**3GPP TSG-RAN WG4 Meeting #112 R4-2412835**

**Maastricht, Netherlands, August 19th – August 23rd, 2024**

**Agenda item:** 8.22.5

**Source:** Moderator (vivo)

**Title:** Topic summary for [112][133] 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** |
| R4-2411095 | CATT | **Proposal 1: For NR bands with SCS based channel raster, no new channel raster is needed for LP-WUR.**  **Proposal 2: Introduce 10kHz channel raster for LP-WUR for an NR band with 100kHz channel raster to ensure an LP-WUS carrier can be flexibly allocated within an NR carrier in that NR band.** |
| R4-2411227 | Huawei, HiSilicon | ***Proposal 1: To accommodate different UE architectures, two sets of requirements at least with different NF should be considered for LP-WUR.***  ***Proposal 2: Whether FAR is only considered for demod test should be revisited once there is a clear vision for testability issues for LP-WUR.***  ***Proposal 3: Both 1% miss-detection rate and false-alarm rate are considered for LP-WUR test.*** |
| R4-2411495 | Spreadtrum Communications | **Proposal 1: Existing channel raster could be reused for LP-WUR, no channel raster is needed for LP-WUR.**  **Proposal 2: Use 1% MDR as the metric for LP-WUR RX RF requirements.**  **Proposal 3: Use 1% FAR as the metric for LP-WUR demodulation requirements.** |
| R4-2411653 | Nokia | [**Observation 1:** Zero-IF architecture supports a high degree of reuse of the NR main radio components.](#_Toc174114883)  [**Observation 2:** To support more than one band, the receiver could use a wideband LNA or multiple LNAs supporting smaller frequency area.](#_Toc174114884)  [**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.](#_Toc174114885)  [**Observation 4:** The NF of the receive chain is being governed by front-end components and LNA, which are common for both sequence based and envelope based receivers.](#_Toc174114886)  [Proposal 1: Agree to use zero-IF receiver as a baseline architecture for LP\_WUR.](#_Toc174114887)  [Proposal 2: Agree to use the estimated NF of 12dB as a baseline for both envelope and sequence based LP\_WUR.](#_Toc174114888)  [Proposal 3: Use 1% MDR and 1% FAR values for defining the requirements.](#_Toc174114889)  [**Observation 5:** RAN4 will evaluate SNR values based on link-level simulations and NF values based on system architecture.](#_Toc174114890)  [Proposal 4: Do not repeat the coverage evaluation work done by RAN1 in RAN4.](#_Toc174114891)  [Proposal 5: Inform RAN1 at a later date if RAN4 find out that coverage of LP-WUS is not sufficient.](#_Toc174114892) |
| R4-2411730 | CMCC | **Proposal 1: Two sets of requirements could be set for OOK-based receivers and OFDM-based receivers.**  **Proposal 2: SNR and NF could be different for these two types.**  **Proposal 3: Channel raster is needed for LP-WUS and the existing requirements could be reused.**  **Proposal 4: Consider 11RBs and 22RBs for LP-WUS signal with 15kHz SCS** |
| R4-2411895 | ZTE Corporation, Sanechips | **Proposal 1: If LP-WUR needs to search LP-WUS by itself, channel raster is needed. Further check in which scenarios LP-WUR needs to search LP-WUS.**  **Proposal 2: Set 1% MDR as the metric for LP-WUR Rx RF requirements and 0.1% FAR as the metric for LP-WUR demodulation requirements.** |
| R4-2412057 | vivo | **Observation: LP-WUR is a new type of receiver, many of the assumptions and RF analysis are different, it is worthwhile if we can have a place to document all our valuable discussions as a reference.**  **Proposal 1: RAN4 agree to request a new RAN4 TR for LP-WUS RF.** |
| R4-2412058 | vivo | **Proposal 1: For in-band WUS operation, the channel raster of LP-WUS can be the same as NR.**  **Proposal 2: RAN4 select 1% MDR as performance metric for LP-WUS RF requirements.** |
| R4-2412975 | Ericsson | **Proposal-1: OFDM WUR and OOK WUR could be tested under the same RF requirements.** |
| R4-2412976 | Ericsson | **Observation 1 RAN2 agrees to configure LP-WUS in SIB.**  **Proposal-1: Channel raster does not apply to WUR.**  **Observation 2 RAN1 agree for the 11 PRBs 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 (X=11 for SCS =30kHz and BW > 5MHz) referencing to the RB grid of MR.** |
| R4-2413223 | Qualcomm Incorporated | **Observation 1: 38.101-2 is expected to be changed by the Rel-19 LP-WUS WI**  **Observation 2: The challenge of designing a LP-WUR with sufficient coverage is equivalent for FR1 and FR2.**  **Observation 3: For the Rel-19 feature, UE REFSENS requirements for LPWUS are driven mainly by LPWUR NF rather than the MSG3 coverage criterion.**  **Observation 4: From a system design and evolutionary perspective, it is advantageous to retain an aggressive net NF target (i.e sum of NF and implementation loss targets) for REFSENS specification.**  **Proposal 1: RAN4 to reflect both idle and connected mode conditions in the side conditions for the LPWUR requirements, at least for FR2.**  **Proposal 2: RAN4 to consider using n258 as the example FR2 band and co-develop the requirements alongside FR1.**  **Proposal 3: RAN4 to define SNR for OOK signals prior to comparison of simulation data** |
| R4-2411538 | Sony | **Observation 1 A reference architecture for the LP-WUR receiver is needed to define the REFSENS requirement.**  Observation 2 The heterodyne and homodyne ED-based receivers provide significant power-saving gain compared to OFDM-based receivers but are still capable of meeting the coverage target of LP-WUS with NF assumption in the range of 10-16 dB.  Observation 3 Adopting a relatively small percentage value on the MDR may lead to an excessive test time.  Observation 4 The target coverage of LP-WUS is to meet Msg. 3 coverage with 1% MDR.  Observation 5: All types of WUS signals and the corresponding receivers shall meet the same coverage target, and thus, one set of minimum requirements is required to ensure this coverage is sufficient.  Observation 6 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 7 The number of guard RB may not affect the receiver performance significantly depends on the processing in the receiver.  Observation 8 Connected mode LP-WUS is mainly for XR devices.  Observation 9 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.  Proposal 1 It is proposed that an ED-based receiver be adopted to define the REFSENS requirement to ensure sufficient power-saving gain unless it is mandatory for UE to decode any OFDM symbols in this LP-WUS.  Proposal 2 It is proposed that the RF-ED receiver be down-selected due to its poor frequency selectivity for being used to derive the REFSENS requirements.  Proposal 3 As a starting point, the heterodyne and homodyne ED based receivers can be used as the reference architecture to derive the REFSENS requirement.  Proposal 4 It is proposed that RAN4 to include additional switch in the RF reference architecture to support antenna sharing between the MR and LP-WUR to support RRM measurement offload.  Proposal 5 No impact on MR requirements should be considered.  Proposal 6 Use 1% MRD as REFSENS metric for LP-WUR as a starting point to define the core requirement and further study if a higher percentage can be used while fulfilling the coverage target of LP-WUS.  Proposal 7 RAN4 may consider adopting a higher percentage MDR value, e.g., 5 %or 10 %, in the conformance test by scaling the REFSENS level accordingly.  Proposal 8 RAN4 should aim to define one set of minimum requirements covering all types of LP-WUS receivers.  **Proposal 9 Define the ACS requirement for LP-WUS as 33 dB and further investigate if the ACSC should be set to the same value as the ACS requirement.**  Proposal 10 RAN4 shall derive the number of guard RB based on some practical filter assumption once the ACS/ASCS requirement is agreed.  **Proposal 11 Define the blocking signal level the same as the MR for LP-WUR, and further study if the offset of the blocking signal to the wanted signal should be shifted with guard RB.**  **Proposal 12 RAN4 can focus on the idle mode first and FFS if the connected mode needs to be addressed separately later on if any impact on the RF requirement of LP-WUR would be identified.**  Proposal 13 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 14 RAN4 may consider leaving the testability discussion to RAN5. |
| R4-2411228 | 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.***  ***Proposal 2: It is proposed to define single SNR value with -2dB for both OFDM based and envelop detection based LP-WUR receivers.***  ***Proposal 3: It is proposed to adopt 11 PRB for LP-WUS with 30kHz SCS for 5MHz channel bandwidth with no additional guard RBs. In case of 15kHz SCS, the guard band should be similar to that of 30kHz. Specific PRB number can be further discussed based on RAN1 progress.***  *Observation 1: 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 2: The filter evaluated by RAN4 in SI stage cannot provide sufficient suppression compared to the level defined in current spec for MR.*  ***Proposal 4: It is proposed to relax ACS requirement for LP-WUR from co-existence and performance perspective. The proposed ACS is 10dB given the poor filtering capability of LP-WUR.***  ***Proposal 5: It is proposed to relax dynamic range for ACS requirement in case 2 while keep the same wanted signal level as MR. The proposed dynamic range for ACS case to is relaxed to 25dB.***  ***Proposal 6: It is proposed to adopt 1 RB as the size of guard RB for LP-WUS ASCS regardless of the applied SCS.***  ***Proposal 7: If guard RB is specified for ASCS scenario, there is no need to define specific requirement for ASCS.*** |

## Open issues summary

### Sub-topic 1-1 General

**Issue 1-1-1: New RAN4 TR to capture simulation and analysis of LP-WUS receiver and requirements**

* Proposals
  + **Proposal 1: RAN4 agree to request a new RAN4 TR for LP-WUS RF. (vivo)**
* Recommended WF
  + Valuable to have a TR to document all our valuable simulations and analysis as a reference for LP-WUS receiver.

Huawei: Support to have TR for RAN4 analysis and agreements on SNR evaluation. The channel model is different.

Samsung: We also support to have RAN4 TR.

ZTE: Support to have TR.

Agreement: RAN4 suggest having a new RAN4 TR to capture the simulations and analysis for LP-WUS RF.

**Issue 1-1-2: Performance metric for Rx RF requirements**

* Proposals
  + **Proposal 1: 1% MDR. (Huawei, vivo, Spreadtrum, ZTE, Nokia, Sony, Samsung)**
* Recommended WF
  + agreeable

Qualcomm: When 1% MDR is used, is it used for evaluation or requirement?

Moderator: this is for both simulation and RF requirements.

Huawei: Share the similar view.

Qualcomm: before agreeing on it, need look how to test it.

Huawei: Testability, we think it is doable.

Nokia: support 1%. Testability is another discussion.

Apple: support 1% MDR for simulation. 1% for RF requirement is too stringent.

Moderator: this value is not only to impact the evaluation. We need define the SNR value. The requirement and guardband depends on the evaluation. Without it we cannot define the requirement.

Ericsson: we agree with moderators’ view.

Samsung: other value is not aligned with RAN1. We have solution for test.

Qualcomm: When setting the requirement, we need the reliable SNR. I do not think we deviate from RAN1 even if we choose the other SNR. They are not independent.

CATT: for 1% evaluation purpose, we are fine. For core requirement, the level that we set is to make sure that network performance does not degrade.

Agreement:

* **1% MDR for evaluation [and core requirements]**
  + **FFS on the testability issue.**

**Issue 1-1-3: Performance metric for Demodulation requirements**

* Proposals
  + **Option 1: 1% FAR. (Spreadtrum, Huawei, Nokia)**
  + **Option 2: 0.1% FAR. (ZTE)**
* Recommended WF
  + Check whether option 1 is agreeable

ZTE: we would like to have 0.1% to be aligned with RAN1. There is no difficulty to use 0.1%. We are also fine with 1%.

Qualcomm: We should leave it to demod expert.

CATT: I have the same view as Qualcomm. This belongs to demodulation. For RF requirement, we do not depend on it. For FAR, the value should ensure the benefit of LP-WUS. The value itself needs more discussions.

Qualcomm: do we need define FAR for MDR?

CATT: This is agreement in the previous meeting. For MDR evaluation, what FAR level should be provided for information.

Samsung: Qualcomm raised the good question. For MDR requirement, we need assumption of FAR.

Nokia: We do need FAR level for evaluation.

Ericsson: According to last meeting agreement, FAR should be together with MDR.

Ericsson: in our simulation we use 0.1%. If FAR is high, UE may waste the power.

Agreement:

* **[1% or 0.1%] FAR as assumption for MDR result calibration.**

**Issue 1-1-4: Whether FAR is only for Demodulation requirements**

* Proposals
  + **Proposal 1: Whether FAR is only considered for demod test should be revisited once there is a clear vision for testability issues for LP-WUR. (Huawei)**
* Recommended WF
  + Group can further check

**Issue 1-1-5: One or two sets of requirements (REFSENS)**

* Proposals
  + **Option 1: To accommodate different UE architectures, two sets of requirements at least with different NF should be considered for LP-WUR. (Huawei, CMCC, LGE, Samsung)**
    - **SNR and NF could be different (CMCC)**
  + **Option 2: OFDM WUR and OOK WUR could be tested under the same RF requirements. (E///, Sony)**
* Recommended WF
  + Suggest to define a single target SNR value for LP-WUS
  + Different NF for each receiver type can be discussed, OOK-based and OFDM-based. Then potentially different REFSENS

**Issue 1-1-6: Specify FR2 LP-WUS RF requirements**

* Proposals
  + **Proposal 1: RAN4 to consider using n258 as the example FR2 band and co-develop the requirements alongside FR1. (Qualcomm)**
* Recommended WF
  + Discuss and confirm

**Issue 1-1-7: Side condition for FR2 requirements**

* Proposals
  + **Proposal 1: RAN4 to reflect both idle and connected mode conditions in the side conditions for the LPWUR requirements, at least for FR2. (Qualcomm)**
* Recommended WF
  + TBA

### Sub-topic 1-2 System parameters

**Issue 1-2-1: Channel raster for LP-WUR**

* Proposals
  + **Proposal 1: For NR bands with SCS based channel raster, no new channel raster is needed for LP-WUR. (CATT)**
  + **Proposal 2：Channel raster is needed for LP-WUS and the existing requirements could be reused. (CMCC, vivo, Spreadtrum)**
  + **Proposal 3: If LP-WUR needs to search LP-WUS by itself, channel raster is needed. Further check in which scenarios LP-WUR needs to search LP-WUS. (ZTE)**
  + **Proposal 4: Channel raster does not apply to WUR. (E///)**
* Recommended WF
  + Discuss and check whether channel raster is needed
  + Feedback from RAN1 might be needed to confirm whether the centre operation frequency of LP-WUS can be set by MR, or RB position indicated by MR.

CATT: in our understanding the channel raster is needed. It is important for LP-WUR to generate. The question is whether the existing one can be used. There would be no new channel raster needed.

Nokia: do not agree with CATT. UE has known exact the location of WUS.

Ericsson: RAN2 has designed the signalling to indicate the location of LP-WUS. UE can decode SIB on MR and then know the location.

ZTE: It depends on the LP-WUS location can be indicated by network. If it can be indicated, no raster is needed.

Huawei: Without channel raster, we do not have SA operation for LP-WUS. We just have in-band operation. For NB-IoT in-band operation, we have sentence to describe the location. We would like to consider the compliance between LP-WUS and NR.

Qualcomm: We appreciate CATT paper. We want some guarantee that WUS is on the FFT grid.

Ericsson: RAN1 does not define the channel for LP-WUS rather than a block of RBs.

CATT: No matter whether it is known to UE or not, this is helpful.

Moderator: RAN1 does not decide how to indicate the frequency.

**Issue 1-2-2: Whether new Channel raster should be defined for LP-WUR?**

* Proposals
  + **Proposal 1: Introduce 10kHz channel raster for LP-WUR for an NR band with 100kHz channel raster to ensure an LP-WUS carrier can be flexibly allocated within an NR carrier in that NR band. (CATT)**
* Recommended WF
  + Further discuss based on aligned understanding of issue 1-2-1

**Issue 1-2-3: number of RBs for LP-WUS with 15kHz SCS**

* Proposals
  + **Proposal 1: Consider 11RBs and 22RBs for LP-WUS signal with 15kHz SCS. (CMCC)**
  + **Proposal 2: Specific PRB number for 15kHz SCS can be further discussed based on RAN1 progress. (Huawei)**
* Recommended WF
  + Wait for RAN1 progress

**Issue 1-2-4: Consideration on System parameters LP-WUR**

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

**Issue 1-2-5: Whether need to define CBW for LP-WUR?**

* Proposals
  + **Proposal 1: The BW of WUR should be specified in X PRB of LP-WUS (X=11 for SCS =30kHz and BW > 5MHz) referencing to the RB grid of MR. (E///)**
* Recommended WF
  + Just define number of LP-WUS RBs within NR CBW, no dedicate CBW definition is needed for LP-WUS

# Topic #2: REFSENS, ASCS and ACS requirements

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2411538 | Sony | **Observation 1 A reference architecture for the LP-WUR receiver is needed to define the REFSENS requirement.**  Observation 2 The heterodyne and homodyne ED-based receivers provide significant power-saving gain compared to OFDM-based receivers but are still capable of meeting the coverage target of LP-WUS with NF assumption in the range of 10-16 dB.  Observation 3 Adopting a relatively small percentage value on the MDR may lead to an excessive test time.  Observation 4 The target coverage of LP-WUS is to meet Msg. 3 coverage with 1% MDR.  Observation 5: All types of WUS signals and the corresponding receivers shall meet the same coverage target, and thus, one set of minimum requirements is required to ensure this coverage is sufficient.  Observation 6 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 7 The number of guard RB may not affect the receiver performance significantly depends on the processing in the receiver.  Observation 8 Connected mode LP-WUS is mainly for XR devices.  Observation 9 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.  Proposal 1 It is proposed that an ED-based receiver be adopted to define the REFSENS requirement to ensure sufficient power-saving gain unless it is mandatory for UE to decode any OFDM symbols in this LP-WUS.  Proposal 2 It is proposed that the RF-ED receiver be down-selected due to its poor frequency selectivity for being used to derive the REFSENS requirements.  Proposal 3 As a starting point, the heterodyne and homodyne ED based receivers can be used as the reference architecture to derive the REFSENS requirement.  Proposal 4 It is proposed that RAN4 to include additional switch in the RF reference architecture to support antenna sharing between the MR and LP-WUR to support RRM measurement offload.  Proposal 5 No impact on MR requirements should be considered.  Proposal 6 Use 1% MRD as REFSENS metric for LP-WUR as a starting point to define the core requirement and further study if a higher percentage can be used while fulfilling the coverage target of LP-WUS.  Proposal 7 RAN4 may consider adopting a higher percentage MDR value, e.g., 5 %or 10 %, in the conformance test by scaling the REFSENS level accordingly.  Proposal 8 RAN4 should aim to define one set of minimum requirements covering all types of LP-WUS receivers.  **Proposal 9 Define the ACS requirement for LP-WUS as 33 dB and further investigate if the ACSC should be set to the same value as the ACS requirement.**  Proposal 10 RAN4 shall derive the number of guard RB based on some practical filter assumption once the ACS/ASCS requirement is agreed. |
| R4-2411653 | Nokia | [**Observation 1:** Zero-IF architecture supports a high degree of reuse of the NR main radio components.](#_Toc174114883)  [**Observation 2:** To support more than one band, the receiver could use a wideband LNA or multiple LNAs supporting smaller frequency area.](#_Toc174114884)  [**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.](#_Toc174114885)  [**Observation 4:** The NF of the receive chain is being governed by front-end components and LNA, which are common for both sequence based and envelope based receivers.](#_Toc174114886)  [Proposal 1: Agree to use zero-IF receiver as a baseline architecture for LP\_WUR.](#_Toc174114887)  [Proposal 2: Agree to use the estimated NF of 12dB as a baseline for both envelope and sequence based LP\_WUR.](#_Toc174114888)  [Proposal 3: Use 1% MDR and 1% FAR values for defining the requirements.](#_Toc174114889)  [**Observation 5:** RAN4 will evaluate SNR values based on link-level simulations and NF values based on system architecture.](#_Toc174114890)  [Proposal 4: Do not repeat the coverage evaluation work done by RAN1 in RAN4.](#_Toc174114891)  [Proposal 5: Inform RAN1 at a later date if RAN4 find out that coverage of LP-WUS is not sufficient.](#_Toc174114892) |
| R4-2411228 | 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.***  ***Proposal 2: It is proposed to define single SNR value with -2dB for both OFDM based and envelop detection based LP-WUR receivers.***  ***Proposal 3: It is proposed to adopt 11 PRB for LP-WUS with 30kHz SCS for 5MHz channel bandwidth with no additional guard RBs. In case of 15kHz SCS, the guard band should be similar to that of 30kHz. Specific PRB number can be further discussed based on RAN1 progress.***  *Observation 1: 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 2: The filter evaluated by RAN4 in SI stage cannot provide sufficient suppression compared to the level defined in current spec for MR.*  ***Proposal 4: It is proposed to relax ACS requirement for LP-WUR from co-existence and performance perspective. The proposed ACS is 10dB given the poor filtering capability of LP-WUR.***  ***Proposal 5: It is proposed to relax dynamic range for ACS requirement in case 2 while keep the same wanted signal level as MR. The proposed dynamic range for ACS case to is relaxed to 25dB.***  ***Proposal 6: It is proposed to adopt 1 RB as the size of guard RB for LP-WUS ASCS regardless of the applied SCS.***  ***Proposal 7: If guard RB is specified for ASCS scenario, there is no need to define specific requirement for ASCS.*** |
| R4-2411494 | Spreadtrum Communications | **Proposal 1: IM value could use 2.5dB for OOK-based and OFDM-based receiver.**  **Proposal 2: 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 (assume MR NF is 9dB).**  **Proposal 3: Homodyne/zero-IF architecture could be a baseline receiver for OOK-based receiver and OFDM architecture could be a baseline receiver for OFDM-based receiver.** |
| R4-2411645 | Apple | **Proposal 1**: Considering the discussion in RAN4#111 it seems that defining a value of 5% for test purpose could be a compromise to achieve balance between actual network performance and test complexity.  **Proposal 2**: 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 9 dB this value is expected to increase considerably for LP-WUR. Measurements indicate that approximately 7dB delta to main receiver is required to satisfy the expected current consumption improvements. Regarding implementation margin we propose to set the value no lower than 2.5dB. |
| R4-2411654 | Nokia | [Proposal 1: Agree to use 1% MDR value for the LLS evaluation.](#_Toc174114533)  [Proposal 2: Agree to have implementation margin to be .](#_Toc174114534)  [**Observation 1:** NF has an impact on the coverage and power consumption of the LR.](#_Toc174114535)  [Proposal 3: Agree to use the estimated NF of 12dB as a baseline for LP-WUR.](#_Toc174114536)  [**Observation 2:** The SNR required for achieving a MDR of 1% does not improve much after third order filter.](#_Toc174114537)  [**Observation 3:** Frequency offset has no significant impact on the envelope detector performance.](#_Toc174114538)  [**Observation 4:** A SNR value of -2.5dB is sufficient to achieve a MDR of 1% in case of an envelope detector based LP-WUR.](#_Toc174114539)  [Proposal 4: Agree to have zero guard RB for the ASCS case.](#_Toc174114540)  [Proposal 5: Agree to have no separate ASCS requirement.](#_Toc174114541)  [Proposal 6: 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.](#_Toc174114542)  [Proposal 7: In test case where Pinterferer depends on REFSENS, LP-WUR REFSENS should be used.](#_Toc174114543) |
| R4-2411694 | Samsung | **Proposal 1: RAN4 to adopt 1% MDR as performance metric for LP-WUR RX RF requirements**  **Proposal 2: The SNR value corresponding to 1% MDR for REFSENS derivation is supposed to partially reflect coverage target, while NF and IM are supposed to reflect UE architecture and implementation.**  **Proposal 3: Better to consider different NF for envelop based receiver and OFDM based receiver, i.e., two sets of REFSENS requirements.**  **Proposal 4: RAN4 to take zero-IF architecture with baseband envelope detection as baseline for envelop based receiver.**  **Proposal 5: RAN4 to take antenna sharing and switching as baseline for RF front end, and additional insertion loss should be considered in the IM value for REFSENS derivation.** |
| R4-2411731 | CMCC | **Proposal 1: Specify two sets of SNR for LP-WUS.**  **Proposal 2: Specify two sets of noise figure values for LP-WUS noise figure.**  **Proposal 3: Set 9dB as the OFDM noise figure for the OFDM signal as the baseline.**  **Proposal 4: Choose 12-15 noise figure as the baseline for the OOK signal.**  **Proposal 5: Legacy IM for NR main radio could be used as baseline.**  **Proposal 6: For ASCS requirement, RAN4 should specify the guard RB and test case to check whether the MDR is within X%.** |
| R4-2411896 | ZTE Corporation, Sanechips | **Observations:**  **Observation 1: With 1 guard RB, there is little improvement on the required SNR to reach 1% BLER for given waveform compared to 0 guard RB.**  **Observation 2: 3rd filter order has much less suppression on sub-carrier interference than 5th filter order.**  **Observation 3: Based on the definition of ASCS, the receive filter attenuation on the adjacent NR subcarrier depends on CBW, WUS location and filter characteristic.**  **Observation 4: There is no need to consider different CBW for ACS of LP-WUR because LP-WUS occupies fixed 3.96MHz and the filter pass bandwidth also matches the fixed 3.96MHz for LP-WUS.**  **Observation 5: To achieve 1% BLER, 2 guard RBs are necessary for OOK-4 waveform and it is relatively easy for OOK-1 waveform to achieve 1% BLER with adjacent channel interference.**  **Observation 6: 3rd filter order has much less suppression on adjacent channel interference than 5th filter order.**  **Proposals:**  **Proposal 1: 1% BLER/MDR is preferred, and 5% BLER/MDR may be too high for LP-WUS.**  **Proposal 2: There is no need to consider FAR in LLS because it is low enough, but for practical test, FAR should be further checked.**  **Proposal 3: 4-bit ADC is enough for LP-WUS LLS.**  **Proposal 4: Based on our simulation results, we propose no guard RB is needed for ASCS.**  **Proposal 5: Determine ASCS requirements for all available CBW under the worst case that WUS is located at center of the NR carrier.**  **Proposal 6: Change “assigned channel frequency” to “assigned LP-WUR channel frequency” in the definition of ACS as follows:**  **Adjacent channel selectivity (ACS) is a measure of a receiver's ability to receive a 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 LP-WUR channel frequency to the receive filter attenuation on the adjacent channel(s).**  **Proposal 7: For ACS, 2 guard RBs are needed and guard RBs can be blank or filled with NR signal.**  **Proposal 8: Determine ACS for LP-WUR after the number of guard RBs is determined.**  **Proposal 9: NF Gap between LR and MR for REFSENS could be +2dB and +5dB for OFDM-based receiver and OOK-based receiver, respectively.**  **Proposal 10: 2dB IM is okay for LR.**  **Proposal 11: Exclude RF envelope detection architecture for LP-WUR.**  **Proposal 12: Use zero-IF architecture as baseline architecture for OOK-based LP-WUR.**  **Proposal 13: To wait for RAN1’s conclusion on the OFDM-based LP-WUR.** |
| R4-2412059 | vivo | **Observation 1: There is about 1dB difference between 1% MDR and 5%MDR.**  **Observation 2: The worst case is OOK-4, M=4, payload = 16bit with envelope receiver, and the SNR at 1%MDR is about -2.3 dB.**  **Observation 3: For same receiver type, the performance between AWGN and TDL-C has a relatively stable offset. To specify RF requirements, there is no need to consider both AWGN and TDL-C channel models.**  **Proposal 1: From RF requirement verification perspective, using AWGN is sufficient.**  **Observation 4: Under similar assumption in RAN1, the estimated SNR with repetition by RAN4 LLS can meet RAN1 coverage target.**  **Observation 5: There is a stable SNR gap between “AWGN+no repetition” case and “TDL-C+repetition” case.**  **Proposal 2: Follow similar approach of MR, RAN4 define the target SNR for WUR Rx requirements at 1% MDR based on AWGN model with no repetition.**  **Proposal 3:** **Define a single target SNR based on worst case of LLS outcome, i.e., Envelope receiver, [-2]dB.**  **Observation 5: The benefit of guard RB in ASCS case is minor, and the impact of adjacent NR signal on the WUS sensitivity is negligible.**  **Proposal 4: No ASCS requirements value is needed, RAN4 just specify the test parameters.**  **Proposal 5: RAN4 can define the ASCS test parameters as following: Achieving 1% MDR without guard RB under the power level of REFSENS+[0.5dB]. detailed test parameters in Table 5**  Table 5: Test parameters for LP-WUS ASCS   |  |  |  | | --- | --- | --- | | RX parameter | Units | Channel bandwidth (MHz) | |  |  | 5-100MHz | | LP-WUS Power | dBm | REFSENS + [0.5] dB | | In-band Pinterferer | dBm | NR signal, same as LP-WUS | | Guard RB between LP-WUS and NR |  | 0 | | MDR |  | 1% |   **Observation 6: For the ACS cases, the ADC plays a critical role and only when ADC bit is enough, the guard RB can help on the MDR performance.**  **Observation 7: To endure same interference power level, i.e., 31.5dB as MR, then 8bit ADC is mandatory with 3rd filter, in addition, 4 guard RBs are still needed.**  **Observation 8: The frequency offset** **has minor impact on ACS performance.**  **Observation 9: No guard RB is required for OFDM receiver to ensure ACS performance.**  **Proposal 6: Define WUR ACS requirement as a value within the range [20~31.5]dB. FFS number of guard RBs.**  **Proposal 7: The following NF can be discussed in RAN4 for RESENS:**  **For OOK based WUR**   * **[9~16] dB**   **For OFDM based WUR**   * **[9~14] dB**   **Proposal 8: For the baseline architecture of LP-WUR, the following two types can be considered: IF envelop receiver for OOK-based, and no** **FFT based OFDM receiver for OFDM receiver.** |
| R4-2412276 | LG Electronics France | ***Observation 1***: The equation format of the REFSENS requirement on legacy LTE/NR can be reused to specify the REFSENS requirement of LP-WUS/WUR.  ***Observation 2***: The power consumption and noise figure can be significantly different according to the LP-WUR architecture. The characteristics of each structure can be applied differently to different LP-WUS/WUR use cases. Therefore, it is necessary to consider more than one set of REFSENS requirement depending on the architecture of the LP-WUR.  ***Observation 3***: Assigning an ASCS guard band of 1 Rb resulted in an SNR improvement of less than 0.5 dB over unassigned.  **Proposal 1**: Use the same REFSENS equation for LP-WUS/WUR as for the legacy LTE/NR MR.  **Proposal 2**: It is necessary to consider more than one set of REFSENS requirement depending on the architecture of the LP-WUR.  **Proposal 3**: Consider the same IM value for LP-WUS/WUR as for the legacy LTE/NR MR.  **Proposal 4**: Do not specify the guard RB for ASCS. |
| R4-2412979 | Ericsson | **Observation 1 Agreed SNR target from RAN1 corresponding to the different NF**  **Observation 2 Network configure the WUS structure to make sure the certain BLER should be achievable with agreed SNR when NF of WUR is in certain range.**  **Proposal-1: Limit the NF of the WUR to 15 dB for low and mid-bands.**  **Proposal-2: RAN4 confirm if the maximum NF of the OFDM WUR can be assumed differently with OOK WUR.**  **Proposal-3: It is possible to specify unified RF requirement for both OOK WUR and OFDM WUR.**  **Observation 3 Larger guard RB size has penalty on the SNR threshold due to less received energy**  **Proposal-4: Maximum of 1 guard RB at each side of WUS signal should be used in ASCS case.**  **Observation 4 Increasing the ACI from 0 to 33 for OOK-1 scenario with filter order 3 and no shift RB will deteriorate the BLER performance maximally by approximately 6 dB.**  **Observation 5 The SNR increase can be reduced when increasing either filter order or shifted RB size.**  **Observation 6 The SNR increase is around 5 dB for OOK4 with filter order 3 and shift RB size of 2 comparing between the ACI =0 and ACI=33 dB case.**  **Observation 7 Filter order of 5 is needed for OOK4 for TDL-C channel and ACI =33 dB case.**  **Observation 8 Additional shifted RB may be needed for OOK1 and OOK4 with a 4 bits ADC for LPF order of 3.**  **Observation 9 WUR can achieve the same ACS as the MR.**  **Observation 10 WUR ACS of case #1 can be tested as the similar with MR ACS case #1.**  **Observation 11 WUR ACS of case #2 can be tested with the same wanted and interference level**  **Observation 12 WUR ACS of case #2 can be test with only the minimum MR channel bandwidth.**  **Proposal-5:Specify the same ACS selectivity for WUR with MR.** |
| R4-2413223 | Qualcomm Incorporated | **Observation 1: 38.101-2 is expected to be changed by the Rel-19 LP-WUS WI**  **Observation 2: The challenge of designing a LP-WUR with sufficient coverage is equivalent for FR1 and FR2.**  **Observation 3: For the Rel-19 feature, UE REFSENS requirements for LPWUS are driven mainly by LPWUR NF rather than the MSG3 coverage criterion.**  **Observation 4: From a system design and evolutionary perspective, it is advantageous to retain an aggressive net NF target (i.e sum of NF and implementation loss targets) for REFSENS specification.**  **Proposal 1: RAN4 to reflect both idle and connected mode conditions in the side conditions for the LPWUR requirements, at least for FR2.**  **Proposal 2: RAN4 to consider using n258 as the example FR2 band and co-develop the requirements alongside FR1.**  **Proposal 3:** **RAN4 to define SNR for OOK signals prior to comparison of simulation data** |
|  |  |  |

## Open issues summary

### Sub-topic 2-1 SNR simulation and values

**Issue 2-1-1: Channel model to specify LP-WUS RF requirements**

* Proposals
  + **Proposal 1: From RF requirement verification perspective, using AWGN is sufficient. (vivo, Huawei)**
* Recommended WF
  + Follow typical RF requirements approach, AWGN should be selected.

Sony: I wonder how many guard RBs assumed.

Ericsson: we just chose one of the cases. In the field we have different situations. We should focus on the test simulation aspects.

Agreement:

* **For Channel model to specify LP-WUS RF requirements**
  + Follow typical RF requirements approach, AWGN should be selected.

**Issue 2-1-2: Target SNR simulation condition**

* Proposals
  + **Proposal 1: Follow similar approach of MR, RAN4 define the target SNR for WUR Rx requirements at 1% MDR based on AWGN model with no repetition. (vivo, Huawei)**
* Recommended WF
  + Follow similar approach of MR NR, no repetition should be used when simulate target SNR.

Agreement:

* **Target SNR simulation condition** 
  + Follow similar approach of MR NR, no repetition should be used when simulate target SNR.

**Issue 2-1-3: Whether RAN4 should conclude a target SNR first**

* Proposals
  + **Proposal 1: RAN4 to define SNR for OOK signals prior to comparison of simulation data. (Qualcomm)**
* Recommended WF
  + Target SNR is the basis for many Rx requirements discussion. Group should conclude SNR first.

Qualcomm: we need clear definition of SNR. Is it entire signal over all the noises or something else?

Agreement:

* Target SNR is the basis for many Rx requirements discussion. Group should conclude SNR definition and SNR values first.

**Issue 2-1-4: Target SNR value**

* Proposals
  + **Option 1: Define a single target SNR based on worst case of LLS outcome, i.e., Envelope receiver, [-2]dB, for both OOK-based and OFDM-based receiver. (vivo, Huawei)**
  + **Option 2: Specify two sets of SNR for LP-WUS. (CMCC)**
* Recommended WF
  + Check whether option 1 is agreeable

CMCC: we would like to set whether single or two sets of SNRs based on the simulation results. We can further check the values next meeting.

Ericsson: We should follow RAN1 consensus, where they put three groups of values.

CATT: There are two issues: 1) one set vs two sets; 2) target SNR values. If we can accept -2dB, what point do we need simulation results.

Qualcomm: We would like to keep the possibility to have two sets depending on capability. Keep it open.

Huawei: Two options of two sets. Different noise figures and SNRs for different architecture.

Apple: OOK and OFDM based needs different capabilities. We should keep the approach to define two sets of requirements.

Sony: We prefer single set of requirements. Maybe different SNRs with different noise figures.

LGE: prefer two sets of requirements according to architecture and waveform.

**Issue 2-1-5: Understanding of RAN4 target SNR for RF requirements**

* Proposals
  + **Proposal 1: The SNR value corresponding to 1% MDR for REFSENS derivation is supposed to partially reflect coverage target, while NF and IM are supposed to reflect UE architecture and implementation. (Samsung)**
* Recommended WF
  + TBD

**Issue 2-1-6: Whether the FAR in LLS should be considered**

* Proposals
  + **Proposal 1: There is no need to consider FAR in LLS because it is low enough, but for practical test, FAR should be further checked. (ZTE)**
* Recommended WF
  + TBD

**Issue 2-1-7: number of ADC for LP-WUS LLS**

* Proposals
  + **Proposal 1: 4-bit ADC is sufficient. (ZTE)**
* Recommended WF
  + No need to specify the number of ADC for LP-WUR, this can be implementation issue.

### Sub-topic 2-2 NF and REFSENS requirements

**Issue 2-2-1: How to specify the REFSENS value**

* Proposals
  + **Proposal 1: Use the same REFSENS equation for LP-WUS/WUR as for the legacy LTE/NR MR. (LGE)**
* Recommended WF
  + Agreeable

Qualcomm: would like to see the actual equation in details. There is some issue with implementation margin.

CATT: SNR derivation rules are different for MR and LP-WUR.

Samsung: it was agreed in the last meeting. We use the legacy equation and check the coverage.

**Issue 2-2-2: Baseline architecture for OOK-based LP-WUS**

* Proposals
  + **Proposal 1: Agree to use zero-IF receiver as a baseline architecture for envelop based LP\_WUR. (Nokia, Samsung, ZTE, Spreadtrum)**
  + **Proposal 2: IF envelop receiver for OOK-based. (vivo)**
  + **Proposal 3: As a starting point, the heterodyne and homodyne ED based receivers can be used as the reference architecture to derive the REFSENS requirement. (Sony)**
  + **Proposal 4: Exclude RF envelope detection architecture for LP-WUR. (Sony, ZTE)**
* Recommended WF
  + Baseline architecture can be selected just for potential NF discussion. Targeting a reasonable NF.
  + No architecture needs to be precluded.

Agreement: **use zero-IF receiver as a baseline architecture for envelop based LP\_WUR**

**Issue 2-2-3: Baseline architecture for OFDM-based LP-WUS**

* Proposals
  + **Proposal 1: To wait for RAN1’s conclusion on the OFDM-based LP-WUR. (ZTE)**
  + **Proposal 2: no FFT based OFDM receiver for OFDM receiver. (vivo)**
* Recommended WF
  + TBD

Moderator: RAN1 is discussing FFT.

**Issue 2-2-4: whether different NF for OOK-based and OFDM-based**

* Proposals
  + **Proposal 1: RAN4 confirm if the maximum NF of the OFDM WUR can be assumed differently with OOK WUR. (E///)**
  + **Proposal 2: It is proposed that an ED-based receiver be adopted to define the REFSENS requirement to ensure sufficient power-saving gain unless it is mandatory for UE to decode any OFDM symbols in this LP-WUS. (Sony)**
* Recommended WF
  + Based on proposals from companies, better to differentiate NF for OOK-based and OFDM-based receiver.

Apple: OOK and OFDM requires different receiver. NFs are different in a few dBs. We can consider different noise figures.

Agreement: Differentiate NF for OOK-based and OFDM-based receiver.

**Issue 2-2-5: NF value for OOK-based LR**

* Proposals
  + **Option 1: 15dB for low and mid-band (E///)**
  + **Option 2: 12dB as baseline for envelope based LP\_WUR. (Nokia)**
  + **Option 3: It is proposed to adopt +8dB on top of 9dB basis as NF for OOK-based receiver respectively as starting point for REFSENS. (Huawei, Spreadtrum)**
  + **Option 4: 16 dB for OOK-based receiver. (vivo)**
  + **Option 5: NF Gap between LR and MR for REFSENS could be +5dB for OK-based receiver. (ZTE)**
  + **Option 6: Choose 12-15 dB noise figure as the baseline for the OOK signal. (CMCC)**
* Recommended WF
  + Check and discuss a potential value within [12-17] dB

Huawei: we have strong view on the range. Different UE architectures. The basic noise figure is 7dB but in RAN4 we assume 9dB. We can use existing values for different receivers.

Nokia: in our opinion, 17dB is too high. If setting too high level of NF, FAR is problematic.

LGE: there is some trade-off relation between power consumption and noise figure. We need consider higher NF values.

Huawei: currently we use different NF for different bands. 17dB may not be such worse. For n104 13dB NF is assumed. Whether we need consider different NF for different bands?

Nokia: we have different NF values for different bands. We use delta values.

Apple: We found the noise can be up to 16dB. We support the range.

Samsung: share the similar understanding as LGE and Huawei. Prefer to higher number of noise figure.

Ericsson: We need respect to RAN1 on coverage management. If RAN4 reaches other value than RAN1, maybe we need ask RAN1 other SNR target value should be used. We need the target noise figure.

**Issue 2-2-6: NF value for OFDM-based LR**

* Proposals
  + **Option 1: 12dB as baseline for sequence based LP\_WUR. (Nokia)**
  + **Option 2: It is proposed to adopt +5dB on top of 9dB basis as NF for OFDM-based receiver. (Huawei, vivo)**
  + **Option 3: NF Gap between LR and MR for REFSENS could be +2dB for OFDM-based receiver. (ZTE, Spreadtrum)**
  + **Option 4: Set 9dB as the OFDM noise figure. (CMCC)**
  + **Option 5: approximately 7dB delta to main receiver. (Apple)**
* Recommended WF
  + Check and discuss a potential value within [9-16] dB

**Issue 2-2-7: REFSENS requirements**

* Proposals
  + **Proposal 1: It is possible to specify unified RF requirement for both OOK WUR and OFDM WUR. (E///)**
  + **Proposal 2: It is necessary to consider more than one set of REFSENS requirement depending on the architecture of the LP-WUR. (LGE)**
* Recommended WF
  + TBD

**Issue 2-2-8: IM value for REFSENS**

* Proposals
  + **Option 1: Same as MR. (LGE, CMCC, Spreadtrum)**
  + **Option 2: no lower than 2.5dB. (Apple)**
  + **Option 3: 1dB. (Nokia)**
  + **Option 4: 2dB. (ZTE)**
* Recommended WF
  + Discuss and decide

**Issue 2-2-9: MDR value for REFSENS test case**

* Proposals
  + **Proposal 1: RAN4 may consider adopting a higher percentage MDR value, e.g., 5 %or 10 %, in the conformance test by scaling the REFSENS level accordingly. (Sony)**
  + **Proposal 2: Defining a value of 5% for test purpose could be a compromise to achieve balance between actual network performance and test complexity. (Apple)**
* Recommended WF
  + Suggest to select same MR to specify RF requirements, and conformance testing, i.e., 1%

**Issue 2-2-10: Detailed architecture for LP-WUS receiver**

* Proposals
  + **Proposal 1: It is proposed that RAN4 to include additional switch in the RF reference architecture to support antenna sharing between the MR and LP-WUR to support RRM measurement offload. (Sony)**
  + **Proposal 2: RAN4 to take antenna sharing and switching as baseline for RF front end, and additional insertion loss should be considered in the IM value for REFSENS derivation. (Samsung)**
* Recommended WF
  + The impacts of architecture variations can be considered in NF discussion, no need to specify.

**Issue 2-2-11: Coverage assumptions**

* Proposals
  + **Proposal 1:** **Do not repeat the coverage evaluation work done by RAN1 in RAN4. (Nokia)**
  + **Proposal 2: Verify the SNR and NF values against the RAN1 derived coverage equations to evaluate if coverage is met or not. (Nokia)**
  + **Proposal 3:** **Inform RAN1 at a later date if RAN4 find out that coverage of LP-WUS is not sufficient. (Nokia)**
* Recommended WF
  + No need to repeat RAN1 coverage evaluation work in RAN4.

### Sub-topic 2-3 ASCS simulation and requirements

**Issue 2-3-1: ASCS requirements value**

* Proposals
  + **Proposal 1: No ASCS requirements value is needed, RAN4 just specify the test parameters. (vivo, LGE, E///, Nokia)**
    - **If guard RB is specified for ASCS scenario, there is no need to define specific requirement for ASCS. (Huawei)**
  + **Proposal 2: Determine ASCS requirements for all available CBW under the worst case that WUS is located at center of the NR carrier. (ZTE)**
* Recommended WF
  + Discuss with issue 2-3-2

ZTE: We would like to wait. Guard RB may depend on implementation. Should we define guard RB in the spec?

CATT: if we do not define ASCS values, then does it mean it can be anything?

Huawei: No requirement does not mean that no typical value. In real deployment, the same signal is transmitted from the same BS. If we define the RB, we do not need consider ASCS level.

Ericsson: We do not think this requirement is needed. The filter order used is larger. Even for that we do not see the impact. We can rely on ACS case.

CATT: we should assume equal PSD.

Sony: we say equal PSD ASCS = 0dB?

CATT: equal PSD does not mean ASCS=0dB.

ZTE: Equal PSD means NR and LP-WUS come from the same BS.

CMCC: we should discuss the test parameter first.

Nokia: ASCS is not stringent than ACS case. We do not have any conformance test for ASCS.

Sony: Ericsson and Nokia are talking about the test or not. But we are discussing the requirements.

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

* Proposals
  + **Proposal 1: No guard RB is needed for ASCS requirements. (vivo, Nokia, ZTE)**
  + **Proposal 2: max 1 RB for ASCS at each side. (E///, Huawei)**
  + **Proposal 3: RAN4 shall derive the number of guard RB based on some practical filter assumption once the ACS/ASCS requirement is agreed. (Sony)**
* Recommended WF
  + No need to specify ASCS requirements value, the test case should be defined. The required number of guard RB (if needed) should be one of the test conditions in the test case.

**Issue 2-3-3: Test parameters for ASCS**

* Proposals
  + **Proposal 1: RAN4 can define the ASCS test parameters as following: Achieving 1% MDR without guard RB under the power level of REFSENS+[0.5dB]. detailed test parameters in Table 5. (vivo)**
* Table 5: Test parameters for LP-WUS ASCS

|  |  |  |
| --- | --- | --- |
| RX parameter | Units | Channel bandwidth (MHz) |
|  |  | 5-100MHz |
| LP-WUS Power | dBm | REFSENS + [0.5] dB |
| In-band Pinterferer | dBm | NR signal, same as LP-WUS |
| Guard RB between LP-WUS and NR |  | 0 |
| MDR |  | 1% |

* Recommended WF
  + TBA

### Sub-topic 2-4 ACS simulation and requirements

**Issue 2-4-1: ACS definition for LP-WUS**

* Proposals
  + **Proposal 1: Change “assigned channel frequency” to “assigned LP-WUR channel frequency” in the definition of ACS as follows: (ZTE)**
    - **Adjacent channel selectivity (ACS) is a measure of a receiver's ability to receive a 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 LP-WUR channel frequency to the receive filter attenuation on the adjacent channel(s).**
* Recommended WF
  + TBA

Ericsson: LP-WUS will not be assigned the frequency range. Better to wait for RAN2 decision on how to signal.

ZTE: This is only for ACS definition.

CATT: without this change, the assigned channel frequency can be NR channel.

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

* Proposals
  + **Proposal 1: Specify the same ACS requirements for LP-WUS as MR. (E///, Sony, Nokia)**
    - **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, LP-WUR REFSENS should be used. (Nokia)**
  + **Proposal 2: Define WUR ACS requirement as a value within the range [20~31.5]dB. (vivo)**
  + **Proposal 3: Determine ACS for LP-WUR after the number of guard RBs is determined. (ZTE)**
  + **Proposal 4: It is proposed to relax ACS requirement for LP-WUR from co-existence and performance perspective. The proposed ACS is 10dB given the poor filtering capability of LP-WUR. (Huawei)**
    - **It is proposed to relax dynamic range for ACS requirement in case 2 while keep the same wanted signal level as MR. The proposed dynamic range for ACS case to is relaxed to 25dB.**
* Recommended WF
  + Joint discussion with issue 2-4-3
  + Due to limited dynamic range of LP-WUR, further discuss whether ACS can be relaxed in case number of ACS guard RB is insufficient, i.e.,
    - Same ACS as MR under large NR CBW operation condition. FFS min guard RBs
    - Relaxed ACS requirements with [0-2] guard RBs under small NR CBW operation condition.

CATT: for recommended WF, what values are the ACS?

ZTE: same feeling. The existing ACS values should be specified.

Ericsson: We do not see the problem to reuse the existing ACS. We should list the range. That is the implementation issue.

Huawei: When talking about the ACS, we discuss different values 1) same as MR; 2) value for signal level. LP-WUR cannot have the same filter as MR. 30dB is not possible.

Sony: We have similar understanding. We do not see the different values for LP-WUR. ACS value should be the same since the interference is the same. We can decide guard RB.

Apple: Some relaxation may be necessary to guarantee the device can pass. We should evaluate the level further.

Nokia: There are two things: 1) interference level; 2) signal level. Interference level should not be relaxed.

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

* Proposals
  + **Proposal 1: no guard RB is needed for ACS. (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: For ACS, 2 guard RBs are needed and guard RBs can be blank or filled with NR signal. (ZTE)**
* Recommended WF
  + TBA

Huawei: guard RB does not mean not guard band. LP-WUS has 5MHz. in RAN1 LP-WUS should be 11RBs. There would be enough guard RBs within 5MHz which would be enough.

Ericsson: We should align the terminology. Huawei’s RB is the NR RB outside LP-WUS. Guard band is needed. It depends on OOK-1 or OOK-4.

CATT: Looking back to discussions. Guard RB is chosen. For guard RB here, it takes the existing guard band. Then we are fine with proposal1.

Sony: We first need understand what the interference level is.

**Issue 2-4-4: 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
  + Further discuss test parameters after concluding ACS value and guard RBs

# Topic #3: Other RF requirements

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2411538 | Sony | **Proposal 11 Define the blocking signal level the same as the MR for LP-WUR, and further study if the offset of the blocking signal to the wanted signal should be shifted with guard RB.**  **Proposal 12 RAN4 can focus on the idle mode first and FFS if the connected mode needs to be addressed separately later on if any impact on the RF requirement of LP-WUR would be identified.**  Proposal 13 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 14 RAN4 may consider leaving the testability discussion to RAN5. |
| R4-2411229 | 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 in blocking scenarios, the interference levels for IBB could be relaxed compared to the values defined for MR. FSS whether OBB could be relaxed.***  ***Proposal 2: If the blocking interferer is relaxed to accommodate the low power design, intermodulation requirement could also be relaxed for LP-WUR.***  ***Proposal 3: The same level of receiver spurious emissions for MR shall be defined for LR as well.***  ***Proposal 4: spurious response as a remedial measure for blocking tests needs to be considered for LP-WUR.*** |
| R4-2411655 | Nokia | [Proposal 1: Specify maximum input level requirements and side conditions for LP-WUR.](#_Toc174031137)  [**Observation 1:** Possible bandwidths being considered for LP-WUS in FR1 are .](#_Toc174031138)  [Proposal 2: A single value for the maximum input level is sufficient for LP-WUR.](#_Toc174031139)  [**Observation 2:** There hasn’t been any change in assumptions regarding MCL and gNB output power.](#_Toc174031140)  [Proposal 3: Use maximum input level of -25 dBm for LP-WUR.](#_Toc174031141)  [Proposal 4: Define reference channel for LP-WUR requirements.](#_Toc174031142)  [**Observation 3:** Narrow band blocking requirements haven’t been discussed in context of LP-WUR.](#_Toc174031143)  [**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.](#_Toc174031144)  [Proposal 5: No need to define narrow band blocking requirements.](#_Toc174031145) |
| R4-2411732 | 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 the OOK signal.** |
| R4-2411897 | ZTE Corporation, Sanechips | **Proposal 1: Same interference level of IBB and OBB as MR can be assumed for LP-WUR.**  **Proposal 2: Postpone the discussion on the test conditions for IBB and OBB until related basic issues are finished, including LP-WUS design, performance metrics, guard RB requirements, REFSENS evaluation, etc..**  **Proposal 3: Postpone the discussion on the test conditions for intermodulation requirements until related basic issues are finished, including LP-WUS design, performance metrics, guard RB requirements, REFSENS evaluation, etc..**  **Proposal 4: Spurious response requirement is needed for LP-WUR.** |
| R4-2412275 | LG Electronics France | **Proposal**: For LP-WUR IBB and OBB requirements, the interferer power can be the same as legacy MR and the REFSENS can be replaced by LP-WUR REFSENS (LP-WUR REFSENS = REFSENS + ΔRLP-WUS relaxation) |
| R4-2412978 | Ericsson | **Proposal-1: The WUR should tolerate the same level RF interferer of IBB and OBB as main receiver.**  **Observation 1 It is possible to define one test case for WUR IBB and OOB with min MR channel bandwidth.**  **Observation 2 There is no need to consider the guard or shifted RB for IBB and OOB case.**  **Proposal-2: For intermodulation response rejection requirement, the WUR requirement should be tested with interferer setting with minimum MR bandwidth.**  **Proposal-3:The same maximum input power of -25 dBm could be tested for WUR, the side condition could be simplified with no UL transmission.** |
|  |  |  |

## Open issues summary

### Sub-topic 3-1 IBB, OBB and Intermodulation requirements for UE RF

***Moderator****: agreements last meeting*

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

*Agreement:*

* + *RAN4 further check and discuss whether same interference level of IBB and OBB as MR is assumed for LP-WUR.*
    - *With assumption that Rx dynamic range for LR may not be as good as MR*

**Issue 3-1-1: 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. FSS whether OBB could be relaxed. (Huawei)**
  + **Proposal 2: In-band blocking requirement for legacy UE could be reused. the OBB requirement for legacy UE in TS 38.101-1 could be reused. (CMCC, ZTE, LGE, Sony, Ericsson)**
    - **further study if the offset of the blocking signal to the wanted signal should be shifted with guard RB. (Sony)**
    - **There is no need to consider the guard or shifted RB for IBB and OOB case (Ericsson)**
* Recommended WF
  + TBA

**Issue 3-1-2: IBB and OBB test case**

* Proposals
  + **Proposal 1: Postpone the discussion on the test conditions for IBB and OBB until related basic issues are finished, including LP-WUS design, performance metrics, guard RB requirements, REFSENS evaluation, etc. (ZTE)**
* Recommended WF
  + TBA

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

* Proposals
  + **Proposal 1: If the blocking interferer is relaxed to accommodate the low power design, intermodulation requirement could also be relaxed for LP-WUR. (Huawei)**
  + **Proposal 2:** **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 the OOK signal.**
* Recommended WF
  + TBD

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

* Proposals
  + **Proposal 1: Postpone the discussion on the test conditions for intermodulation requirements until related basic issues are finished, including LP-WUS design, performance metrics, guard RB requirements, REFSENS evaluation, etc. (ZTE)**
  + **Proposal 2: For intermodulation response rejection requirement, the WUR requirement should be tested with interferer setting with minimum MR bandwidth. (E///)**
* Recommended WF
  + TBA

### Sub-topic 3-2 Other Rx requirements

*Moderator: The agreements last meeting:*

*Agreement:*

* + *RAN4 conclude Spurious emissions requirements can be reused for LP-WUR.*
  + *RAN4 further discuss whether spurious response requirements is needed for LP-WUR.*

**Issue 3-2-1: spurious response requirements**

* Proposals
  + **Proposal 1: spurious response as a remedial measure for blocking tests needs to be considered for LP-WUR. (Huawei, ZTE)**
* Recommended WF
  + TBD

**Issue 3-2-2: Maximum input level requirements**

* Proposals
  + **Proposal 1: Specify maximum input level requirements and side conditions for LP-WUR.** 
    - **A single value as of -25 dBm is sufficient (Nokia)**
    - **side condition could be simplified with no UL transmission (E///)**
* Recommended WF
  + TBD

**Issue 3-2-3: Reference channel for LP-WUR requirements**

* Proposals
  + **Proposal 1: Define reference channel for LP-WUR requirements. (Nokia)**
* Recommended WF
  + TBD

# Topic #4: Testability issues

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2411230 | 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.***  *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 also incurring 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.*** |
| R4-2411656 | Nokia | [Proposal 1: RAN5 defines the detailed test procedure for the conformance tests.](#_Toc173768565)  [Proposal 2: A higher SNR for the main radio signals can be used, so that we just test the performance of the LP-WUR.](#_Toc173768566)  [Proposal 3: Discuss if a LS to RAN5 or a note in RAN4 specification is sufficient.](#_Toc173768567)  [Proposal 4: RAN5 can design the details of Test mode required to test the LP\_WUR.](#_Toc173768568) |
| R4-2411898 | 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 IDLE mode test, if only MDR is chosen as test metric, there is no need to design dedicated feedback to help test MDR.**  **Proposal 3: 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, and tests for MDR and FAR should be designed separately.**  **Proposal 4: To test the LP-WUR in CONNECTED mode.**  **Proposal 5: For CONNECTED mode test, if only MDR is chosen as test metric, there is no need to design dedicated feedback to help test MDR.**  **Proposal 6: 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, and tests for MDR and FAR should be designed separately.** |
| R4-2412061 | vivo | **Proposal 1: RAN4 should agree the general guidance first that the MDR can be counted without waking up the MR each time for LP-WUS RF performance testing.**  **Proposal 2: the following two options can be considered for LP-WUS general procedure:**   * **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.** * **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.**   **Proposal 3: Details test parameters can be left to RAN5, however the general procedure and metric should be defined in RAN4 first.** |
| R4-2412977 | Ericsson | Proposal-1: One test condition is enough for same RF requirements, no need to repeat the same RF requirement with different test conditions.  Proposal-2: 1% MDR (BLER) should be used and postpone FAR discussion to performance phase.  Proposal-3: Send a LS to RAN5 to see if test time could be further optimized from testing perspective.  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%). 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* |
| R4-2411538 | Sony | **Proposal 12 RAN4 can focus on the idle mode first and FFS if the connected mode needs to be addressed separately later on if any impact on the RF requirement of LP-WUR would be identified.**  Proposal 13 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 14 RAN4 may consider leaving the testability discussion to RAN5. |

## Open issues summary

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

**Issue 4-1-1: General framework on LP-WUS testing**

* 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
  + Group discuss and conclude the general framework for LP-WUS performance verification. Further discuss other details.

**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)**
  + **Proposal 2: RNA4 should determine to perform the test of LP-WUR in IDLE mode or CONNECTED mode first. (ZTE)**
  + **Proposal 3: RAN4 can focus on the idle mode first and FFS if the connected mode needs to be addressed separately later on if any impact on the RF requirement of LP-WUR would be identified. (Sony)**
* Recommended WF
  + TBA

**Issue 4-1-3: Test metric**

* Proposals
  + **Proposal 1: both 1% for MDR and FAR. (Huawei)**
  + **Proposal 2: 1% for MDR. And FFS FAR in performance phase. (E///)**
* Recommended WF
  + Select same test metric and requirement metric. Both 1%

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

* + **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**
* Recommended WF
  + TBA

**Issue 4-1-5: Whether need feedback from LP-WUR after test to help calculate MDR and FAR**

* + **Proposal 1: RNA4 should determine to perform the test of LP-WUR in IDLE mode or CONNECTED mode first. (ZTE)**
    - **For IDLE mode test, if only MDR is chosen as test metric, there is no need to design dedicated feedback to help test MDR;** **if both MDR and FAR are chosen as test metric, a feedback mechanism should be designed to help TE to know FAR, and tests for MDR and FAR should be designed separately**
    - **For CONNECTED mode test, if only MDR is chosen as test metric, there is no need to design dedicated feedback to help test MDR; if both MDR and FAR are chosen as test metric, a feedback mechanism should be designed to help TE to know FAR, and tests for MDR and FAR should be designed separately.**
* Recommended WF
  + TBA

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

* + **Proposal 1: RAN5 defines the detailed test procedure for the conformance tests. (Nokia, Huawei, Sony)**
  + **Proposal 2: Details test parameters can be left to RAN5, however the general procedure and metric should be defined in RAN4 first. (vivo)**
* Recommended WF
  + TBA

**Issue 4-1-7: UE test mode for LP-WUR**

* Proposals
  + **Proposal 1: Test mode as well as the details of test mode for LP-WUS verification can be left to RAN5. (Huawei, Nokia)**
  + **Proposal 2: 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. (Sony)**
* Recommended WF
  + TBA

**Issue 4-1-8: 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