**3GPP TSG-RAN WG4 Meeting #109 R4-2318141**

**Chicago, US, November 13 – 17, 2023**

**Agenda item:** 8.20.5

**Source:** Moderator (vivo)

**Title:** Topic summary for [109][135] FS\_NR\_LPWUS

**Document for:** Information

# Introduction

This email summary covers the discussions in AI 8.20.1~8.20.3 for Rel-18 LP-WUS RF.

# Topic #1: LP-WUR architectures

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2318974 | vivo | **Proposal 1: The following delta NF (gap between LR and MR) with *Y* dB SNR for WUR can be discussed in RAN4:**  **For OOK based WUR:**   * **RF-ED delta NF: [3~10] dB** * **IF-ED delta NF: [1~6] dB** * **BB-ED delta NF: [1~7] dB**   **For OFDMA based WUR:**   * **Time-domain correlation delta NF: [0~7] dB** * **Frequency-domain correlation delta NF: [0~3] dB**   **Proposal 2: RAN4 should further discuss sensitivity in WI based on clear Rel-19 scope of waveform and coverage consideration.**  **Proposal 3: Keep 6dB as tentative value of [x] in SI phase. Specify this power boosting requirement in WI phase.**  **Proposal 4: The term guard RB should not be changed, it is generic for both ACS and ASCS, which means the required number of RBs for interference protection/rejection.**  **Proposal 5: The required number of guard RBs for ACS (all RBs or partial RBs) may not be blanked RBs which depends on BS implementation. If guard RBs are allocated for NR signal, then ASCS guard RB is needed.**  **Proposal 6: Update the interpretation of guard RBs in TR based on above descriptions and diagrams.** |
| R4-2319734 | Huawei, HiSilicon | ***Proposal 1: It is proposed to confirm that there are three cases for the guard RBs for LP-WUS in terms of co-existence with NR carrier and determine the guard RB range for ASCS and ACS cases in SI stage. Leave the required RB discussion for ACS+ASCS to the WI stage when to decide the specific number of guard RB for ACS and ASCS cases.***  ***Proposal 2: 6dB as upper bound for LP-WUS power boosting can be considered in the SI stage, however, specific value and the value versus boosted RB number(s) and RB locations should be further discussed in WI stage.***  ***Proposal 3: It is proposed to discuss the viable NF together with SNR in WI phase when to determine the REFSENS for LP-WUR with consideration of the coverage target.*** |
| R4-2320084 | ZTE Corporation | ***Proposal 1. For ASCS, the guard RBs belongs to “WUS carrier”, the overall RBs should within “WUS carrier” bandwidth.***  ***- The guard RB within WUS carrier shall be blanked.***  ***Proposal 2. For ACS,***   * + ***Option 1: the required RBs are RB offset between WUS carrier bandwidth edge and transmission bandwidth configuration edge,***      - ***RBs within the offset may not be blanked.***     - ***Guard RBs within WUS carrier bandwidth should be taken into account in addition to required RBs***   ***Proposal 3. If it is purely declared by manufacture which means there are no requirements defined in TS38.104, there is no need to define upper bound of power boosting level.***  ***Proposal 4: No power boosting for OFDM based LP-WUS, 3dB power boosting is feasible for OOK based LP-WUS evaluation to keep fairness comparison with OFDM based LP-WUS.***  ***Observation 1. If the Power boosting requirements for WUS signal are defined in TS38.104, it should be minimum requirements, which means at least [x]dB boost level, rather than boosting level from 0 dB to [x]dB.***  ***Observation 2. Power boosting for WUS signal(OFDM based) is not always feasible, and it would impact the power for the left NR RB.*** |
| R4-2320516 | Nokia, Nokia Shanghai Bell | ***Observation 1: The above assumed NF for each OOK based LP-WUR architecture is derived considering the minimum detection performance of the envelope detectors and the trade-off between power consumption and coverage.***  ***Proposal 1: NF for Zero-IF/Low-IF BB envelope detector architecture can be assumed to be 9 dB.***  ***Proposal 2: NF for heterodyne IF envelope detector architecture can be assumed to be 10 dB.***  ***Proposal 3: NF for RF envelope detector architecture can be assumed to be 30 dB.***  ***Proposal 4: NF for OFDM based WUR (frequency or time domain correlator) architecture can be assumed to be 9 dB.***  ***Observation 2: For modulation type OOK-2 and OOK-4 with M=2, power can be increased up to 3dB without affecting the overall power budget for the BS.***  ***Proposal 5: Do not use power boost as it will affect the overall power budget for the BS.***  ***Proposal 6: Power pulling of 3 dB can be used when possible (symbol constellation 1-0 and 0-1 for OOK-2 and OOK-4 with M=2).*** |
| R4-2320548 | Ericsson | **Proposal-1:Use the RB offset instead of guard RB for ACS case.**  **Observation 1 When more guard RB is configured within the same WUS BW, SNR performance will be degraded due to less detected energy for LP-WUS signal.**  **Observation 2 It is necessary to introduce additional RB offset between WUS signal to the ACI in the ACS test.It is necessary to introduce additional RB offset between WUS signal to the ACI in the ACS test.**  **Proposal-2:Further discuss the ACS test case in work item phase.** |
| [R4-2320817](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_109/Docs/R4-2320817.zip) | Murata Manufacturing Co Ltd. | **Observation 1:** Further degradation of the RXLO integrated phase noise to improve current consumption requires increasing the number of Guard RBs.  **Observation 2:** Larger PLL bandwidths in WUR could be difficult to implement in WUR since relatively more guard RBs are required than with lower PLL bandwidths.  **Observation 3:** Large guard RB offset needs to be considered for IMD, CFO, and limited filter order implementation.  **Proposal 1:** Consider the phase noise parameters for reciprocal mixing shown in Table 2-1 for TR38.820 section 7.1.2.4. |
| R4-2320546 | Ericsson | 1. Lowing the ADC sampling rate benefits power consumption for a SAR ADC. 2. The sampling rate of the ADC should be adapted for the overlaid LP-WUS structure if both OFDM and OOK signal would be used. 3. There is SNR degradation when ADC sampling rate is reduced for the same number of ADC bits and the same BPF order. 4. SNR degradation is more prominent for lower ADC bits combined with lower BPF order. 5. SNR degradation can be reduced with higher ADC bits and higher BPF order. |
| R4-2320547 | Ericsson | 1. RAN1 has not agreed on the WUS signal duration, bandwidth and payload size and the MCL in link budget may change if different assumption would be used. 2. With a moderate assumption of OOK WUR NF 4dB worse than NF of MR, the coverage of WUR cannot match with either MSG3 PUSCH or PDCCH (1 Rx, AL 16) 3. OFDM WUR can match to the MSG PUSCH or PDCCH (1Rx, AL 16) assuming 1 dB worse NF than NF of MR 4. Whether to introduce the coverage enhancement of the LP-WUS for OOK WUR is up to RAN1 in Rel-19 WI. |

## Open issues summary

### Sub-topic 1-1 updated Guard RB for ACS/ASCS

**Issue 1-1-1: guard RBs definition for LP-WUS ACS**

* Proposals
  + **Proposal 1: The term guard RB should not be changed, it is generic for both ACS and ASCS, which means the required number of RBs for interference protection/rejection. (vivo)**
  + **Proposal 2: The required number of guard RBs for ACS (all RBs or partial RBs) may not be blanked RBs which depends on BS implementation. If guard RBs are allocated for NR signal, then ASCS guard RB is needed. (vivo)**
  + **Proposal 3: It is proposed to confirm that there are three cases for the guard RBs for LP-WUS in terms of co-existence with NR carrier and determine the guard RB range for ASCS and ACS cases in SI stage. Leave the required RB discussion for ACS+ASCS to the WI stage when to decide the specific number of guard RB for ACS and ASCS cases. (Huawei)**
  + **Proposal 4: For ASCS, the guard RBs belongs to “WUS carrier”, the overall RBs should within “WUS carrier” bandwidth. (ZTE)**
    - **The guard RB within WUS carrier shall be blanked.**
  + **Proposal 5: For ACS, select option 1: *the required RBs are RB offset between WUS carrier bandwidth edge and transmission bandwidth configuration edge* (ZTE)**
  + **Proposal 6: Use the RB offset instead of guard RB for ACS case (Ericsson)**
* Recommended WF
  + TBA

**Issue 1-1-2: Whether to further update the number of guard RBs for ACS**

* Observations and Proposals
  + **Option 1: Yes**
  + **Option 2: No. Further discuss in WI phase**
* Recommended WF
  + TBA

### Sub-topic 1-2 UE Noise Figure

**Issue 1-2-1: Noise Figure range for LP-WUR (LR)**

* Proposals
  + **Proposal 1: The following delta NF (gap between LR and MR) with Y dB SNR for WUR can be discussed in RAN4: (vivo)**

**For OOK based WUR:**

* **RF-ED delta NF: [3~10] dB**
* **IF-ED delta NF: [1~6] dB**
* **BB-ED delta NF: [1~7] dB**

**For OFDMA based WUR:**

* **Time-domain correlation delta NF: [0~7] dB**
* **Frequency-domain correlation delta NF: [0~3] dB**
  + **Proposal 2: It is proposed to discuss the viable NF together with SNR in WI phase when to determine the REFSENS for LP-WUR with consideration of the coverage target. (Huawei)**
  + **Proposal 3: The noise figure can be assumed as (Nokia)**
    - **NF for Zero-IF/Low-IF BB envelope detector architecture can be assumed to be 9 dB.**
    - **NF for heterodyne IF envelope detector architecture can be assumed to be 10 dB.**
    - **NF for RF envelope detector architecture can be assumed to be 30 dB.**
    - **NF for OFDM based WUR (frequency or time domain correlator) architecture can be assumed to be 9 dB.**
* Recommended WF
  + TBA

### Sub-topic 1-3 WUS power range

**Issue 1-3-1: Possible LP-WUS power range**

* Proposals
  + **Proposal 1: Keep 6dB as tentative value of [x] in SI phase. Specify this power boosting requirement in WI phase. (vivo)**
  + **Proposal 2: 6dB as upper bound for LP-WUS power boosting can be considered in the SI stage, however, specific value and the value versus boosted RB number(s) and RB locations should be further discussed in WI stage. (Huawei)**
  + **Proposal 3. If it is purely declared by manufacture which means there are no requirements defined in TS38.104, there is no need to define upper bound of power boosting level. (ZTE)**
  + **Proposal 4: No power boosting for OFDM based LP-WUS, 3dB power boosting is feasible for OOK based LP-WUS evaluation to keep fairness comparison with OFDM based LP-WUS. (ZTE)**
  + **Proposal 5: Do not use power boost as it will affect the overall power budget for the BS. Power pulling of 3 dB can be used when possible (symbol constellation 1-0 and 0-1 for OOK-2 and OOK-4 with M=2) (Nokia)**
* Recommended WF
  + TBA

### Sub-topic 1-4 LP-WUR RF requirements

**Issue 1-4-1: LP-WUR Sensitivity**

* Observations and Proposals
  + **Proposal 1: RAN4 should further discuss sensitivity in WI based on clear Rel-19 scope of waveform and coverage consideration (vivo)**
  + **Proposal 2: It is proposed to discuss the viable NF together with SNR in WI phase when to determine the REFSENS for LP-WUR with consideration of the coverage target. (Huawei)**
* Recommended WF
  + TBA

**Issue 1-4-3: LP-WUR test cases**

* Proposals
  + **Proposal 1: Further discuss the ACS test case in work item phase. (Ericsson)**
* Recommended WF
  + TBA

### Sub-topic 1-5 LP-WUR architectures and RF impairments

**Issue 1-5-1: Phase noise impacts on LP-WUR ACS and ASCS**

* Observations and Proposals
  + *Observation 1: Further degradation of the RXLO integrated phase noise to improve current consumption requires increasing the number of Guard RBs.*
  + *Observation 2: Larger PLL bandwidths in WUR could be difficult to implement in WUR since relatively more guard RBs are required than with lower PLL bandwidths.*
  + *Observation 3: Large guard RB offset needs to be considered for IMD, CFO, and limited filter order implementation.*
  + **Proposal 1: Consider the phase noise parameters for reciprocal mixing shown in Table 2-1 for TR38.820 section 7.1.2.4. (Murata)**
* Recommended WF
  + TBA

# Topic #2: TPs to RAN1 TR

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2318973 | vivo | TP to TR 38.869 on LP-WUS RF summary |
| R4-2318975 | vivo, CMCC | TP to TR 38.869 on LP-WUS receiver architectures |
| R4-2320085 | ZTE Corporation | TP for TR 38.869\_Updates for guard band definition |
| R4-2320546 | Ericsson | TP on ADC impairment |
| R4-2320547 | Ericsson | TP on WUR Noise figure |
| R4-2320643 | Qualcomm Inc. | TP to TR 38.869: Low-power wake-up receiver RF aspects |
| R4-2320662 | Sony Europe B.V. | LP WUR ACS with phase noise |

## Open issues summary

### Sub-topic 2-1 Outcome to RAN1

**Issue 2-1-1: RAN4 RF summary to TR**

* Proposals
  + **Proposal 1: Approve the RF summary in TP** **R4-2318973. (vivo)**
* Recommended WF
  + TBA

**Issue 2-1-2: Guard RBs term interpretation TP**

* Proposals
  + **Proposal 1: Update the guard RB interpretation based on outcome of issues in 1-1. Proposals in** **R4-2318975, R4-2320085, R4-2320643, and R4-2320547 can be considered. (Moderator)**
* Recommended WF
  + TBA

*Moderator: the following description and diagram can be starting point for refinement*

For evaluation purpose, RAN4 define a new term named as guard RB for LP-WUS, which is Granularity of RB for ACS/ASCS protection. Meanwhile, the traditional guardband for NR channel bandwidth defined in Clause 5.3, TS 38.101-1 is unchanged. The LP-WUS guard RB definition can be described different for ASCS and ACS as following:

* For ASCS guard RB, the required guard RB(s) should be blanked RB(s), which belong to WUS carrier/BW (i.e., WUS signal plus ASCS guard RB(s)).
* For ACS guard RB, the required guard RB(s) are RB(s) between WUS signal edge and nearest edge of guardband in a configured NR transmission bandwidth.
  + It includes ASCS guard RB(s) (if allocated) and RBs (which may be used for NR transmission) between WUS carrier/BW edge and nearest edge of guardband in a configured NR transmission bandwidth as in spec TS 38.101-1.

RAN4 agrees there is no need to restrict symmetric guard RBs for interference rejection of WUS, both ACS and ASCS.

RAN4 suggests overall bandwidth of the wake-up signal in the NR channel i.e., desired signal along with all the required guard RBs shall fit in the maximum transmission bandwidth configuration as defined in Table 5.3.2-1 of TS 38.101-1.



(case 1: WUS within large NR channel)



(case 2: WUS within ~5MHz NR channel)

**Figure 7.1.2.1-1: Definition of the guardband of NR channel and guard RBs for both LP-WUS ACS and ASCS**



**Figure 7.1.2.1-2: Definition of the guardband of NR channel and guard RBs only for LP-WUS ACS**

**Issue 2-1-3: Noise Figure TP for LP-WUR (LR)**

* Observations and Proposals
  + *Observation 1: RAN1 has not agreed on the WUS signal duration, bandwidth and payload size and the MCL in link budget may change if different assumption would be used.*
  + *Observation 2: With a moderate assumption of OOK WUR NF 4dB worse than NF of MR, the coverage of WUR cannot match with either MSG3 PUSCH or PDCCH (1 Rx, AL 16)*
  + *Observation 3: OFDM WUR can match to the MSG PUSCH or PDCCH (1Rx, AL 16) assuming 1 dB worse NF than NF of MR*
  + *Observation 4: Whether to introduce the coverage enhancement of the LP-WUS for OOK WUR is up to RAN1 in Rel-19 WI.*
  + **Proposal 1: Endorse the content in TP for NF in R4-2320547. (Ericsson)**
    - With the assumption of 8 bits payload size and 12 symbols duration for WUS signal, for OFDM WUR, the NF can be 1 dB greater than NF of the main receiver to match the coverage of the MSG3 PUSCH or PDCCH (1 Rx, AL 16). For OOK WUR with the same assumption of assumption of 8 bits payload size and 12 symbols duration for WUS signal, when the NF is 4dB greater than NF of main receiver, the coverage of WUR cannot match either MSG3 PUSCH or PDCCH (1 Rx, AL 16) unless the coverage enhancement of LP-WUS is provided.
* Recommended WF
  + TBA

**Issue 2-1-4: TP for ADC sampling rate impacts on LP-WUR**

* Observations
  + *Lowing the ADC sampling rate benefits power consumption for a SAR ADC.*
  + *The sampling rate of the ADC should be adapted for the overlaid LP-WUS structure if both OFDM and OOK signal would be used.*
  + *There is SNR degradation when ADC sampling rate is reduced for the same number of ADC bits and the same BPF order.*
  + *SNR degradation is more prominent for lower ADC bits combined with lower BPF order.*
  + *SNR degradation can be reduced with higher ADC bits and higher BPF order.*
  + **Proposal 1: Endorse the content in TP for ADC impairment in R4-2320546. (Ericsson)**
* Recommended WF
  + TBA

**Issue 2-1-5: TP for Coverage aspects on LP-WUR**

* Observations and Proposal
  + *Observation 1 The coverage range shall be something between same as PDCCH for paging, and same as PUSCH Msg. 3.*
  + *Observation 2 The coverage is determined by a combination of the LP-WUR design and the LP-WUS design.*
  + *Observation 3 There is a delicate balance between complexity/energy consumption and coverage and network resources.*
  + *Observation 4 The aggregated cost, for all devices in the system, in terms of energy consumption and network resources should be balanced against the benefit of the higher level of coverage.*
  + **Proposal 1: Endorse the content in TP for Coverage aspects on WUR in R4-2320662. (Sony)**
    - The coverage target for the LP-WUR/WUS design has been decided to be comparable to the coverage of the main radio. Two candidates for the coverage range have been proposed: the same as PDCCH for paging and the same as PUSCH Msg. 3. A value in between (as a third option) is not precluded. The better coverage option, PDCCH for paging, could have advantages for a device with higher mobility, such as a wearable. For a static or almost static device, however, most likely the UE is supposed to respond with a message, and then the PUCH Msg. 3 coverage may be enough since the response anyhow has to reach the gNB.
    - The coverage is determined by a combination of the LP-WUR design and the LP-WUS design, since coverage depends on the LP-WUR receiver noise figure and the required SNR, which in turn depends on the LP-WUS design. Consequently, to reach the better coverage a better receiver in terms of sensitivity can be used. However, better performing receivers in terms of sensitivity, in general, have higher energy consumption. Thus, for the WUS/WUR design there is a delicate balance between complexity/energy consumption and coverage and network resources.
    - Among the devices targeted for low-power LP-WUS/WUR, that benefit the most from a LP-WUR are the power-sensitive, small form-factor devices including IoT use cases (such as industrial sensors, controllers). In many cases they are static or low mobility devices, with low traffic volume but high expectation on availability. For such a device, with very low or zero mobility, it may be a waste of precious resources such as device current consumption and also network resources to design the system using a set-up for the worst scenario in terms of coverage and/or channel property. The aggregated cost, for all devices in the system, in terms of energy consumption and network resources should be balanced against the benefit of the higher level of coverage.
* Recommended WF
  + TBA