**3GPP TSG-RAN4 Meeting #116bis *R4-25xxxxx***

**Prague, Czech, 13th – 17th October, 2025**

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| *CR-Form-v12.3* |
| **CHANGE REQUEST** |
|  |
|  | **38.774** | **CR** | **draft** | **rev** | **-** | **Current version:** | **19.0.0** |  |
|  |
| *For* [***HE******LP***](http://www.3gpp.org/3G_Specs/CRs.htm#_blank)*on using this form: comprehensive instructions can be found at* [*http://www.3gpp.org/Change-Requests*](http://www.3gpp.org/Change-Requests)*.* |
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| ***Proposed change affects:*** | UICC apps |  | ME | **X** | Radio Access Network |  | Core Network |  |

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|  |
| ***Title:***  | Draft CR to TR 38.774 on LP-WUS FR2 part update |
|  |  |
| ***Source to WG:*** | Samsung, vivo, Qualcomm |
| ***Source to TSG:*** | R4 |
|  |  |
| ***Work item code:*** | NR\_LPWUS-Core |  | ***Date:*** | 2025-09-30 |
|  |  |  |  |  |
| ***Category:*** | F |  | ***Release:*** | Rel-19 |
|  | *Use one of the following categories:****F*** *(correction)****A*** *(mirror corresponding to a change in an earlier release)****B*** *(addition of feature),* ***C*** *(functional modification of feature)****D*** *(editorial modification)*Detailed explanations of the above categories canbe found in 3GPP [TR 21.900](http://www.3gpp.org/ftp/Specs/html-info/21900.htm). | *Use one of the following releases:Rel-8 (Release 8)Rel-9 (Release 9)Rel-10 (Release 10)Rel-11 (Release 11)…Rel-17 (Release 17)Rel-18 (Release 18)Rel-19 (Release 19) Rel-20 (Release 20)* |
|  |  |
| ***Reason for change:*** | Most of the TR is focusing on FR1 now and FR2 content in the TR is not sufficient. |
|  |  |
| ***Summary of change:*** | Refine the TR in UE RF requirements clauses with FR2 LP-WUS update. |
|  |  |
| ***Consequences if not approved:*** | TR would be lack of FR2 content |
|  |  |
| ***Clauses affected:*** | 6.3.2, 7.1 |
|  |  |
|  | **Y** | **N** |  |  |
| ***Other specs*** |  | **X** |  Other core specifications  | TS/TR ... CR ...  |
| ***affected:*** |  | **X** |  Test specifications | TS/TR ... CR ...  |
| ***(show related CRs)*** |  | **X** |  O&M Specifications | TS/TR ... CR ...  |
|  |  |
| ***Other comments:*** |  |
|  |  |
| ***This CR's revision history:*** | This draft CR is merged by R4-2513877 and R4-2513578 |

**<<Start of Change>>**

6.3.2 SNR simulations

In this sub-clause, SNR simulation results from different companies are collected for analysis of target SNR for LP-WUR.

Table 6.3.2-1 SNR simulation summary for FR1 Envelop-detection LP-WUR (OOK-4 M=4)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Companies Input | SNR | RM coding | Timing error | Note |
| A | -6 to -2dB | 32/**16**/8 | 4us | -2.15 dB (8 bit), -4.63 dB (16 bit), -5.94 dB (32 bit) |
| B | -7 to -3dB |  | 0us | 5th order of lowpass Butterworth  |
| C | -7.5 dB to -2.5dB | 32/**16**/8 | 0us | simulated SNR with 4bit ADC or 8bit ADC is nearly the same |
| D | -7.1 to -2.5dB | 32/**16**/8 |  | OOK SNR: RM coding, 8bit with -2.5dB, 16bit with -5.3dB, 32bit with -7.1dB. |
| F | -7.7dB to -3.2dB | 32/**16**/8 | 0/0.9us | 0.9us TE will introduce less than 1dB degradation |
| G | -9.2 to -5.9dB |  |  | 8bit with -5.9dB, 16bit with -7.5dB, 32bit with -9.2dB. |
| H | -8.0 dB | 32 bits |  | under 4us TE has no impact |
| I | -7.8 to -5.9 dB | 32/**16**/8 |  | Payload: 5 bitswith RM, w/o MC |

Observations and Summary of SNR simulation outcome for envelop-detection receiver: most companies perform analysis based on RM coding of 8/16/32 bits, and majority views prefer to use 16bit RM coding as RMC and derive target SNR. The final target SNR is agreed as -4.5dB for LP-WUS envelop-detection.

Table 6.3.2-2 SNR simulation summary for FR1 OFDM-based LP-WUR

|  |  |  |  |
| --- | --- | --- | --- |
| Companies Input | SNR | Timing error | Note |
| A | -4dB |  | no big difference for the applicable SNR for both OOK based and OFDM based signals |
| B | -4dB |  |  |
| C | -5.5dB |  |  |
| D | -7.4dB |  |  |
| F | -8.0dB |  | OFDM-based receiver outperforms OOK-based receiver by 2.5~3dB SNR |
| G | -13.8 to -9.9dB |  |  |
| H | -3.5dB |  |  |

Observations and Summary of SNR simulation outcome for OFDM-based receiver: There is no repetition for OFDM-based receiver, the simulated SNR from companies is not much far from the simulated performance of LP-WUS envelop-detection. With consideration of other impacted aspects, the final target SNR of OFDM-based receiver is also specified as -4.5dB.

For FR2, simulation results provided by companies suggest that the FR2 OFDM-based receiver w is more sensitive than in FR1 primarily due to lower chip rate ‘M’ for FR2. For the sake of uniformity, RAN4 agree the same value of -4.5 dB for FR2 LP-WUS SNR.

<<< Skip Unchanged Sections >>>

7 RF requirements

7.1 UE RF

*<Editor’s note: Analysis background for UE RF requirements can be added further, if needed.>*

7.1.1 General

The minimum requirements will be determined assuming there is only one receiver for FR1. For FR2, 1RX is assumed at baseband but two selection-based Rx chains are assumed at RF domain. A 1% MDR criterion will be used for verification of all core RF requirements. Following LP-WUS parameters will be used

**Table 7.1.1-1. Common reference channel parameters for FR1**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Unit** | **Value** |
| MR Channel bandwidth | MHz | All CBW |
| LP-WUS bandwidth | RB | 11 |
| Subcarrier spacing | kHz | 15/30kHz |
| RM coding | Bits | 16 |
| CRC |  | No CRC |
| Chip rate |  | M=4 (4 chips in an OFDM symbol) |
| Overlaid OFDM sequence |  | Length 33: generated by 31-length ZC sequence with extension |
| Number of overlaid OFDM sequence per chip to carry information |  | 4 |
| WUS duration for OOK |  | 8 OFDM symbols |
| WUS duration for OFDM |  | 2 OFDM symbols |
| Manchester coding for OOK |  | 1/2 |
| Number of information bits | Bits | 5 |

**Table 7.1.1-2. Common reference channel parameters for FR2**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **Unit** | **Value** |
| MR Channel bandwidth | MHz | All CBW |
| LP-WUS bandwidth | RB | 11 |
| Subcarrier spacing | kHz | 120kHz |
| RM coding | bits | 3 bits |
| Chip rate |  | M=1 (1 chip in an OFDM symbol) |
| overlaid OFDM sequence |  | Length 132: generated by 131-length ZC sequence with extension |
| Number of overlaid OFDM sequence per chip to carry information |  | L = 2 |
|  |  |  |
| WUS duration for OFDM |  | 6 OFDM symbols |
| Manchester coding for OOK |  | 1/2 |
| Number of information bits |  | 3 |

In the specification, tables will be defined corresponding to 15 kHz and 30 kHz SCS for FR1, and 120kHz SCS for FR2.

7.1.2 Rx SNR evaluations

To derive SNR performance of LP-WUS, it was agreed to select OOK-4 M=4 under AWGN channel model with 1% MDR without repetition as worst case for FR1. M=1 is adopted for FR2.

7.1.3 Architecture and NF considerations

The basic architecture considered for the LP\_WUR is a zero-IF architecture for both envelope and sequence based detectors. This assumption is common for both FR1 and FR2. Multiple frequency conversion in RF domain is not precluded for FR2. This is just an assumption made to derive parameters which dictate the requirements. This assumption does not preclude any other RF implementations.

In case of FR1, only single RX is assumed. For FR2 requirement derivation, the baseline assumption is an OFDM based receiver with two receiver chains with mutually orthogonally polarized antennas. The combining strategy of FR2 LP-WUR is selection-based diversity for the two Rx chains. Antenna gain for each of the chains is that of a single element.

In RAN4, there had been no consensus on what IM includes, and no agreement was achieved on individual values of NF and IM, so a joint number was agreed. For FR1, there are two sets of NF + IM values agreed, and these will be used for REFSENS calculations. The values are,

- Set 1: 18 dB,

- Set 2: 13.5 dB.

For FR2, only OFDM based LR type is pursued, and the NF + IM value is agreed as 12dB which represents a 1dB degradation in NF compared with MR assumption at 28GHz.

7.1.4 REFSENS requirements

It was agreed to derive the REFSENS for LP-WUR in the typical RF manner with AWGN being the channel for which SNR is derived. Thus, for FR1 the REFSENS for LR is defined as

REFSENSLR (dBm) = -174 + 10log10(BWLR)+ (NFLR + IMLR) + SNRLR

Here, BWLR corresponds to the bandwidth of the LP-WUS signal in hertz. RAN1 has decided to have 11 RBs for LP-WUS irrespective of SCS, thus the LP-WUS bandwidth will be 1.98 MHz and 3.96 MHz, for 15 and 30 KHz SCS, respectively. Further, there are two sets of values for NFLR + IMLR, i.e. 18.0dB and 13.5dB for Type 1 and Type 2 LP-WURs, respectively. There is only one Rx antenna port for LP-WUR so there is no diversity gain included in the REFSENS.

In the REFSENS test, only the RBs allocated for LP-WUS are populated with the LP-WUS and the rest of the RBs for a given channel bandwidth are left empty. This configuration, however, does not correspond to the real-life case where NR signals in other RBs are generally present and thus can create a coverage shortfall. Separately, the ASCS requirement allows a maximum degradation of 0.5 dB and the side conditions incorporate populated adjacent RBs.

Given the small value of the ASCS degradation factor (0.5 dB), it was agreed not to include this factor in the REFSENS.

For FR1, a SNR value of -4.5 dB for both Type 1 and Type 2 LP-WURs was selected by RAN4 to be used for the REFSENS equation.

To keep the specifications simpler and given the frequency and NF assumptions made, it was agreed to keep the REFSENS same for majority of bands, irrespective of the band to band variation. For some specific bands with FDL\_low higher than 2400 MHz and higher noise figure, there can be additional relaxation and that relaxation will be recorded in the specification.

For FR2, given the band number and power classes are limited, an offset approach is adopted. The REFSENS for LR is derived based on the differences contributed by various factors compared with MR’s REFSENS for each band. The following factors are considered in derivation for power class 3:

* NF+IM is 12 dB, (1dB degraded from low FR2 band MR)
* Diversity gain is -3 dB (3dB degraded from MR)
* Antenna gain assumption is based on single element rather a 4-element array (6 dB degraded from MR)
* The SNR proposal for FR2 LP-WUS is -4.5 dB (3.5 dB improvement from MR)
* BW adjustment (degraded by 10log(NRB/11) from MR)

The net degradation of LP-WUS sensitivity from MR connected mode PDSCH requirement is therefore (1+3 + 6 -3.5 +10log(NRB/11)) dB, i.e. 6.5 + 10log(NRB/11) dB. For power class 7, antenna gain assumption is based on 2-element array and thus 3dB degradation instead of 6dB, resulting in a 3dB smaller offset than PC3, i.e. 3.5 + 10log(NRB/11) dB.

So the FR2 LR REFSENS is defined as

 dB

Where X=6 for FR2 power class 3 and X=3 for FR2 power class 7.

7.1.5 ASCS requirements

Adjacent subcarrier selectivity (ASCS) is a measure of a receiver's ability to receive an LP-WUS signal at its configured channel frequency in the presence of adjacent in-band NR signal(s). The in-band LP-WUS and NR signal should be same PSD and be separated by a given frequency offset (guard RB) between LP-WUS and NR, and the NR signal occupies the remaining RB resources within the maximum transmission bandwidth configuration, excluding the LP-WUS RBs.

7.1.6 ACS requirements

It is agreed that the LR and MR has the same jammer level for ACS test case. The ACS of LR is derived using the below formular.

As an example, the conversion formula between the ACS and the interference signal levels can be written as

a N = N + I/ACS

ACS = I/{(a-1)N)

Where a is the margin of wanted signal level above reference sensitivity in linear unit; N is the noise floor in linear unit; I is the adjacent channel interference signal level expressed in linear unit, ACS is the adjacent Channel Selectivity expressed in linear unit.

Assuming the relaxing factor for MR is 11 dB, the MR inteferer level can be expressed with the formular below:

The relaxing factor for LR can be 14 dB, the LR inteferer level can be expressed with the formular below:

With the equal jammer level of LR and MR, the ACS of LR is derived below

7.1.7 In-Band Blocking

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.

In the specification, the absolute interferer levels are adopted for both in-band blocking (IBB) and out-of-band blocking (OBB) for MR. IBB refers to interference that occurs within the second adjacent and next adjacent channels, while OBB occurs outside a frequency range 15 MHz below or above the UE receive band.

The main challenges for receiver design in presence of strong interferer are the Rx chain dynamic range as well as the filter suppression capability, which could be the channel filters to alleviate interfering by ACS or IBB, or could be the band filter/duplexer to suppress OBB.

Regarding the dynamic range, the main determining components are ADC and AGC. The more ADC bits, the larger dynamic range for the receiver. However, the ADC bits cannot be increased without limitation. The relationship between ADC bit depth and power consumption is typically inversely proportional. Higher bit-depth ADCs generally offer greater precision and resolution but tend to consume more power due to the increased complexity of circuitry required for finer quantization and digitalization. Conversely, lower bit-depth ADCs consume less power but sacrifice resolution and dynamic range.

In the context of 5G smartphones, ADCs with 12 bits or higher are commonly employed. These higher precision ADCs are favoured to accommodate the demanding requirements of 5G communication, such as higher data rates and broader spectrum ranges. While some 5G smartphones may opt for even higher bit-depth ADCs like 14 or 16 bits for enhanced performance, the general trend revolves around 12 bits.

However, there's a trade-off to consider. LP-WUR which aims to minimize power consumption in smartphones, often utilize lower bit-depth ADCs to reduce power consumption. While this approach yields power-saving benefits, it may compromise the dynamic range and overall performance of the ADC. During the SI evaluation, 4 bits, 6 bits and 8 bits are considered for LLS simulation. Apparently, if low power consumption is the main target for LP-WUR design, it may not be possible that a LP-WUR could adopt the same ADC as MR, which means the dynamic range for LP-WUR could be sacrificed to some extent.

Apart from ADC, the dynamic range of AGC is another main factor which could have impact on the possibly large interferer handled by LP-WUR. On the other hand, due to the limited suppression capability of the LP-WUR filters, it may not guarantee the same level of resistance against IBB and OBB interference as the main receiver (MR). Or if the same interference levels are kept as MR, the wanted signal for blocking requirements should be relaxed more instead.

7.1.8 Out-of-Band Blocking

For out-of-band blocking (OBB), with suppression of the out-of-band interferer by band filter and the analog filter before ADC, the blocking could be suppressed to relatively low level even with less dynamic range of LR, unless band filter is not considered for better coverage with less insertion loss for LP-WUR design.

7.1.9 Narrow Band Blocking

Narrow Band Blocking (NBB), it was initially considered to address coexistence scenarios with GSM at a 200 kHz frequency offset, inherited from LTE for NR. Given the close offset to the desired signal, NBB can significantly degrade REFSENS, particularly if the phase noise of the interferer is poor.

7.1.10 Max Input Level

It is agreed that a single maximum input power level is specified for all channel bandwidths. It is also agreed to introduce two test cases. One test case without the NR signal and the other one NR signal with the same PSD. This is to make sure the LR operate in the presence of the NR signal near the cell centre.

Above basic principle applies to both FR1 and FR2 LP-WUR.

7.1.11 Other Rx requirements

For other Rx requirements for LP-WUR, only spurious emissions is defined for LP-WUR because this is a regularity requirement.

The spurious emissions power is the power of emissions generated or amplified in a receiver that appear at the UE antenna connector. For receiver, the emissions at the antenna connector usually come from the reverse LO leakage. As illustrated in Figure 7.1.11-1 marked with the green line, the LO leakage ends at the antenna or antenna connector. The main LO frequency will dominate in-band spurious emissions, and the harmonic will dominate out-of-band spurious emissions. In a design with potential low isolation from LO to RF input, an LNA is required to attenuate the in-band spurious, and a band pass filter is required to ensure that out-of-band spurious is suppressed. Since the emissions could be considered as kind of regulatory requirements, the same levels for MR should also be defined for LR. Namely, the spurious emissions as specified in clause 7.9 in TS38.101-1/2 still applies.



**Figure 7.1.11-1 Illustration of a DC receiver**

**<<End of Change>>**