**3GPP TSG-RAN WG4 Meeting #111 R4-2408947**

**Fukuoka City, Fukuoka, Japan, 20th – 24th May, 2024**

**Agenda item:** 10.14.5

**Source:** Moderator (vivo)

**Title:** Topic summary for [111][136] NR\_LPWUS\_UERF

**Document for:** Information

# Introduction

This topic summary covers the discussions for Rel-19 LP-WUS UE RF.

# Topic #1: General and system parameters

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2407649 | Huawei, HiSilicon | ***Proposal 1: It is proposed to select some FR1 bands lower than 2GHz as starting point for LP-WUS/WUR in Rel-19.***  *Observation 1: Required RB numbers for CBW equal or larger than 5MHz are already determined by RAN1*  *Observation 2: Channel BW is relevant to the operating bands, which is also related to the discussion of BS power boosting as power is shared between LP-WUS and NR signal*  ***Proposal 2: It is proposed to specify the LP-WUS requirements based on 5MHz and FFS on the NR CBW. Determination of NR CBW depends on further discussion on operating bands and BS power boosting.***  ***Proposal 3: To accommodate different UE architectures, two sets of requirements at least with different NF should be considered for LP-WUR.*** |
| R4-2409100 | Ericsson | ***Proposal-1: Strive for the single set of RF requirement, may allow the different RF requirement for OOK WUR or OFDM WUR if needed depending on further discussion.***  ***Proposal-2: Same conducted test should be applied to WUR and MR.***  ***Proposal-3: More discussion around Rx diversity for WUR.*** |
| R4-2407546 | CATT | **Observation 1: The PRB grid of LP-WUS and in-band NR signals are aligned.**  **Proposal 1: RAN4 to consider the selection of three example bands for band-specific requirements LP-WUR, with one band representing each band group, e.g., n1, n8, and n77.**  **Proposal 2: RAN4 to clarify the NR channel bandwidth and RB number in which LP-WUS is deployed for ACS/ASCS simulation purpose.**  **Proposal 3: Channel raster design for LP-WUR should guarantee flexible placement within the in-band NR signal PRB grid, and be specified after RAN1 design is completed.** |
| R4-2407953 | CMCC | ***Proposal 1: Not limit the LPWUS example bands under 2GHz, and NR bands n28 and n41 could be chosen as example bands.***  ***Proposal 2: Two sets of requirements could be discussed for OOK-based receivers and OFDM-based receivers.***  ***Proposal 3: SNR and NF could be different for these two types.***  ***Proposal 4: The SCS of LP-WUS is considered same as in-band NR signals as the starting point.***  ***Proposal 5: 5MHz channel bandwidth could be used as the starting point.***  ***Proposal 6: No sync raster is needed for LP-WUS based on RAN1 design.*** |
| R4-2408032 | Qualcomm Incorporated | **Observation 1: The gNB does not know if its LP-WUS is beneficial for idle mode UEs, but it is aware of the connected mode UEs using LP-WUS.**  **Observation 2: For typical usage patterns, UEs stand to enjoy more significant energy consumption reduction in FR2 bands than FR1.**  **Proposal 1: RAN4 to consider using n258 as the example FR2 band.**  **Observation 3: For typical usage patterns, connected mode energy consumption dominates the long-term usage energy consumption. Idle mode consumption reduction is less important.**  **Proposal 2: RAN4 to reflect both idle and connected mode conditions in the side conditions for the LPWUR requirements.** |
| R4-2408108 | vivo | **Proposal 1: RAN4 should not limit LP-WUS feature applicability on specific example bands.**  **Proposal 2: RAN4 should analyze and decide the minimum NR operation bandwidth for LP-WUS, e.g., 5MHz or 10MHz, based on outcome of ACS/ASCS requirements and guard RBs.** |
| R4-2408362 | ZTE Corporation, Sanechips | **Propose 1: Choose band n28 (700MHz), band n3 (1800MHz) and band n41 (2.6GHz) as example bands for band specific requirement study.**  **Proposal 2: Reuse existing channel raster as a start point for LP-WUS study.**  **Observation 1: For in-band operation of LP-WUS, a frequency offset should be considered to support flexible location of LP-WUS RBs in NR carrier. For standalone operation of LP-WUS, there is no need to consider frequency offset.** |
| R4-2409101 | Ericsson | ***Observation 1 Channel raster will not apply to WUR and WUR BW should be indicated with the RB position occupied by LP-WUS.***  ***Proposal-1: Channel raster does not apply to WUR.***  ***Observation 2 RAN1 agree for the X PRBs (11 or 12 up to RAN1 decision) for LP-WUS for SCS 30kHz.***  ***Proposal-2: No specification impact on WUR in terms of system parameter.***  ***Proposal-3: The BW of WUR should be specified in X PRB of LP-WUS referencing to the RB grid of MR.*** |
| R4-2407069 | Apple | **Observation 1**: To achieve reasonable lifetimes for different LP-WUR implementations and scenarios, RAN4 should at least two sets of receiver requirements.  **Proposal 1**: RAN4 should keep discussing two sets of receiver requirements. One requirement suited for OFDM based receiver and one set for OOK which can be based on power detector type receiver.  **Proposal 2**: Keep support of 1Rx in FR1 for now. To minimize current consumption for wake-up receiver do not include Rx diversity. |
| R4-2408046 | Nokia Poland | **Proposal 1: Agree to have diversity gain as zero for LP\_WUR REFSENS calculation.** |

## Open issues summary

### Sub-topic 1-1 General and system parameters

**Issue 1-1-1: Operation bands for LP-WUS feature**

* Proposals
  + **Proposal 1: RAN4 confirm LP-WUS is a general feature not limited to specific example band(s). (vivo)**
* Recommended WF
  + TBA

**Issue 1-1-2: FR1 example bands for requirements as phase 1**

* Proposals
  + **Proposal 1: It is proposed to select some FR1 bands lower than 2GHz as starting point for LP-WUS/WUR in Rel-19. (Huawei)**
  + **Proposal 2: RAN4 to consider the selection of three example bands for band-specific requirements LP-WUR, with one band representing each band group, e.g., n1, n8, and n77. (CATT)**
  + **Proposal 3: Not limit the LPWUS example bands under 2GHz, and NR bands n28 and n41 could be chosen as example bands. (CMCC)**
  + **Proposal 4: Choose band n28 (700MHz), band n3 (1800MHz) and band n41 (2.6GHz) as example bands for band specific requirement study. (ZTE)**
* Recommended WF
  + Check whether n28, n41, n78 can be selected

**Issue 1-1-3: FR2 example bands for requirements as phase 1**

* Proposals
  + **Proposal 1: RAN4 to consider using n258 as the example FR2 band. (Qualcomm)**
* Recommended WF
  + FFS FR2 work. Current not considered in RAN1

**Issue 1-1-4: one or two sets of requirements (REFSENS)**

* Proposals
  + **Proposal 1: To accommodate different UE architectures, two sets of requirements at least with different NF should be considered for LP-WUR. (Huawei, CMCC, Apple, vivo)**
    - **Different NF for OOK-based receivers and OFDM-based receivers**
    - **Whether SNR is different, is FFS**
  + **Proposal 2: Strive for the single set of RF requirement, may allow the different RF requirement for OOK WUR or OFDM WUR if needed depending on further discussion. (E///, Sony)**
* Recommended WF
  + Working on two sets of requirements, not preclude final harmonize to one

**Issue 1-1-5: Rx antenna assumption for LP-WUR**

* Proposals
  + **Proposal 1: More discussion around Rx diversity for WUR. (E///)**
  + **Proposal 2: To minimize current consumption for wake-up receiver do not include Rx diversity. (Apple)**
  + **Proposal 3: Consider No diversity gain for RENSENS. (Nokia)**
  + **Proposal 4: fully consider the antenna sharing and switching architecture. (Samsung)**
* Recommended WF
  + No diversity gain as baseline. More Rx could be implementation choice

**Issue 1-1-6: CBW and RB number for LP-WUR**

* Proposals
  + **Proposal 1: It is proposed to specify the LP-WUS requirements based on 5MHz and FFS on the NR CBW. Determination of NR CBW depends on further discussion on operating bands and BS power boosting. (Huawei)**
  + **Proposal 2: RAN4 should analyze and decide the minimum NR operation bandwidth for LP-WUS, e.g., 5MHz or 10MHz, based on outcome of ACS/ASCS requirements and guard RBs. (vivo)**
  + **Proposal 3: The BW of WUR should be specified in X PRB of LP-WUS referencing to the RB grid of MR. (E///)**
  + **Proposal 4: RAN4 to clarify the NR channel bandwidth and RB number in which LP-WUS is deployed for ACS/ASCS simulation purpose. (CATT)**
  + **Proposal 5: 5MHz channel bandwidth could be used as the starting point. (CMCC)**
* Recommended WF
  + 5MHz NR CBW should be studied

**Issue 1-1-7: Channel raster for LP-WUR**

* Proposals
  + **Proposal 1: Channel raster design for LP-WUR should guarantee flexible placement within the in-band NR signal PRB grid, and be specified after RAN1 design is completed. (CATT)**
  + **Proposal 2：Reuse existing channel raster as a start point for LP-WUS study. (ZTE)**
  + **Proposal 3: Channel raster does not apply to WUR. (E///)**
* Recommended WF
  + Check and confirm proposal 3

**Issue 1-1-8: system parameters for LP-WUR**

* Proposals
  + **Proposal 1: No specification impact on WUR in terms of system parameter. (E///)**
* Recommended WF
  + TBA

**Issue 1-1-9: Side condition for LP-WUR requirements**

* Proposals
  + **Proposal 1: RAN4 to reflect both idle and connected mode conditions in the side conditions for the LPWUR requirements. (Qualcomm)**
* Recommended WF
  + TBA

**Issue 1-1-10: conducted test for LP-WUR**

* Proposals
  + **Proposal 1: Same conducted test should be applied to WUR and MR. (E///)**
* Recommended WF
  + TBA

# Topic #2: REFSENS, ASCS and ACS requirements

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2407069 | Apple | **Observation 1**: To achieve reasonable lifetimes for different LP-WUR implementations and scenarios, RAN4 should at least two sets of receiver requirements.  **Proposal 1**: RAN4 should keep discussing two sets of receiver requirements. One requirement suited for OFDM based receiver and one set for OOK which can be based on power detector type receiver.  **Proposal 2**: Keep support of 1Rx in FR1 for now. To minimize current consumption for wake-up receiver do not include Rx diversity.  **Observation 3**: RAN1 is currently discussion the physical layer design and first needs to complete link budge analysis. RAN4 requires the RAN1 input to finalise SNR for REFSENS.  **Observation 4**: To achieve high linearity and high gain the LNA requires more stages translating in more power consumption. To effectively reduce the power consumption gain and noise performance needs to be reduced. While typical NR FR1 receiver feature a noise figure of approximately 10 dB this value is expected to increase considerably for LP-WUR. Depending on the architecture and power saving choices the noise figure could rise to 22-25dB. |
| R4-2407412 | Sony | **Observation 1 Adopting a relatively small percentage value on the MDR may lead to an excessive test time.**  **Observation 2 The coverage of LP-WUS shall meet the Msg. 3 coverage with 1% MDR.**  **Observation 3 REFSENS is a requirement on the receiver to detect a signal over its noise floor and, therefore, should be based on missed detection rate solely.**  **Observation 4 The envelope detector (ED) based receivers provide more power saving gain than OFDM based receivers but are still capable of meeting the coverage target of Msg. 3. As a starting point, they can, therefore, be used as the reference architecture to derive the REFSENS requirement.**  **Observation 5 Since the LP-WUS needs to co-exist with other NR signals, it is reasonable to set the same ACS level for the LP-WUS receiver as the main receiver.**  **Observation 6 As there is no feedback on the LP-WUS receiver upon the wake-up signal, it may need a test mode so that the TE can measure the missed detection rate.**  **Observation 7 As an alternative to the test mode, 3GPP may also investigate whether succeeding transmissions from the main radio can be detected by the TE to measure the missed detection rate once the UE has been woken up.**  **Proposal 1 Use 1% missed detection rate as REFSENS metric for LP-WUR as a starting point to define the core requirement, and further study if higher percentage can be used while fulfilling the coverage target of LP-WUS.**  **Proposal 2 RAN4 may consider adopting a higher percentage MDR value, e.g. 10 %, in conformance test by scaling the REFSENS level accordingly.**  **Proposal 3 RAN4 shall wait for RAN1 to finalize the LP-WUS signal design before concluding on the REFSENS requirement.**  **Proposal 4 It is proposed that RAN4 start to select candidate LP-WUR reference architectures, which will be used to derive the REFSENS requirements in the future.**  **Proposal 5 It is proposed to down-select the RF-ED receiver for being used to derive the REFSENS requirements.**  **Proposal 6 It is proposed to adopt the zero-IF architecture with baseband ED and/or heterodyne architecture with IF ED receiver for being used to derive the REFSENS requirements.**  **Proposal 7 Based on the legacy method, RAN4 shall further refine the estimation of NF and SNR, once the LP-WUS signal design is stable, to ensure that the MIL of LP-WUS can be comparable with msg.3, based on the defined REFSENS requirement of LP-WUS.**  **Proposal 8 RAN4 should aim to define one set of requirements covering all types of LP-WUS receiver.**  **Proposal 9 The same test metric as used for REFSENS, shall also be used for ACS and ACSC for LP-WUR.**  **Proposal 10 Define the ACS requirement for LP-WUS as 33 dB and further investigating if the ACSC should be set to the same value as the ACS requirement. Once RAN4 agrees on the ACS and ASCS requirements, RAN4 could further derive the number of guard RB based on some practical filter assumption.**  **Proposal 11 RAN4 shall derive the number of guard RB based on some practical filter assumption once the ACS/ASCS requirement is agreed.**  **Proposal 12 RAN4 may consider leaving the testability discussion to RAN5.** |
| R4-2407650 | Huawei, HiSilicon | ***Proposal 1: It is proposed to adopt +5dB and +8dB on top of 9dB basis as NF for OFDM-based receiver and OOK-based receiver respectively as starting point for REFSENS.***  *Observation 1: RAN1 decided that the required RB number for a channel bandwidth equal or larger than 5MHz would be down-selected from 11 or 12 PRBs.*  *Observation 2: If 5MHz is considered as CBW for LP-WUS, 12 PRB is not aligned with RAN4 conclusion in Rel-18 SI study.*  ***Proposal 2: It is proposed to adopt 11 PRB for LP-WUS with 30kHz SCS for 5MHz channel bandwidth. In case of 15kHz SCS, at least the guard band should be similar to that of 30kHz. Specific PRB number can be further discussed based on RAN1 progress.***  *Observation 3: With worse REFSENS for LR, if keep the same REFSENS degradation level, i.e. 14dB, the ACS value range would be decreased even with the same interferer level as MR.*  *Observation 4: The filter evaluated by RAN4 in SI stage cannot provide sufficient suppression compared to the level defined in current spec for MR.*  ***Proposal 3: It is proposed to relax ACS requirement for LP-WUR from co-existence and performance perspective. The proposed ACS could be in the range of 20~25dBc.***  ***Proposal 4: It is proposed to adopt 1 RB as the size of guard RB for LP-WUS ASCS regardless of the applied SCS.***  ***Proposal 5: If guard RB is specified for ASCS scenario, there is no need to define specific requirement for ASCS.*** |
| R4-2407794 | CATT | **Proposal 1: RAN4 to consider 10% miss detection rate for LP-WUS as starting point and check further if it can meet the coverage target.**  **Proposal 2: RAN4 to introduce a requirement for false alarm rate for LP-WUS in order to guarantee the merits of introducing LP-WUS/LP-WUR.**  **Proposal 3: RAN4 to decide one or two reference architectures prior to proceeding with the detailed specification of RF requirements for LP-WUR** |
| R4-2407825 | Xiaomi | **Proposal 1: False alarm rate is a demodulation requirement related to the setting of the demodulation threshold. Whether to have false alarm rate should discuss in demodulation part not in FR part.**  **Proposal 2: using 1% missed detection rate as the starting point in the LLS.**  **Proposal 3: RAN4 can use the same assumption that +2dB, +5dB, +8dB on top of NF of MR (9dB) for LR’s NF as the starting point to evalue the feasible from coverage and implementation perspective.**  **Proposal 4: Using link level simulation assumptions in Table 2-1 as the starting point, whether ADC considered for RF impairments can further discuss.** |
| R4-2407894 | Samsung | **Proposal 1: missed detection rate can be taken as sole performance metric if false alarm performance can be directly or indirectly verified separately**  **Proposal 2: the REFSENS requirements can be derived only based on legacy approach, and the coverage target is not necessary to be considered as long as the architecture assumption is reasonable**  **Proposal 3: It is proposed to fully consider the antenna sharing and switching architecture when deciding NF and REFSNES requirements.**  **Proposal 4: it is proposed that both LP-SS and LP-WUS should be configured in REFSNES test** |
| R4-2407954 | CMCC | **Proposal 1: Use 1% missed detection rate as the starting point for performance metric for LP-WUS RF requirements, and not to use false alarm rate.**  **Proposal 2: Specify two sets of noise figure values for LP-WUS noise figure.**  **Proposal 3: Set 7dB or 9dB as the OFDM noise figure for the OFDM signal as the baseline.**  **Proposal 4: Choose 12-15dB noise figure as the baseline for the OOK signal.**  **Proposal 5: Specify two sets of SNR for LP-WUS.**  **Proposal 6: The ASCS requirement definition should consider both the ASCS value in dB scale and also applicable guard RB.** |
| R4-2408046 | Nokia Poland | **Proposal 1: Agree to have diversity gain as zero for LP\_WUR REFSENS calculation.**  **Proposal 2: Agree to have implementation margin to be significantly less than 2.5 dB.**  **Observation 1: NF has an impact on the coverage and power consumption of the LR.**  **Proposal 3: Agree to use the estimated NF of 12 dB as a baseline for LP\_WUR.**  **Observation 2: Parameters required for SNR evaluation are still being discussed in RAN1.**  **Observation 3: SNR has impact on the coverage and power consumption of the LR.**  **Proposal 4: Use 1% miss detection rate at 1% false alarm rate in link level simulation for deriving the SNR.**  **Proposal 5: Wait for RAN1 design before agreeing to a SNR value.**  **Proposal 6: Additional relaxation on SNR value is to be agreed once SNR values based on simulations are available.**  **Observation 4: Filter order has no impact on the performance with two guard RBs.**  **Observation 5: There is a minor performance improvement going beyond one guard RB.**  **Proposal 7: Test parameters defined in Table 7.5-3, 7.5-4, 7.5-5, and 7.5-6 of TS 38.101-1 apply for LP\_WUR ACS test case.**  **Proposal 8: In test case where Pinterferer depends on REFSENS, main receiver REFSENS should be used.** |
| R4-2408109 | vivo | **Proposal 1: For ACS and ASCS simulation, selecting 900MHz, 2.6GHz and 3.5GHz as example frequencies.**  **Proposal 2: RAN4 adopt the following detailed simulation parameters to evaluate ACS and ASCS guard RBs.**  **Proposal 3: RAN4 should specify the definition of ASCS, the following definition can be considered:**   * **Adjacent SubCarrier Selectivity (ASCS) is a measure of a receiver's ability to receive an LP-WUS signal at its assigned channel frequency in the presence of an adjacent subcarrier NR signal at a given frequency offset (guard RB) between LP-WUS and NR. ASCS is the ratio of the receive filter attenuation on the assigned LP-WUR channel frequency to the receive filter attenuation on the adjacent NR subcarrier.**   **Proposal 4: RAN4 should discuss and decide a proper BWinterferer for ASCS evaluation, e.g.,**   * **5MHz for CBW>20MHz case** * **All RBs between WUS edge to channel edge, for 5MHz/10MHz CBW case**   **Proposal 5: The ASCS requirements can not be verified directly, the test case should be designed at a fixed DL power of NR and LP-WUS (same PSD, X dB higher than REFSENS) to check whether the MDR is within X%.**  **Proposal 6: For ASCS, RAN4 do not need to specify the requirement value but just need to specify the test case condition (e.g., bandwidth, power level, MDR) and required guard RB.**  **Proposal 7: the ACS requirement definition for LP-WUR should be:**   * **Adjacent channel selectivity (ACS) is a measure of a receiver's ability to receive an ~~NR~~ LP-WUS signal at its assigned channel frequency in the presence of an adjacent channel signal at a given frequency offset from the center frequency of the assigned channel. ACS is the ratio of the receive filter attenuation on the assigned channel frequency to the receive filter attenuation on the adjacent channel(s).**   **Proposal 8: Consider performance metric X as [1~5] % for MDR.**  **Proposal 9: For REFSENS requirement, the performance metric should be MDR only.**  **Proposal 10: False alarm rate can be considered as a dedicated performance requirements for baseband demodulation, e.g., X% FAR at -Y dBm AWGN level.**  **Proposal 11: The following delta NF (gap between LR and MR) can be discussed in RAN4 for RESENS:**  **For OOK based WUR**   * **[3~7] dB**   **For OFDMA based WUR**   * **[0~7] dB** |
| R4-2408137 | Spreadtrum Communications | **Proposal 1: Whether we should define requirements of false alarm rate depends on RAN1’s progress.**  **Proposal 2: 1% missed detection rate can be used as a performance metric for REFSENS.**  **Proposal 3: The target SNR, we can wait for RAN1’s conclusion.**  **Proposal 4: NF can be defined as delta NF on top of MR (e.g., OOK based LP-WUS is + 8 dB and OFDM based LP-WUS is +2 dB on top of MR).**  **Proposal 5: Define REFSENS requirements to ensure LP-WUR meet the coverage target.** |
| R4-2408363 | ZTE Corporation, Sanechips | **Observation 1: If CRC is configured and the length of the CRC bits is decided, there is no need to consider FAR as performance metric.**  **Observation 2: If there is no CRC configured, power threshold is needed to help check LP-WUS and there is a tradeoff between MDR and FAR.**  **Proposal 1: Wait for RAN1’s conclusion on LP-WUS structure to decide the performance metric.**  **Proposal 2: Exclude RF envelope detection architecture for LP-WUR.**  **Proposal 3. To consider middle values of the SID’s results for OOK receiver architectures, i.e. 14 dB, as a start point.**  **Proposal 4: RAN4 should decide whether legacy 2.5dB IM can be used in LP-WUR RF requirements.**  **Proposal 5: To evaluate ASCS/ACS and guard RBs under fixed performance metric, filter order, RF impairments, SNR, ADC bit assumptions should be aligned first.**  **Proposal 6: The LLS simulation assumptions for ASCS/ACS evaluation are shown in Table 1.** |
| R4-2408825 | OPPO | **Observation 1: For simulation perspective, the MDR and FAR are used as 1% and 1% respectively.**  **Observation 2: The conclusion of Rel-18 SI doesn’t give a concrete value of FAR.**  **Observation 3: RAN1 use delta method to consider NF of LR compared to MR and to derive the required SNR.**  **Proposal 1: It is proposed to set the 1% missed detection rate as the performance metric for LP-WUS REFSENS requirement and not to limit the FAR.**  **Proposal 2: To wait for the RAN1 study of NF and SNR to further determine the REFSENS requirement.** |
| R4-2409104 | Ericsson | ***Proposal-1: For REFSENS, RAN4 wait RAN1 progress on SNR and coverage matching investigation.***  ***Proposal-2: 1% BLER can be used also as metric for LLS.***  ***Proposal-3: Companies report the RF impairment model together with simulation results.***  ***Proposal-4: Same 1% BLER to be used for simulation metric as ASCS and RF impairment reported by companies.***  ***Proposal-5: Focus on OOK1 simulation for the ASCS and ACS simulation and specify OOK1 RMC in the end.*** |
| R4-2407649 | Huawei, HiSilicon | ***Proposal 4: No need to combine SNR and NF together to target the same coverage of MSG3 for different set of requirements.***  ***Proposal 5: It is proposed to consider 4-bit ADC as assumption for the following LLS evaluations.***  ***Proposal 6: It is proposed to consider max 50ppm as assumption for frequency error of LP-WUR in the LLS evaluation.***  *Observation 3: The reciprocal mixing has less impact on ACS and blocking requirement even with a worse performed LO for LP-WUR.*  ***Proposal 7: Phase noise as an RF impairment could be considered as a UE implementation issue, but no need to be considered in specifying the ACS and blocking requirements.***  ***Proposal 8: Both miss-detection rate and false-alarm rate should be considered in specifying the Rx requirements for LP-WUR.*** |
| R4-2408032 | Qualcomm Incorporated | **Observation 1: The gNB does not know if its LP-WUS is beneficial for idle mode UEs, but it is aware of the connected mode UEs using LP-WUS.**  **Observation 2: For typical usage patterns, UEs stand to enjoy more significant energy consumption reduction in FR2 bands than FR1.**  **Proposal 1: RAN4 to consider using n258 as the example FR2 band.**  **Observation 3: For typical usage patterns, connected mode energy consumption dominates the long-term usage energy consumption. Idle mode consumption reduction is less important.**  **Proposal 2: RAN4 to reflect both idle and connected mode conditions in the side conditions for the LPWUR requirements.**  **Proposal 3: The Refsens condition is determined as the more stringent on the two:**   * **A NF and SNR based projection (UE feasibility consideration)**   **Coverage consideration including legacy DL signal in adjacent subcarriers (network consideration)** |
| R4-2408049 | Nokia Poland | [***Observation 1: Zero-IF architecture supports a high degree of reuse of the NR main radio components.***](#_Toc166509888)  [***Observation 2: To support more than one band, the receiver could use a wideband LNA or multiple LNAs supporting smaller frequency area.***](#_Toc166509889)  [***Observation 3: As the bandwidth of the WUS signal is expected to be scaled according to the sub carrier spacing the LP filter will most likely be required to have different cut off frequencies, e.g., one configuration for each sub-band spacing configuration.***](#_Toc166509890)  [***Observation 4: DC offset cancellation loop to attenuate the DC signal though could cause information loss.***](#_Toc166509891)  [***Proposal 1: Agree to use zero-IF receiver as a baseline architecture for LP\_WUR.***](#_Toc166509892)  [***Proposal 2: Agree to use the estimated NF of 12dB as a baseline for LP\_WUR.***](#_Toc166509893)  [***Observation 5: Inconsistent assumptions regarding impairments will lead to results which cannot be merged.***](#_Toc166509894)  [***Proposal 3: Agree to impairments and used models before collating the simulation results.***](#_Toc166509895)  [***Proposal 4: Agree to use common simulation parameters defined above in Table 2 for the LLS to determine the guard RBs for ACS and ASCS test cases.***](#_Toc166509896) |
| R4-2407826 | Xiaomi | **Proposal 1: Wen LP-WUS is located in a NR UE channel bandwidth larger than WUS signal and packed with NR legacy DL signal on both sides:**   * + **The ACS can keep the same requirements with legacy NR UE**   + **The parameters of unwanted interferring for the narrow band blocking and in band blocking can reuse the values of legacy NR UE, the wanted signalling can be defined based on the REFSENS of LP-WUS.**   **Proposal 2: Side conditions for ACS test:**   * + **LP-WUS occupies all assigned NR UE channel bandwidth standalone as figure 2-4.**   **Proposal 3: Wen LP-WUS occupies all assigned NR UE channel bandwidth:**   * + **The parameters of unwanted interferring for the narrow band blocking and in band blocking need be re-evaluated, the wanted signalling can be defined based on the REFSENS of LP-WUS.** |

## Open issues summary

### Sub-topic 2-1 Alignment of LLS parameters to specify ACS/ASCS requirements

**Issue 2-1-1: Center frequencies for LLS simulation**

* Proposals
  + **Proposal 1: For ACS and ASCS simulation, selecting 900MHz, 2.6GHz and 3.5GHz as example frequencies. (vivo)**
* Recommended WF
  + TBD

Xiaomi: agree with the proposal. We should keep the consistency to choose bands for requriements.

Huawei: we can 2.7GHz as threshold. We do not need band above it. The selection of example bands depends on other issues.

CATT: the current example bands can cover low, middle and high frequency ranges. We are fine with proposal.

ZTE: The low, middle and high bands are fine. We can set the threshold for the selection of bands.

Qualcomm: we do not want to change any discussion here. We need do the same exercise for FR2 also. Consider n258 as example.

**Agreement:**

* For ACS and ASCS simulation, select 900MHz, 2.6GHz and 3.5GHz as example frequencies for FR1.
* FFS on FR2 example band(s)

**Issue 2-1-2: Performance metric (MDR/BLER value) for LLS simulation (apply to ACS/ASCS and REFSENS)**

* Proposals
  + **Option 1: Use 1% MDR/BLER.**
  + **Option 2: Use 5% MDR/BLER.**
  + **Option 3: Use 10% MDR/BLER.**
* Recommended WF
  + check and confirm 5%

Sony: Agree with observation from moderator that 1% is used in study phase in RAN1. 10% is considered to accommodate the testability issue. We can keep all for the time being and down-select in future.

Ericsson: For LLS, we prefer 1% which is the same as study phase. For test purpose, the metric could be relaxed but not for the simulation.

CATT: It is for simulation rather than for requirement. We propose 10%. We are fine with 5%. The performance includes both false alarm rate and MDR.

Huawei: Agree with Ericsson. The most important thing is to determine SNR. In both RAN1 and RAN4 study phase, we use 1%. For the test we can further consider whether it can be relaxed.

ZTE: Share the same view as Huawei. 1% should be used to align with RAN1.

Samsung: We can consider large MDR. At this stage, we do not need down-selection. In the simulation we can consider different percentage and based on results we can consider which value is used for test and requirements.

CMCC: Agree with Huawei and ZTE. 1% is better value. The value is the same as study phase in Ran1 and RAN4.

OPPO: Support 1% MDR.

Apple: Fine with 1% for simulation. For testing we can discuss further.

Vivo: In RAN4 we use 95% throughput for requirements.

Ericsson: False alarm rate as optional.

Nokia: If you do not set the false alarm rate, the simulation results will vary and SNR is very low.

Ericsson: False alarm rate is linked to threshold.

Agreement:

* For LLS simulation (apply to ACS/ASCS and REFSENS), the metric includes
  + 1% MDR/BLER as baseline and 5% MDR/BLER as optional
  + The following false alarm rate can be considered
    - 1%
    - 5%
    - Providing the information whether the false alarm rate is considered or not
* Further down-select the performance metric for the requirements and testing

**Issue 2-1-3: Waveform for LLS simulation**

* Proposals
  + **Option 1: Use both OOK1 and OOK4 based on RAN1 agreements.**
  + **Option 2: Only OOK1.**
* Recommended WF
  + Option 1

CATT: Clarify whether UE supports OOK1 or OOK4 depending on capability.

Ericsson: in the legacy, we only have one RMC. We are not sure if we need specify both waveform for testing. We may reduce the scope of simulation.

Nokia: in the design, OOK 1 m equals to 1 and OOK4 m equals to 1 or 4. We should run simulations for all options.

Huawei: Purpose of link level simulation is to determine the SNR and guard RBs. Both waveforms should be considered.

Agreement:

* Use both OOK1 and OOK4 based on RAN1 agreements for link level simulations

**Issue 2-1-4: number of LP-WUS RBs for LLS simulation**

* Proposals
  + **Proposal 1: It is proposed to adopt 11 PRB for LP-WUS with 30kHz SCS for 5MHz channel bandwidth. In case of 15kHz SCS, at least the guard band should be similar to that of 30kHz. Specific PRB number can be further discussed based on RAN1 progress. (Huawei)**
  + **Proposal 2: consider different RB cases. (vivo)**
    - **Fixed 12RB ~ 4.32MHz LP-WUS for 10MHz and 20MHz NR CBW cases**
    - **Dynamic WUS RBs for 5MHz case, less WUS RB with more ACS guard RBs, e.g., [9 RB+2 guard RB, 7 RB+4 guard RB, or other cases]**
  + **Proposal 3: 11 PRBs irrespective of SCS. (Nokia)**
* Recommended WF
  + 11PRB for 30kHz SCS, 15kHz SCS FFS. RB number for 15kHz SCS wait for RAN1 decision this meeting

Qualcomm: We should wait for RAN1 to finish. I do not see value to decide this.

CATT: if LP-WUS signal has already been finished by RAN1, the RB# will be decided by RAN1.

Huawei: last RAN1 meeting the required RBs is for purpose of PHY design. They just considered 11 and … Less 1 RB will be considered for guard RB if only 12 RB is considered for 5MHz. We can tell RAN1 that they only can consider 11 RB for 5MHz CBW.

Xiaomi: Agree with Huawei. We need tell RAN1 that only 11 RB can be used. RAN1 said 11~12 RB for equal to or larger than 5MHz.

Apple: I wonder if it is not limited to FR1. If LP-WUS includes both paging and RRM function, we need consider further reduce the RB number. We need wait for RAN1.

Huawei: Final agreement will be decided by RAN1. We need consider the guard RB in RAN1.

Moderator: for link level simulation, we select 11RB for 30KHz SCS. RAN1 can decide. We do not need LS to RAN1.

CMCC: As Huawei mentioned, 12 RPB is not suitable for 30KHz SCS. But if we consider CBW larger than 5MHz, 12 RPBs cannot be precluded. We should have some limiting agreement 11RB for 30KHz SCS, and tell RAN1 that 11 PRB for 30KHz SCS is only considered for 5MHz.

Apple: Agree with CMCC. Can we inform RAN1 that 11 RPB is considered for 5MHz with 30HKz SCS and what numbers of RB for LP-WUS can be decided by RAN1.

Ericsson: at this stage, we are not sure if we need inform RAN1 now. Maybe we need consensus of guard RB first.

ZTE: RAN1 has already realized 11 RB is used.

CATT: one important issue is that RAN4 does not conclude whether 1 RB guard RB is sufficient.

Huawei: we should inform RAN1.

**Agreement:**

* Assume 11PRB for LP-WUS signal with 30kHz SCS for simulations
* FFS on RB number(s) for 15KHz SCS depending on RAN1 decision

**Issue 2-1-5: number of ADC assumption for LLS simulation**

* Proposals
  + **Option 1: 4 bit**
  + **Option 2: 8 bit**
* Recommended WF
  + Option 2

Sony: we would like to keep all options. Less bit used, less power consumption.

Huawei: Agree with Sony. In previous study in RAN1, 5 bit is enough. We do not need exclude 4 bit option.

Vivo: we prefer to keep 8 bit for simulation. For simulations, we can provide results based on both.

Agreement:

* Number of ADC assumption for LLS simulation
  + Option 1: 8 bit
  + Option 2: 4 bit
  + Encourage companies to provide simulation results with both options for comparison

**Issue 2-1-6: Frequency error assumption for LLS simulation**

* Proposals
  + **Option 1: up to 20ppm**
  + **Option 2: up to 50ppm**
* Recommended WF
  + TBD

Moderator: based on RAN1, 20ppm is sufficient for simulation.

Agreement

* Frequency error assumption for LLS simulation
  + Up to 20ppm

**Issue 2-1-7: Phase noise model for LLS simulation**

* Proposals
  + **Option 1: Not needed in LLS. Consider as RF impairment of implementation.**
  + **Option 2: other**
* Recommended WF
  + TBD

Agreement:

* Not needed in LLS. Consider as RF impairment of implementation.

**Issue 2-1-8: For ASCS, the BWinterferer for ASCS evaluation**

* Proposals
  + **Proposal 1: RAN4 should discuss and decide a proper BWinterferer for ASCS evaluation, e.g., (vivo)**
    - **5MHz for CBW>20MHz case**
    - **All RBs between WUS edge to channel edge, for 5MHz/10MHz CBW case**
* Recommended WF
  + TBD

CATT: what is the CBW for 15MHz. We should include 15MHz.

Huawei: What is the meaning of subbullets?

Vivo: for 10MHz, 11 PRB will be occupied for LP-WUS. We just need calculated a limited number for interference. For wider CBW, we just calculate the near RB interference.

Qualcomm: 5MHz is the size of interference of ASCS? This assumption is for what UE filter looks like. All the RBs not occupied by LP-WUS and guardband will cause interference.

Huawei: Since it is for evaluation we need consider the typical case. In study phase we just use 20MHz for NR channel bandwidth with 5MHz LP-WUS embedded.

Agreement:

* For ASCS evaluation, only 10MHz and 20MHz NR CBWs are assumed and the BWinterferer is
  + All RBs between WUS edge to channel edge

**Issue 2-1-9: RF impairment mode for LLS simulation**

* Proposals
  + **Proposal 1: Companies report the RF impairment model together with simulation results. (E///)**
* Recommended WF
  + TBD

Ericsson: we have discussed some of them in the previous topic. We do not need discuss it at all.

*Moderator: several companies propose the full set of simulation parameters, details should be aligned.*

**Issue 2-1-10: The overall simulation parameters for LLS simulation**

* Proposals
  + **Proposal 1: suggest to use following table to start discussions on each simulation parameter one by one, and conclude this meeting. (Moderator)**

Table 1: Simulation parameters for LP-WUS ACS and ASCS

|  |  |  |
| --- | --- | --- |
| Attributes | Assumptions | |
| Carrier Frequency | 900MHz, 2.6GHz, 3.5GHz | |
| Case name | OOK-1 waveform | OOK-4 waveform |
| Channel structure [TBD impacts] | Total 8/16 bits: data: 8/16 bits CRC: 8 bits | data: 20bits CRC: 8 bits |
| Chip rate | M=1 | M=2/4 |
| WUS duration | 28 symbols | |
| Waveform | OOK-1/OOK-4 | |
| Coding | 1/2 rate Manchester coding | |
| Time error | 0 | |
| Residual Frequency error | 0/10/20 ppm | |
| SCS | 30kHz | |
| UE Channel BW | 20MHz (51 RB)-case 1  10MHz (24 RB)-case 2  5MHz (11 RB)-case 3 | |
| WUS RB | * Fixed 12RB ~ 4.32MHz for 10MHz and 20MHz cases * Dynamic WUS RBs for 5MHz case, less WUS RB with more ACS guard RBs, e.g., [9 RB+2 guard RB, 7 RB+4 guard RB, or other cases] | |
| Position within channel | * For 10/20MHz CBW, Center for ASCS, edge for ACS [assume ASCS no impact] * For 5MHz CBW, fixed center of channel | |
| Guardband of NR channel, both wanted cell and interfer cell (ACS) | * For wanted signal: 505kHz for 5MHz, 665kHz for 10MH, 805kHz for 20Mhz * For interference cell2 5MHz: fixed 505kHz | |
| Guard RB | * For ASCS: 0 or 1RB on each side of LP-WUS bandwidth * For ASCS: 1/2/3/4 RB | |
| Filter | * 3th/5th Order lowpass Butterworth with fixed 4.32MHz bandwidth for 10MHz/20MHz case * The filter bandwidth is adapted with actual WUS RBs, for 5MHz case | |
| ASCS | PDSCH mapped on RBs not used for LP-WUS and Guard RB;  EPRE of PDSCH /EPRE of LP-WUS = 0 dB  Same PSD with WUS signal | |
| ACS | PDSCH mapped on interference RBs(11RB for 5MHz CBW), one side;  EPRE of PDSCH /EPRE of in-band LP-WUS = 31.5 dB, and other value? | |
| Wanted signal SNR level | For ACS, High SNR of LP-WUS | |
| Sampling rate | 7.68MHz | |
| ADC bit width | 8 bits ADC for ASCS/ACS | |
| Phase noise | none | |
| Non-linearities | Not modelled | |
| Power boosting | 0dB/3dB for OOK-1/OOK-4 | |
| Channel Model | TDL-C 300 | |
| Performance metric | MDR x%; BLER x% | |

* + **Proposal** 2: Additional parameters to be considered are, OOK4 M=4, CRC= none, NR transmission= QPSK, information bits=8 for both OOK1 and OOK4. (Nokia)
* Recommended WF
  + To be decided.

Agreement:

* Wait for RAN1 conclusion on FR2 to decide the parameters for evaluations

|  |  |  |  |
| --- | --- | --- | --- |
| Attributes | Assumptions | | |
| Case name | OOK-1 waveform | | OOK-4 waveform |
| Channel structure [TBD impacts] | Total 8/16 bits | | |
| Chip rate | M=1 | M=1/2/4 | |
| WUS duration | FFS | | |
| Waveform | OOK-1/OOK-4 | | |
| Coding | 1/2 rate Manchester coding | | |
| Time error | 0 | | |
| Residual Frequency error | 0/10/20 ppm | | |
| SCS | 30kHz | | |
| UE Channel BW | 20MHz (51 RB)-case 1  10MHz (24 RB)-case 2  5MHz (11 RB)-case 3 | | |
| WUS RB | * Fixed 11RB ~ 3.96MHz for 10MHz and 20MHz cases | | |
| Position within channel | * For 10/20MHz CBW, Center for ASCS, edge for ACS [assume no ASCS impact] * For 5MHz CBW, fixed center of channel | | |
| Guardband of NR channel, both wanted cell and interfer cell (ACS) | * For wanted signal: 505kHz for 5MHz, 665kHz for 10MH, 805kHz for 20Mhz * For interference cell2 5MHz: fixed 505kHz | | |
| Guard RB | * For ASCS: 0 or 1RB on each side of LP-WUS bandwidth * For ACS: 1/2/3/4 RB | | |
| Filter | * 3th/5th Order lowpass Butterworth matching fixed 3.96MHz RF bandwidth for 10MHz/20MHz case   + Other order lowpass filter is not precluded * The filter bandwidth is adapted with actual WUS RBs, for 5MHz case | | |
| ASCS | PDSCH mapped on RBs not used for LP-WUS and Guard RB;  EPRE of PDSCH /EPRE of LP-WUS = 0 dB  Same PSD with WUS signal | | |
| ACS | PDSCH mapped on interference RBs (11RB for 5MHz CBW), one side;  EPRE of PDSCH /EPRE of in-band LP-WUS = [20~33] dB  NOTE: decide the interference level depending on SNR | | |
| Wanted signal level | For ACS, REFSENS + 14 dB for LP-WUS | | |
| Sampling rate | 7.68MHz | | |
| ADC bit width | 8 bits ADC for ASCS/ACS | | |
| Phase noise | none | | |
| Non-linearities | Not modelled | | |
| Power boosting | EPRE ratio: 0dB/3dB for OOK-1/OOK-4  NOTE: 3dB is optional for simulation | | |
| Channel Model | Option 1: TDL-C 300  Option 2: AWGN  Note: encourage companies to provide simulation results with both options | | |
| Performance metric | MDR/BLER x% | | |

### Sub-topic 2-2 REFSENS requirements

**Issue 2-2-1: Only MDR for REFSENS**

* Proposals
  + **Option 1: Only MDR is sufficient for REFSENS.** 
    - **FAR can be considered as a dedicated demodulation requirements**
  + **Option 2: Both MDR and FAR should be considered.**
* Recommended WF
  + TBD

Ericsson: false alarm could be used for demodulation test. We do not need test it in RF.

Huawei: when we discuss the requirement, we need consider the testability issue. False alarm rate needs be considered in FESENS. We need consider both to ensure it can work.

Apple: What is the metric to indicate the false alarm? Message 1? It is not easy to test.

Xiaomi: MDR and FAR are different definitions. FAR is just with noise. FAR should be checked in the demodulation.

Nokia: with or without FAR the performance will be different. UE can easily pass the requirement.

Sony: we only discuss the test metric for REFSENS requirement. It is not only test for receiver. We can guarantee the FRA performance by demod.

Moderator: for REFSENS, the test is under external noise free condition. FAR test needs considering the higher noise level.

*Moderator: agreed only LP-WUS is needed for REFSENS, in WF*

**Issue 2-2-2: signal configuration for REFSENS requirements**

* Proposals
  + **Proposal 1: Both LP-SS and LP-WUS should be configured in REFSNES test. (Samsung)**
* Recommended WF
  + TBD

**Issue 2-2-3: SNR value (not requirement) for REFSENS**

* Proposals
  + **Proposal 1: Specify two sets of SNR for LP-WUS. (CMCC)**
  + **Proposal 2: Additional relaxation on SNR value is to be agreed once SNR values based on simulations are available. (Nokia)**
  + **Proposal 3: Wait for RAN1 SNR progress. (E///, Nokia,** **Spreadtrum, OPPO)**
  + **Proposal 4: No need to combine SNR and NF together to target the same coverage of MSG3 for different set of requirements. (Huawei)**
  + **Proposal 5: The Refsens condition is determined as the more stringent on the two: (Qualcomm)**
    - **A NF and SNR based projection (UE feasibility consideration)**
    - **Coverage consideration including legacy DL signal in adjacent subcarriers (network consideration)**
  + **Proposal 6: Based on the legacy method, RAN4 shall further refine the estimation of NF and SNR, once the LP-WUS signal design is stable, to ensure that the MIL of LP-WUS can be comparable with msg.3, based on the defined REFSENS requirement of LP-WUS. (Sony)**
* Recommended WF
  + Wait for RAN1 SNR progress

**Issue 2-2-4: NF Gap between LR and MR for REFSENS (assume MR as 9dB)**

* Proposals
  + **Option 1: +5dB for OFDM-based, +8dB for OOK-based (Huawei)**
  + **Option 2: +2dB, +5dB, +8dB for LR’s NF. (Xiaomi)**
  + **Option 3: 0dB for the OFDM signal, +3-6dB gap for OOK signal. (CMCC)**
  + **Option 4:** +**3 dB gap as a baseline for LP\_WUR. (Nokia)**
  + **Option 5: +0-7dB for OFDM-based, +3~7dB for OOK-based. (vivo)**
  + **Option 6: +2 dB for OFDM-based, +8dB for OOK-based. (Spreadtrum)**
  + **Option 7: +5dB for OOK-based. (ZTE)**
* Recommended WF
  + Discuss based on the summarized value

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| NF gap (on top of MR 9dB) | Huawei | Xiaomi | CMCC | Nokia | vivo | Spreadtrum | ZTE |
| **OFDM-based** | 5dB | 2/5/8dB | 0dB | 3dB | 0-7dB | 2dB | ? |
| **OOK-based** | 8dB | 2/5/8dB | 3-6dB | 3dB | 3-7dB | 8dB | 5dB |

**Issue 2-2-5: Diversity Gain value for REFSENS**

* Proposals
  + **Option 1: Set to 0. (Nokia, Apple)**
  + **Option 2: other**
* Recommended WF
  + Agreeable

**Issue 2-2-6: IM value for REFSENS**

* Proposals
  + **Option 1: less than 2.5 dB. (Nokia)**
  + **Option 2: Check whether to reuse legacy 2.5dB. (ZTE)**
* Recommended WF
  + TBD

**Issue 2-2-7: False alarm rate requirements for LP-WUS receiver**

* Proposals
  + **Proposal 1: False alarm rate is a demodulation requirement related to the setting of the demodulation threshold. Whether to have false alarm rate should discuss in demodulation part not in FR part. (Xiaomi)**
  + **Proposal 2: False alarm rate can be considered as a dedicated performance requirements for baseband demodulation, e.g., X% FAR at -Y dBm AWGN level. (vivo)**
  + **Proposal 3: Whether we should define requirements of false alarm rate depends on RAN1’s progress. (Spreadtrum)**
  + **Proposal 4: RAN4 to introduce a requirement for false alarm rate for LP-WUS in order to guarantee the merits of introducing LP-WUS/LP-WUR. (CATT)**
* Recommended WF
  + Consider FAR as demodulation requirements

**Issue 2-2-8: Whether a baseline architecture is needed for LP-WUS receiver**

* Proposals
  + **Proposal 1: Agree to use zero-IF receiver as a baseline architecture for LP\_WUR. (Nokia)**
  + **Proposal 2: Exclude RF envelope detection architecture for LP-WUR. (ZTE, Sony)**
  + **Proposal 3: It is proposed that RAN4 start to select candidate LP-WUR reference architectures, which will be used to derive the REFSENS requirements in the future. (Sony)**
  + **Proposal 4: RAN4 to decide one or two reference architectures prior to proceeding with the detailed specification of RF requirements for LP-WUR. (CATT)**
  + **Proposal 5: It is proposed to fully consider the antenna sharing and switching architecture when deciding NF and REFSNES requirements. (Samsung)**
* Recommended WF
  + Discuss NF for each type as architecture agnostic.

### Sub-topic 2-3 ASCS requirements

**Issue 2-3-1: Align the definition of ASCS requirements**

* Proposals
  + **Proposal 1: The ASCS requirement definition should consider both the ASCS value in dB scale and also applicable guard RB. (CMCC)**
  + **Proposal 2: RAN4** **can specify the definition of ASCS, as following**
    - **Adjacent SubCarrier Selectivity (ASCS) is a measure of a receiver's ability to receive an LP-WUS signal at its assigned channel frequency in the presence of an adjacent subcarrier NR signal at a given frequency offset (guard RB) between LP-WUS and NR. ASCS is the ratio of the receive filter attenuation on the assigned LP-WUR channel frequency to the receive filter attenuation on the adjacent NR subcarrier**
* Recommended WF
  + TBD

**Issue 2-3-2: ASCS requirements value**

* Proposals
  + **Proposal 1: If guard RB is specified for ASCS scenario, there is no need to define specific requirement for ASCS. (Huawei, vivo)**
    - **test case condition (e.g., bandwidth, power level, MDR) and required guard RB should be specified**
  + **Proposal 2: further investigating if the ACSC should be set to the same value as the ACS requirement. (Sony)**
* Recommended WF
  + Check whether proposal 1 is agreeable

**Issue 2-3-3: Required number of guard RB for ASCS**

* Proposals
  + **Proposal 1: It is proposed to adopt 1 RB as the size of guard RB for LP-WUS ASCS regardless of the applied SCS. (Huawei)**
  + **Proposal 2: RAN4 shall derive the number of guard RB based on some practical filter assumption once the ACS/ASCS requirement is agreed. (Sony)**
* Recommended WF
  + Guard RB value needs further discussion based on LLS outcome

**Issue 2-3-4: Test case for ASCS**

* Proposals
  + **Proposal 1: The ASCS requirements can not be verified directly, the test case should be designed at a fixed DL power of NR and LP-WUS (same PSD, X dB higher than REFSENS) to check whether the MDR is within Y%. (vivo)**
* Recommended WF
  + TBA

### Sub-topic 2-4 ACS requirements

**Issue 2-4-1: Whether to update the ACS definition for LP-WUS**

* Proposals
  + **Proposal 1: the ACS requirement definition for LP-WUR. (vivo)**
    - **Adjacent channel selectivity (ACS) is a measure of a receiver's ability to receive an ~~NR~~ LP-WUS signal at its assigned channel frequency in the presence of an adjacent channel signal at a given frequency offset from the center frequency of the assigned channel. ACS is the ratio of the receive filter attenuation on the assigned channel frequency to the receive filter attenuation on the adjacent channel(s).**
* Recommended WF
  + TBA

**Issue 2-4-2: ACS requirements value**

* Proposals
  + **Proposal 1: It is proposed to relax ACS requirement for LP-WUR from co-existence and performance perspective. The proposed ACS could be in the range of 20~25dBc. (Huawei)**
  + **Proposal 2: Wen LP-WUS is located in a NR UE channel bandwidth larger than WUS signal and packed with NR legacy DL signal on both sides: (Xiaomi)**
    - **The ACS can keep the same requirements with legacy NR UE**
    - **The parameters of unwanted interferring for the narrow band blocking and in band blocking can reuse the values of legacy NR UE, the wanted signalling can be defined based on the REFSENS of LP-WUS.**
  + **Proposal 3: Define the ACS requirement for LP-WUS as 33 dB. (Sony)**
* Recommended WF
  + TBA

**Issue 2-4-3: Required guard RB for ACS case**

* Proposals
  + **Proposal 1: It is proposed to define 1 RB for 30kHz SCS as guard RB size for LP-WUR ACS case. (Huawei)**
  + **Proposal 2: RAN4 shall derive the number of guard RB based on some practical filter assumption once the ACS/ASCS requirement is agreed. (Sony)**
  + **Proposal 3: Define the ACS requirement with guard RBs as the LP-WUS signal at the edge of NR channel and the interference NR signal is directly next to the first NR channel. (OPPO)**
* Recommended WF
  + TBA

**Issue 2-4-4: Side condition for ACS test case**

* Proposals
  + **Proposal 1: - LP-WUS occupies all assigned NR UE channel bandwidth standalone as figure 2-4. (Xiaomi)**
* Recommended WF
  + TBA

**Issue 2-4-5: Test parameters for LP-WUR ACS case**

* Proposals
  + **Proposal 1: Test parameters defined in Table 7.5-3, 7.5-4, 7.5-5, and 7.5-6 of TS 38.101-1 apply for LP\_WUR ACS test case. (Nokia)**
    - **In test case where Pinterferer depends on REFSENS, main receiver REFSENS should be used**
* Recommended WF
  + TBD

# Topic #3: Other RF requirements

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2407651 | Huawei, HiSilicon | *Observation 1: LP-WUR may have less dynamic range and capability to resist against strong blocking interference as MR could do owing to the tradeoff for the implementation of low power consumption.*  ***Proposal 1: In order to guarantee the coverage of LP-WUR, the interference levels for IBB and OBB could be relaxed compared to the values defined for MR.***  ***Proposal 2: FFS whether LR can work well in presence of strong interference.***  ***Proposal 3: FFS whether intermodulation requirement needs to be relaxed for LP-WUR.***  ***Proposal 4: The same level of receiver spurious emissions for MR shall be defined for LR as well.***  ***Proposal 5: spurious response as a remedial measure for blocking tests needs to be considered for LP-WUR.*** |
| R4-2407795 | CATT | **Not uploaded yet** |
| R4-2407826 | Xiaomi | **Proposal 3: Wen LP-WUS occupies all assigned NR UE channel bandwidth:**   * + **The parameters of unwanted interferring for the narrow band blocking and in band blocking need be re-evaluated, the wanted signalling can be defined based on the REFSENS of LP-WUS.**   **Proposal 4: The out of band blocking and spurious response for LP-WUS can reuse the requirements of legacy NR UE.** |
| R4-2407955 | CMCC | **Proposal 1: In-band blocking requirement for legacy UE could be reused.**  **Proposal 2: the OBB requirement for legacy UE in TS 38.101-1 could be reused.**  **Proposal 3: specify two sets of requirements for OFDM signal and OOK signal.**  **- The requirements in TS 38.101-1 for legacy UE could be reused for OFDM signal.**  **- New intermodulation requirements need to be specified for OOK signal.**  **Proposal 4: the legacy spurious emission for legacy UE in TS 38.101-1 could be reused.** |
| R4-2408047 | Nokia Poland | **Proposal 1: Specify maximum input level requirements and side conditions for LP-WUR.**  **Observation 1: Possible bandwidths being considered for LP-WUS in FR1 are ≤5MHz.**  **Proposal 2: A single value for the maximum input level is sufficient for LP-WUR.**  **Observation 2: There hasn’t been any change in assumptions regarding MCL and gNB output power.**  **Proposal 3: Use maximum input level of -25 dBm for LP-WUR.**  **Observation 3: Narrow band blocking requirements haven’t been discussed in context of LP-WUR.**  **Observation 4: Additional requirements will not provide additional information regarding receiver performance if some more stringent requirement already exists. They will just increase the time for conformance tests.**  **Proposal 4: No need to define narrow band blocking requirements.** |
| R4-2408110 | vivo | **Proposal 1: The IBB/OBB/intermodulation requirements for LP-WUS is related to the allocated position of LP-WUS signal within NR channel, the definition and test cases should be modified.**  **Proposal 2: The DL power level for IBB/OBB/intermodulation requirements should also be re-evaluated for LP-WUS at different bandwidth and different location.**  **Proposal 3: The Guard RBs for ACS/ASCS should be configured for the above requirements.**  **Proposal 4: LP-WUR can reuse the general spurious emissions requirements directly.** |
| R4-2408824 | OPPO | **Observation 1: For blocking requirement, the interfere is based on outside EM environment and it is the same for LR when compared to MR.**  **Proposal 1: It is proposed to reuse the same IBB and OBB requirement of MR to LP-WUR.**  **Proposal 2: For RX spurious emission, reuse current MR requirement.** |
| R4-2409103 | Ericsson | **Proposal-1: The WUR should tolerate the same level RF interferer of IBB and OBB as main receiver.**  **Proposal-2: The WUR requirement should be set in relation to the MR channel bandwidth.**  **Proposal-3: The same of the degradation of wanted power level of the WUR.**  **Proposal-4: The same condition set for WUR REFSESN requirements should be extended for IBB and OBB test.**  **Proposal-5: Spurious response should be treated the same with the IBB and OBB for WUR.**  **Proposal-6: For intermodulation response rejection requirement, the WUR requirement should be tested with interferer setting from MR.**  **Proposal-7: Same spurious emission requirement for WUR and MR.** |
|  |  |  |

## Open issues summary

### Sub-topic 3-1 General for UE RF

**Issue 3-1-1: IBB and OBB assumption**

* Proposals
  + **Proposal 1: The WUR should tolerate the same level RF interferer of IBB and OBB as main receiver. (E///)**
  + **Proposal 2: FFS whether LR can work well in presence of strong interference (Huawei)**
* Recommended WF
  + TBA

**Issue 3-1-2: IBB and OBB requirements**

* Proposals
  + **Proposal 1: In order to guarantee the coverage of LP-WUR, the interference levels for IBB and OBB could be relaxed compared to the values defined for MR. (Huawei)**
  + **Proposal 2: The IBB/OBB can reuse legacy NR UE requirements. (CMCC, OPPO, Xiaomi)**
  + **Proposal 3: The IBB/OBB/intermodulation requirements for LP-WUS is related to the allocated position of LP-WUS signal within NR channel, the definition and test cases should be modified. (vivo)**
  + **Proposals 4: The WUR requirement should be set in relation to the MR channel bandwidth. (E///)**
* Recommended WF
  + TBA

**Issue 3-1-3: IBB and OBB test case**

* Proposals
  + **Proposal 1: The DL power level for IBB/OBB requirements should also be re-evaluated for LP-WUS at different bandwidth and different location. (vivo)**
    - **The Guard RBs for ACS/ASCS should be configured for the above requirements**
  + **Proposal 2: The same of the degradation of wanted power level of the WUR. The same condition set for WUR REFSESN requirements should be extended for IBB and OBB test (E///)**
* Recommended WF
  + TBA

**Issue 3-1-4: Intermodulation requirements**

* Proposals
  + **Proposal 1: FFS whether intermodulation requirement needs to be relaxed for LP-WUR. (Huawei)**
  + **Proposal 2: the WUR requirement should be tested with interferer setting from MR. (E///)**
  + **Proposal 3: The DL power level for intermodulation requirements should also be re-evaluated for LP-WUS at different bandwidth and different location. (vivo)**
    - **The Guard RBs for ACS/ASCS should be configured for the above requirements**
  + **Proposal 4:** **specify two sets of requirements for OFDM signal and OOK signal. (CMCC)**
* **The requirements in TS 38.101-1 for legacy UE could be reused for OFDM signal.**
* **New intermodulation requirements need to be specified for OOK signal.**
* Recommended WF
  + TBD

**Issue 3-1-5: IF LP-WUS occupies all assigned NR UE channel bandwidth**

* Proposals
  + **Proposal 1: - The parameters of unwanted interferring for the narrow band blocking and in band blocking need be re-evaluated, the wanted signalling can be defined based on the REFSENS of LP-WUS. (Xiaomi)**
* Recommended WF
  + TBD

### Sub-topic 3-2 spurious emissions and response requirements

**Issue 3-2-1: Spurious emissions requirements**

* Proposals
  + **Proposal 1: The same level of receiver spurious emissions for MR shall be defined for LR as well. (Huawei, CMCC, vivo, Xiaomi, OPPO, E///)**
* Recommended WF
  + TBD

**Issue 3-2-2: spurious response requirements**

* Proposals
  + **Proposal 1: spurious response as a remedial measure for blocking tests needs to be considered for LP-WUR. (Huawei)**
  + **Proposal 2: Spurious response should be treated the same with the IBB and OBB for WUR. (E///)**
* Recommended WF
  + TBD

### Sub-topic 3-3 Other Rx requirements

**Issue 3-3-1: Maximum input level requirements**

* Proposals
  + **Proposal 1: Specify maximum input level requirements and side conditions for LP-WUR. (Nokia)**
    - **A single value as of -25 dBm is sufficient**
* Recommended WF
  + TBD

**Issue 3-3-2: Narrow band blocking requirements**

* Proposals
  + **Proposal 1: No need to define narrow band blocking requirements. (Nokia)**
* Recommended WF
  + TBD

# Topic #4: Testability issues

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2407652 | Huawei, HiSilicon | ***Observation 1: LP-WUS operation in IDLE/INACTIVE mode and CONNECTED mode are discussed in RAN1. The LP-WUS signals could be different for these modes, which is still under discussion.***  ***Proposal 1: Test cases should be designed separately LP-WUS operation in IDLE/INACTIVE mode and CONNECTED mode since the procedures are different and the LP-WUS signals could be different for these modes.***  ***Observation 2: LP-WUS operation in IDLE/INACTIVE mode and CONNECTED mode depends on UE capability, which means UE may not support both modes.***  ***Observation 3: Test with complete procedure of waking up MR and report ACK in connected mode is not only time consuming but could also incur fake detection with MR is always on.***  ***Proposal 2: Counter the detection rate without waking up the MR would be enough for the LP-WUS test in terms of verifying the RF requirements.***  ***Proposal 3: False alarm rate should be considered for the LP-WUS test.***  ***Proposal 4: Consider 1% as value for both detection rate and false alarm rate.***  ***Proposal 5: Leave the details of test cases design to RAN5.***  ***Proposal 6: Test mode as well as the details of test mode for LP-WUS verification can be left to RAN5.*** |
| R4-2408050 | Nokia Poland | **Observation 1: Specifications are used by vendors as design guidelines.**  **Observation 2: Conformance testing is used to make sure the final device is performing well enough in the field.**  **Observation 3: It is not possible to test just the performance of the LP-WUR without the MR unless there is a test mode to enable LP-WUR to have direct external interface to the TE.**  **Observation 4: If a no sleeping (DRX) cycle is configured, then MR can just stay awake and pass the tests cases meant for testing LP-WUR performance.**  **Proposal 1: Link level simulations with ≤ 1% missed detection rate will be used for deriving the LP-WUR requirements.**  **Observation 5: Only motivation to have a higher (≥1%) MDR is to save conformance test time.**  **Observation 6: Lot of factors impacting the time taken for test case execution are under the scope of RAN5 work.**  **Proposal 2: RAN5 can decide the confidence level to be used for testing the LP-WUR requirements in a reasonable amount of time.**  **Observation 7: As the LP\_WUR is receive only, the MR can be used for uplink transferring of data required for evaluating the LP-WUR performance.**  **Proposal 3: Feedback from the UE regarding LP-WUR performance should be gathered in the RRC\_CONNECTED mode.**  **Observation 8: False alarm rate is required to have a higher confidence on the calculated miss detection rate.**  **Proposal 4: False alarm rate should be reported by the LP\_WUR.**  **Proposal 5: RAN5 defines the detailed test procedure for the conformance tests.**  **Proposal 6: A higher SNR for the main radio signals can be used, so that we just test the performance of the LP-WUR.**  **Proposal 7: Discuss if a LS to RAN5 or a note in RAN4 specification is sufficient.** |
| R4-2408111 | vivo | **Proposal 1: Option1: Using MR connection mode, but MR should not receive and detect LP-WUS signal. The miss detection ratio can be calculated based on “ACK/NACK” results of LP-WUR which is feedback to gNB by MR.**  **Proposal 2: Option2: Using MR idle mode, there is no LP-WUS feedback to gNB during testing, a new UE test mode is needed. MR should be waken-up after testing of all LP-WUS signal and connected to gNB to feedback the LP-WUS detection results.** |
| R4-2408364 | ZTE Corporation, Sanechips | **Proposal 1: RNA4 should determine to perform the test of LP-WUR in IDLE mode or CONNECTED mode fir**s**t.**  **Proposal 2: For IDEL mode test, TE should be designed to transmit Paging message corresponding to LP-WUS and receive PRACH from the main radio after LP-WUS is transmitted.**  **Observation 1: For IDLE mode test, if only MDR is chosen as test metric, there is no need to design dedicated feedback to help test MDR.**  **Observation 2: For IDLE mode test, if both MDR and FAR are chosen as test metric, a feedback mechanism should be designed to help TE to know FAR. Besides, test mode should be designed for MDR and FAR separately. When testing MDR, there are successive LP-WUS transmitted (including Paging message transmitting and PRACH receiving). When testing FAR, no LP-WUS is transmitted and only noise exists.**  **Proposal 3: For CONNECTED mode test, legacy test method can be reused while the test metric is MDR (or with FAR together) rather than throughput.**  **Observation 3: For CONNECTED mode test, if only MDR is chosen as test metric, there is no need to design dedicated feedback to help test MDR.**  **Observation 4: For CONNECTED mode test, if both MDR and FAR are chosen as test metric, a feedback mechanism should be designed to help TE to know FAR. Besides, test mode should be designed for MDR and FAR separately. When testing MDR, there are successive LP-WUS transmitted (including PDCCH and PDSCH). When testing FAR, no LP-WUS is transmitted and only noise exists.** |
| R4-2408826 | OPPO | **Observation 1: For MR connected mode, the UE can report whether it has detected the wake-up signal to TE.**  **Observation 2: Whether this test function can be implemented with current UE signalling need further study.**  **Proposal 1: To use the missed detection rate for all the RX requirements for LP-WUR.**  **Proposal 2: Use test mode for LP-WUR for RX requirements.** |
| R4-2409102 | Ericsson | **Proposal-1: Consider the false alarm rate in demodulation test metric but not the RF test metric.**  **Proposal-2: Send a LS to RAN5 to see if MDR could be further optimized from testing perspective.**  **Proposal-3:** **If the additional test mode would be preferred from RAN5 perspective, ask also if other testing metric would be better than MDR. E.g (BER/BLER)**  **Proposal-4:LS to RAN5 to confirm this with text below:**  **RAN4 are discussing the test metric for wake up receiver RF performance test. As the WUR only detect LP-WUS/LP-SS and no other signals, legacy throughout monitoring for PDSCH is not possible anymore. Therefore, RAN4 propose the test metric of Miss Detection Rate of LP-WUS (target 1%) as one option. To test MDR of LP-WUS, there are two options to do it and RAN4 agree that it will be up to RAN5 to decide which options is suitable for WUR receiver test.**  **Two options below to test**  **1. Using the legacy paging procedure to detect successfully LP-WUS reception by WUR**  **2. New test mode for testing the successfully LP-WUS reception by WUR**  **RAN4 also want to ask if the new test mode would be preferred from testing time perspective, would the test metric of BER/BLER be a better performance metric than MDR (1%).** |

## Open issues summary

### Sub-topic 4-1 Testability for UE RF requirements

**Issue 4-1-1: Test performance metric**

* Proposals
  + **Proposal 1: Test metric should be aligned with the performance metric of each requirement.**
  + **Proposal 2: If the additional test mode would be preferred from RAN5 perspective, ask also if other testing metric would be better than MDR. E.g (BER/BLER)**
* Recommended WF
  + TBA

**Issue 4-1-2: Separate RF test case for idle and connection mode**

* Proposals
  + **Proposal 1: Test cases should be designed separately LP-WUS operation in IDLE/INACTIVE mode and CONNECTED mode since the procedures are different and the LP-WUS signals could be different for these modes. (Huawei)**
* Recommended WF
  + TBA

**Issue 4-1-3: BLER/MDR counting based on MR wake-up or not**

* Proposals
  + **Proposal 1: Counter the detection rate without waking up the MR would be enough for the LP-WUS test in terms of verifying the RF requirements. (Huawei, vivo)**
* Recommended WF
  + TBA

**Issue 4-1-4: How to get feedback from LP-WUR**

* + **Proposal 1: For LP-WUR testability issue, RAN4 can consider the following two options, e.g., (vivo)**
    - **Option1: MR connection mode, but MR should not receive and detect LP-WUS signal. The MDR can be calculated based on “ACK/NACK” results of LP-WUR which is feedback to gNB by MR**
    - **Option2: MR idle mode, there is no LP-WUS feedback to gNB during testing, a new UE test mode is needed. MR should be waken-up after testing of all LP-WUS signal and connected to gNB to feedback the LP-WUS detection results**
  + **Proposal 2: Feedback from the UE regarding LP-WUR performance should be gathered in the RRC\_CONNECTED mode. (Nokia)**
  + **Proposal 3: RNA4 should determine to perform the test of LP-WUR in IDLE mode or CONNECTED mode first. (ZTE)**
    - **For IDEL mode test, TE should be designed to transmit Paging message corresponding to LP-WUS and receive PRACH from the main radio after LP-WUS is transmitted**
    - **For CONNECTED mode test, legacy test method can be reused while the test metric is MDR (or with FAR together) rather than throughput**
  + **Proposal 4: After setting up the test mode in connected mode, when the UE enters into the IDLE/INACTIVE mode, the UE can record the detection rate and false alarm rate then report the rates to TE when the UE enter back to the connected mode. The test mode as well as the details of the test mode can also be left to RAN5. (Huawei)**
* Recommended WF
  + TBA

**Issue 4-1-5: Consider FAR for LP-WUS RF test or not?**

* + **Proposal 1: False alarm rate should be considered for the LP-WUS test. (Huawei, Nokia)**
  + **Proposal 2: FAR is considered as demodulation test metric but not RF. (E///, vivo)**
* Recommended WF
  + TBA

**Issue 4-1-6: detailed Test configuration**

* + **Proposal 1: Set the SNR of the PDCCH higher than TS 38.101-4 for the corresponding antenna configuration of main receiver to decrease the PDCCH detection impact on WUR testing metric. (E///)**
  + **Proposal 3: A higher SNR for the main radio signals can be used, so that we just test the performance of the LP-WUR. RAN5 can decide the confidence level to be used for testing the LP-WUR requirements in a reasonable amount of time. (Nokia)**
* Recommended WF
  + TBA

**Issue 4-1-7: detailed Test procedure**

* + **Proposal 1: RAN5 defines the detailed test procedure for the conformance tests. (Nokia)**
  + **Proposal 2: Leave the details of test cases design to RAN5. (Huawei)**
* Recommended WF
  + TBA

**Issue 4-1-8: UE test mode for LP-WUR**

* Proposals
  + **Option 1: UE test mode is needed.**
  + **Option 2: other**
* Recommended WF
  + TBA

**Issue 4-1-9: whether a LS to RAN5 on test issue**

* Proposals
  + **Proposal 1: Discuss if a LS to RAN5 or a note in RAN4 specification is sufficient. (Nokia)**
  + **Proposal 2: Send a LS to RAN5 to see if MDR could be further optimized from testing perspective. (E///)**
    - **RAN4 are discussing the test metric for wake up receiver RF performance test. As the WUR only detect LP-WUS/LP-SS and no other signals, legacy throughout monitoring for PDSCH is not possible anymore. Therefore, RAN4 propose the test metric of Miss Detection Rate of LP-WUS (target 1%) as one option. To test MDR of LP-WUS, there are two options to do it and RAN4 agree that it will be up to RAN5 to decide which options is suitable for WUR receiver test**
    - **Two options below to test**
      * **Using the legacy paging procedure to detect successfully LP-WUS reception by WUR**
      * **New test mode for testing the successfully LP-WUS reception by WUR**
    - **RAN4 also want to ask if the new test mode would be preferred from testing time perspective, would the test metric of BER/BLER be a better performance metric than MDR (1%).**
* Recommended WF
  + TBA