

For uplink LTE signals, they are PUCCH and PUSCH, PRACH and SRS which is configurable.

As the DMRS and CSI-RS occupy PDSCH positions, they can be treated as dynamic signals same as PDSCH which is UE specific. NR signals should avoid the overlapping of LTE static signals so the legacy LTE UE performance will not be affected.

For LTE-M, the cell-specific subframe bitmap broadcasted on the System Information (SI) indicates which subframes are capable of LTE-M transmissions. On top of this, there are additional signals MPDCCH and RSS signal:

MPDCCH: MPDCCH carries the LTE-M downlink control information (DCI) and maps to the LTE PDSCH region.

RSS (Resynchronization Signal): Maps to the LTE PDSCH region at periodicity of 8, 16, 32 or 40 subframes and 2 consecutive PRBs.

LTE-M subframes can be configured as valid or invalid for LTE-M transmission, and invalid subframes are not used for LTE-M transmissions. LTE-M signals occupy the NR PDSCH region which makes it possible for an NR UE to perform rate matching around it. For the PDCCH, PSS/SSS/PBCH in the middle 6 PRBs, and CRS are static signals that are always transmitted.

NR has the following channels and signals:

1) SSB, default 20ms periodicity,
2) TRS, needed for PDSCH demodulation
3) CORESET #0 for transmitting PDCCH for SIB1 scheduling SIB1
4) PDCCH at symbol 2,
5) PDSCH + DMRS
6) CSI-RS, symbol 12 and 13

In the NR signals, the SSB signal is a mandatory transmission for the UE initial cell search and thus is a static signal. CORESET #0 is also a static signal which is mandatory to transmit. The other reference signals to help demodulate the PDSCH should not collide with LTE signal so the NR UE performance would be preserved. A solution for avoiding the LTE static signals when NR static signals are transmitted will be needed and one of the options is to use the MBSFN subframes in LTE and the other one is using LTE-MTC invalid subframe bitmaps.

MBSFN in LTE:

MBSFN is an LTE Release 9 feature, so for the LTE-M from R13, there is no problem for the LTE-M device with the awareness of the MBSFN subframe configuration. The LTE-M will ignore these MBSFN subframes so these MBMS subframes could be used for NR to transmit the static signals or other important signals which otherwise would collide with LTE signals.

The number and locations of MBSFN subframes within a specific radio frame are defined in SIB2 with MBSFN-SubframeConfig IE. It is determined by two parameters radioframeAllocationPeriod and radioframeAllocationOffset, as long as below equation is fulfilled for the MBSFN configuration,

[SFN] *mod* [radioframeAllocationPeriod] = radioframeAllocationOffset

With the MBSFN subframe, LTE-M device could ignore the NR “always on” signal contained in MBSFN frames seen by LTE-M device. Furthermore, in R15, NR can reserve resources using a bitmap for the NR PDSCH region, so NR signals can be rate matched by NR UEs around the resource elements used by LTE signals. By utilizing these methods and scheduler help for uplink, the LTE and NR will avoid the colliding signal each other and can coexist within a NR carrier. Table 8-1 and Table 8-2 lists summary of protection schemes for static signals in two system.

Table 8-1: NR (SCS=15kHz) solution to avoid the collision with LTE signals

	Signal	symbol position	frequency position	NR solution
LTE-M DL signal	PSS/SSS,	symbol 5, 6	middle 6 PRB	resource reserve with NR rate matching
	PBCH	slot 0	middle 6 PRB	resource reserve with NR rate matching
	CRS	0,1,4,7,8,11	interleaved within whole LTE PRB	reserve resource with NR rate matching
	DMRS	5,6, 12,13		resource reserve with NR rate matching
	CSI-RS	5,6,12,13		resource reserve with NR rate matching
	PDCCH	0,1		NR PDCCH only on symbol 2
	PDSCH			resource reserve with NR rate matching
	MPDCCH			resource reserve with NR rate matching
LTE-M UL signal	PRACH			Scheduling
	PUCCH		edge PRB at LTE BW	Scheduling
	SRS			Scheduling

Table 8-2: LTE-M solution to avoid the collision with NR signals (SCS=15kHz)

	Signal	symbol position	frequency position	LTE-M solution
NR DL signal	SSB	2,3,4,5	20 PRB, sync raster	MBSFN frame and/or configure invalid subframe for LTE-M
	CORESET SIB1			MBSFN frame and/or configure invalid subframe for LTE-M
	PDCCH	2		CFI max=2, avoid overlap of LTE PDCCH to NR PDCCH and/or configure invalid subframe for LTE-M
	PDSCH			Scheduling and/or configure invalid subframe for LTE-M
	DMRS			MBSFN and/or configure invalid subframe for LTE-M
	TRS			MBSFN and/or configure invalid subframe for LTE-M
	CSI-RS			MBSFN and/or configure invalid subframe for LTE-M
NR UL signal	PRACH			Scheduling;
	PUCCH			Scheduling
	SRS			Scheduling

8.2 Numerologies

As NR could support several numerology, e.g. 15KHz, 30KHz and 60KHz in FR1 which might be different from LTE-MTC numerologies (only support 15KHz SCS in downlink and uplink), there might exist mixed numerology configuration which could result in interference between NR subcarrier and LTE-MTC subcarrier In general, guardband between different numerology should be reserved for performance protection, however this should be up to the BS implementation. Similar as the mixed numerology in the NR scenarios, no requirement is defined for mixed numerology between NR and LTE-MTC. In case of LTE-MTC is located close to the channel edge of NR channel bandwidth, the minimum guardband at channel edge is illustrated in Figure 7.1-1.

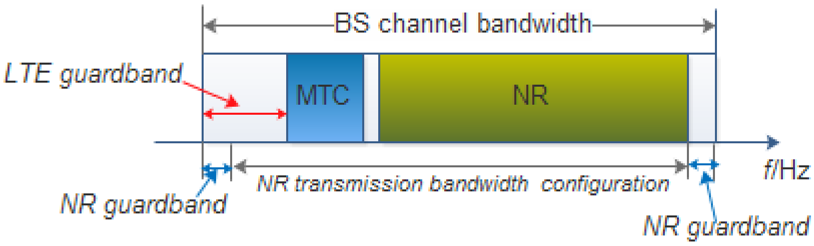


Figure 7.1-1. the guard band for NR coexist with MTC

8.3 Power boosting for LTE-MTC

This section investigates the impact from power boosting applied to LTE-MTC for coexistence with NR.

8.3.1 Signalling range

Power boosting for LTE-MTC was introduced in Rel-15 for the purpose of enhanced coverage and improved power saving. In particular this is applied to

RSS (Re-Synchronization Signal) introduced in Rel-15 to allow the BL/CE UE to perform faster network synchronization in DRX periods after wake-up from light sleep. RSS is transmitted as part of MPDCCH.

RSS uses two consecutive RBs which can be allocated anywhere, according to 3GPP TS 36.331, in the configured LTE channel bandwidth (i.e. frequency location is one RB pair out of 100 RBs covering the 20 MHz bandwidth case).

According to 3GPP TS 36.213, the power offset for RSS EPRE versus CRS EPRE depends on the number of cell specific antenna ports. For one cell specific antenna port, the power offset versus CRS EPRE can be {0, 3, 4.8 and 6 dB), as specified in 3GPP TS 36.331. Power stealing across other RBs can be applied.

However, RSS is transmitted with given periodicity and at most in 25% of the subframes (3GPP TS 36.331).

MWUS (MTC Wake-Up Signal) introduced in Rel-15 to allow the BL/CE UE to save energy for the purpose of paging monitoring. Rather than to decode the paging channel data for determining if a paging request is received, a wake-up signal was specified to indicate a valid page in the next PO to the UE. MWUS is transmitted as part of MPDCCH.

MWUS uses two consecutive RBs which are allocated in the configured paging narrowband (6 RBs), thus allowing for three disjunct allocations. According to 3GPP TS 36.331, only one RB pair is allocated per cell for MWUS.

According to 3GPP TS 36.213, the power offset for MWUS EPRE versus CRS EPRE depends on the number of cell specific antenna ports. For one cell specific antenna port, the power offset versus CRS EPRE can be {0, 1.8, 3 and 4.8 dB), as specified in 3GPP TS 36.331. However, MWUS sequence has a limited duration and is not transmitted in all subframes. Power stealing across other RBs can be applied.

GMWUS (group MWUS) added in Rel-16 to allow the BL/CE UEs to be grouped and to dedicate a wake-up signal not to all UEs (common WUS) but to a particular UE group to make paging monitoring even more efficient. GMWUS is transmitted as part of MPDCCH.

GMWUS uses two consecutive RBs which are allocated in the configured paging narrowband (6 RBs), allowing for two disjunct allocations. Up to 2 GMWUS can be allocated per cell. In case 2 GMWUS and 1 MWUS are FDM'ed in the paging narrowband, all 6 RBs in the NB are transmitted.

For GMWUS, the same power offset versus CRS EPRE applies as for MWUS. Thus, for a cell transmitting MWUS and 2 GMWUS, the power offset versus CRS may go up to 4.8 dB in the narrowband, which requires power stealing from outside the narrowband. Again, GMWUS sequence has a limited duration and is not transmitted in all subframes.

Thus, LTE-MTC RBs carrying RSS, MWUS or GMWUS in MPDCCH, can have a higher PSD versus other LTE-MTC RBs of up to 6 dB due to the signalling range.

8.3.2 Minimum NR BS requirements for RE Power control dynamic range

On the other side, minimum requirements for power boosting for NR BS exist in 3GPP TS 38.104. In particular, subclause 6.3.2.2 specifies minimum requirements for RE power control dynamic range, where power offset above and below average RE power for a BS at maximum output power is specified. This defines a range between -6 dB and +4 dB for QPSK (PDCCH) and between -6 dB and +3 dB for QPSK (PDSCH), which needs to be supported by the NR BS. These power dynamic ranges are the same as specified for LTE in 3GPP TS 36.104, subclause 6.3.1.1. As MPDCCH maps to LTE PDSCH region and also uses QPSK modulation, from RF perspective similar power boosting performance is expected to be achieved as for NR / LTE RE power boosting for PDSCH (using QPSK).

In conclusion, the NR BS is not mandated to support power boosting for LTE-MTC RBs, which are allocated within the NR transmission bandwidth. The NR BS may support power boosting for LTE-MTC RBs according to the above depicted signalling range, provided that the network still fulfils existing RF performance requirements.

8.4 Specific aspects for TDD

LTE-MTC supports all E-UTRA TDD configurations as specified in 3GPP TS 36.211 [3]. In the meantime, NR TDD configurations are very flexible. Not only slots but also individual symbols within a slot can be configured as either DL, UL or flexible (i.e. GP). For the sake of co-existence, the NR TDD configuration should be set up to match that of LTE-MTC.

More explicitly, two different patterns may be configured via the IE TDD-UL-DL-ConfigCommon in SIB1. Furthermore, the common settings may be overridden by UE specific configuration: TDD-UL-DL-ConfigDedicated. Table 8.4-1 shows the details of the RRC signalling.

Table 8.4-3: RRC Signaling for NR TDD Configuration

Field Name	Note
TDD-UL-DL-ConfigCommon:	**Signalled by SIB1**
referenceSubcarrierSpacing	Subcarrier spacing in kHz: 15, 30, 60, etc
dl-UL-TransmissionPeriodicity	Pattern periodicity in ms
nrofDownlinkSlots	Can be used to configure DL transmissions that matches the duration of DL subframes or forms part of the DwPTS in LTE-MTC
nrofDownlinkSymbols	Specifies a partial DL slot, together with other DL slots (if needed), can match the duration of DwPTS in LTE-MTC
nrofUplinkSymbols	Specifies a partial UL slot, together with other UL slots (if needed), can match the duration of UpPTS in LTE-MTC
nrofUplinkSlots	Can be used to configure UL transmissions that matches the duration of UL subframes or forms part of the UpPTS in LTE-MTC
TDD-UL-DL-ConfigDedicated:	UE specific RRC signalling
slotIndex	Depending on the SCS, the duration of a NR slot may be less (i.e. ½, ¼, etc) or equal to a subframe in LTE-MTC
allDownlink	The whole slot is for DL, more than one DL slot may be needed to match the duration of a DL subframe in LTE-MTC
allUplink	The whole slot is for UL, more than one UL slot may be needed to match the duration of a UL subframe in LTE-MTC
nrofDownlinkSymbols	Specifies a partial DL slot, together with other DL slots (if needed), can match the duration of DwPTS in LTE-MTC
nrofUplinkSymbols	Specifies a partial UL slot, together with other UL slots (if needed), can match the duration of UpPTS in LTE-MTC

The main limitation of the NR TDD configuration is that the pattern has to be defined in the order of DL, GP and UL. A combination use of TDD-UL-DL-ConfigCommon and TDD-UL-DL-ConfigDedicated shall enable the NR TDD configuration to match that of any LTE UL-DL configuration. For example, Table 8.4-2 shows the NR TDD configuration that matches the LTE-MTC uplink/downlink configuration 1 with the special subframe configuration 7 (i.e. uplink/downlink subframe ratio is 1:1, DwPTS = 10 symbols, GP = 2 symbols, UpPTS = 2 symbols).

Table 8.4-2: Example of NR TDD configuration which matches with LTE TDD UL/DL configuration 1 and special subframe configuration 7

NR TDD		LTE TDD
Tdd-UL-DL-Configuration		
referenceSubcarrierSpacing	15	
dl-UL-TransmissionPeriodicity **(ms)**	5	
nrofDownlinkSlots	1	Subframe 0 is DL
nrofDownlinkSymbols	0	
nrofUplinkSlots	0	
nrofUplinkSymbols	0	
Tdd-UL-DL-ConfigDedicated		
slotIndex	1	Subframe 1 is a special subframe
nrofDownlinkSymbols	10	DwPTS=10
nrofUplinkSymbols	2	UpPTS=2
slotIndex	2,3	Subframe 2,3 is UL
symbols	allUplink	
slotIndex	4	Subframe 4 is DL
symbols	allDownlink	

9 Synchronization issue between LTE-MTC and NR

In order to analyze the LTE-M coexisting with NR, longest CP and shortest CP for NR are considered as two extreme cases in which whether timing misalignment between LTE-M and NR would exceed CP or not could be identified.

If 15kHz SCS is used in the NR carrier where NR has the longest CP, then the TAGs misalignment analysis between LTE-M and NR will be the same as that between LTE-M and E-UTRA. Therefore,there should be no interference issue due to TAGs misalignment between LTE-M and NR if 15kHz SCS is used in the NR system, otherwise such issue would have occurred already between LTE-M and E-UTRA before the migration to NR. Meanwhile some detailed analysis is done in Case 1 where it could be found that timing misalignment between LTE-M and NR is still within the CP, this also indicates there should be no interference issues due to TAGs misalignement.

On the other hand, if 30kHz or 60kHz SCS is used in the NR carrier, the LTE-M UE maximum transmit timing error of 60Ts (= 48Ts+4Ts+8Ts) alone as explained in the following will be larger than the CP length of the NR symbol. Therefore, when the NR UE maximum transmit timing error (which is varied according to the SCS used in the NR carrier) is also considered, there would potentially be interference issue due to the inter-symbol-interference between the LTE-M and NR symbols as illustrated in Case 2. However, it has been agreed that this type of mixed numerology cases between LTE-M and NR should be up to the BS implementation and no requirement is defined in the RAN4 specifications. Feasible BS implementation options include separate digital filtering and internal gap between the LTE-M and NR carriers.

Case 1: the timing misalignment scenario with NR SCS 15KHz

For NR UE transmit timing, if uplink subcarrier spacing is configured with 15KHz and SSB SCS is configured with 15KHz which is specified with worst transmit timing error for uplink SCS 15KHz, the maximum transmit timing error should be 12*64*Tc+256*Tc+8*64*Tc equal to (12+4+8)*64*Tc equal to 24*Ts which is the same as the maximum LTE UE transmitting error. Based on the above considerations, maximum arrival timing difference between NR carrier and LTE-MTC carrier should be 2.7344us as shown in Figure 8.1 which is less than the NR CP length 4.96us if SCS 15KHz is configured for NR.

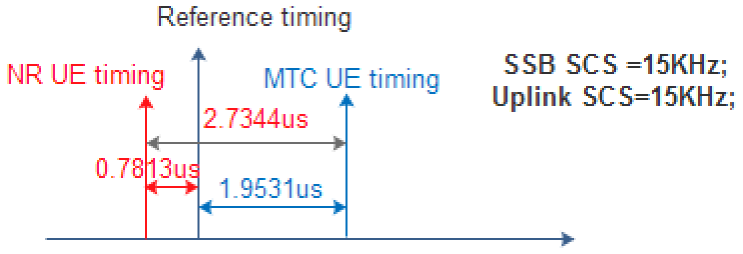


Figure 9.1. the maximum arrival timing difference between NR and LTE-M in Uplink

Case 2: the timing misalignment scenario with NR SCS 60KHz

For NR UE transmit timing, if uplink subcarrier spacing is configured with 60KHz and SSB SCS configured with 30KHz which is specified with the worst transmit timing error for uplink SCS 60KHz, the maximum transmit timing error should be 10*64*Tc+128*Tc+8*64*Tc/4 equal to 14 Ts (0.4557us). Based on the above consideration, the maximum arrival timing difference between NR carrier an LTE-M carrier should be 2.4088us as shown in Figure 8.2 which is larger than the NR CP length 1.17us if SCS 60KHz is configured for NR.

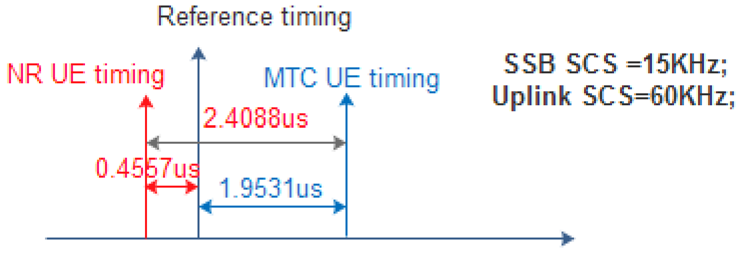


Figure 9.2. the maximum arrival timing difference between NR and LTE-M in Uplink.

10 Testability applicability

When LTE-M service is configured within one NR carrier at BS, the LTE-M UE operate it as LTE carrier so no new test on LTE-M UE will be needed.

For a BS supporting both LTE and NR, there is no NR RF impact foreseen because NR can avoid the LTE signal using either dynamic scheduling or MBSFN subframe seen by LTE-M UE. Transmitting LTE signal within a NR carrier does not change the NR signal characteristic and performance (unwanted emission, TX signal quality etc), similarly, receiving a LTE signal on NR BS would not require additional performance requirement. Therefore, no additional test will be needed when LTE-M coexisting within NR carrier. In such case, NR BS RF spec would still apply.

11 LTE-MTC coexisting with NR specific feature in R16

11.1 Subcarrier puncturing

Figure 11.1-1: Illustrative example of RB misalignment between NR and LTE-MTC in DL.

In R16, subcarrier puncturing is introduced as a feature to further improve spectrum utilization for the NR coexisting with LTE-MTC deployment scenario. This feature is useful for handling RB misalignment between NR and LTE-MTC in DL, as shown in Figure 11.1-1. By puncturing we refer to the case where the base station avoids transmitting the subcarriers belonging to LTE-MTC with or without informing the UEs. This will cause somewhat degraded performance for the UE whose transmission is punctured (up to 2 subcarrier punctured), but the eNB/gNB scheduler is aware of this, and may compensate by proper adjustment of code rates etc. It should be noted that in DL, since NR UEs can rate match around LTE CRS, there is no need to puncture CRS when it is on outlying subcarriers.

11.2 Resource reservation

In R16, finer LTE-MTC resource reservation than subframe level is introduced. LTE-MTC resource reservation for DL can be configured at slot level or symbol level. UL resource reservation for LTE-MTC with slot-level and symbol(s)-level granularity in addition to subframe-level granularity is supported. For DL, frequency-domain resource reservation is also supported, and non-contiguous PRB allocation can be indicated using an RBG bitmap. The unused frequency/time resources for LTE-MTC then can be used by an NR UE. As a result, the NR spectrum utilization will be improved when the traffic on LTE-MTC cell is low.

12 Summary

MSR BS supporting NR and E-UTRA can operate NR with LTE-MTC in-band allocation and there is no need to introduce new conformance testing. To ensure efficient operation for coexistence of NR with LTE-MTC, certain technical considerations as described in Chapter 7 & 8 are needed for channel raster, PRB and subcarrier alignment, LTE-MTC power boosting and simultaneous operation of LTE-MTC and NR.

Annex A: Change history

Change history

Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2019-04-08	RAN4#90 BIS	R4-1904260				TR skeleton proposal	V0.0.1
		R4-1905108				TP proposal for TR LTE-M and NR coexistance	
2019-5-13	RAN4#91	R4-1906627				TP on general aspect	
		R4-1907620				TP for background and channel raster for TR 36.abc	V0.1.0
		R4-1907621				TP to the new TR related to MTC: mixed numerologies	
2019-10-3	RAN4#92	R4-1910482				TP to the new TR related to MTC: mixed numerologies	V.0.2.0
		R4-1910481				TP for TR 37.832: Testability applicability	
		R4-1910483				TP for Simultaneously operation with LTE_MTC and NR	
		R4-1910612				TP for TR 37.823: LTE-MTC in-band deployment configurations	
2019-10-18	RAN4#92 bis	R4-1913001				TP for TR 37.823: PRB Alignment	V.0.3.0
		R4-1913002				TP to the new TR related to MTC: TAG misalignment	
		R4-1912995				TP for TR 37.823: Addition of n90 frequency band	
2020-2-11	RAN4#93	R4-1915166				TP for TR 37.823: Correction to n90 frequency band	V.0.4.0
2020-4-10	RAN4#94e	R4-2002739				TP for TR 37.823: Specific aspects for TDD	V 0.5.0
		R4-2002740				TP for TR 37.823 : R16 RAN1 impact on co-existing	
2020-6-15	RAN4#95e	R4-2008423				TP for TR 37.823: Power boosting for LTE-MTC	V.1.0.0
		R4-2008424				TP to 37.823: Conclusion	

Change history

Date	Meeting	TDoc	CR	Rev	Cat	Subject/Comment	New version
2020-06	RAN#88					Approved by plenary – Rel-16 spec under change control	16.0.0