**3GPP TSG-RAN WG4 Meeting #109 R4-2321737**

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

**Agenda item:** 8.20.5

**Source:** vivo

**Title:** Ad-hoc minutes for [109][135] FS\_NR\_LPWUS

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# Introduction

This is meeting minutes for ad-hoc session of LP-WUS RF discussions in AI 8.20.1~8.20.3, chaired by Ruixin Wang (vivo).

# Topic #1: LP-WUR architectures

## Companies’ contributions summary

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

## Open issues summary

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

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

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

***Discussions:***

*Nokia: it is better to define two guard RB definition for ACS and ASCS*

*E///: when placed outside the WUS carrier, the guard RBs can be used for NR. This should be concluded first.*

*Nokia: for 5MHz WUS within 5MHz channel, then the guard RBs can not be used for NR*

*QC: the guard RBs can be used for NR based on BS decision*

*Huawei: the definition of guard RB for ACS and ASCS is clear enough. The RB offset does not have impact on guard RB definition. The RBs is used for NR or not is network scaling, should not be finalized in SI phase, this can be further discussed in WI. The number of RB is the key issue.*

*MTK: generally agree with Huawei. How the network can work, should be decided in WI phase.*

*QC: the guard RBs for NR or not, up to BS transmission*

*E///: the guard RB means no WUS, but should not be mandated as blanked RBs, which could be used for NR. So RB offset would be better. The WUS CBW is limited, the SNR will be impacted if WUS RB is reduced.*

*Apple: For the SI phase, we should know the min guard RB. Support vivo proposal.*

*Nokia: we do not have to differentiate the ACS and ASCS case, we just define the number of guard RB for each side.*

*E///: the guard RB not means all the RB should be blanked.*

*Huawei: for some cases, the RBs can be used for the other NR UE. Suggest to discuss guard RB for NR usage in WI phase.*

*Sony: in channel NR RB will impact WUS receiving. There should be guard RBs between WUS and NR.*

*QC: there would be misunderstanding. We are discussing the guard RBs for NR, under ACS case but not ASCS.*

***Agreements:***

***General guard RB term for both ASCS and ACS. For ACS, the guard RBs could be used for NR, whether the guard RBs will be used for NR depends on BS usage.***

**Issue 1-1-2: Whether to further update the number of guard RBs/[RB Offset] for ACS**

* Observations and Proposals
  + **Option 1: Yes**
  + **Option 2: No. Further discuss in WI phase**
* Recommended WF
  + collecting views and decide whether update guard RB number from 3 to 6?

***Discussion:***

*E///: this is mainly designed for test case, related to filter order. We can not define a specific number in SI phase.*

*QC: the TR has suggested the number of guard RBs for ACS case. RF impairment will increase the number of RBs, we would like to reflect this condition in TR.*

*Sony: we support to update the ACS RB number.*

*E///: need clarify the guard RBs, within WUS carrier or outside?*

*QC: we assume it is outside WUS.*

*Nokia: we are OK to update the number. But the corresponding waveform should be reflected.*

***Agreement:***

***Update the number of guard RBs for ACS to 6 in [ ]. Add more information of simulation assumption.***

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

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

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

**For OOK based WUR:**

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

**For OFDMA based WUR:**

* **Time-domain correlation delta NF: [0~7] dB**
* **Frequency-domain correlation delta NF: [0~3] dB**
  + **Proposal 2: It is proposed to discuss the viable NF together with SNR in WI phase when to determine the REFSENS for LP-WUR with consideration of the coverage target. (Huawei)**
  + **Proposal 3: The noise figure can be assumed as (Nokia)**
    - **NF for Zero-IF/Low-IF BB envelope detector architecture can be assumed to be 9 dB.**
    - **NF for heterodyne IF envelope detector architecture can be assumed to be 10 dB.**
    - **NF for RF envelope detector architecture can be assumed to be 30 dB.**
    - **NF for OFDM based WUR (frequency or time domain correlator) architecture can be assumed to be 9 dB.**
  + **Proposal 4: The noise figure assumption. (Ericsson)**
    - With a moderate assumption of OOK WUR NF 4dB worse than NF of MR, the coverage of WUR cannot match with either MSG3 PUSCH or PDCCH (1 Rx, AL 16)
    - OFDM WUR can match to the MSG PUSCH or PDCCH (1Rx, AL 16) assuming 1 dB worse NF than NF of MR
    - Whether to introduce the coverage enhancement of the LP-WUS for OOK WUR is up to RAN1 in Rel-19 WI.
* Recommended WF
  + Could be a range agreeable in SI phase?
  + Specific NF together with SNR in WI phase when to determine the REFSENS

***Discussions:***

*Apple: for 0 dB NF gap between LR and MR, any consideration of power consumption? We should consider low power target.*

*E///: for OFDM architecture, it would be 1dB worse NF, from coverage perspective, if compared with Message 3. Given the SNR difference, we can not reach conclusion of NF at this stage, how worse NF can be adopted.*

*QC: we can capture some examples of NF for each architecture. But for requirements phase, we can further decide values.*

*Huawei: it is difficult to decide NF this stage. Based on RAN1 and RANP decision, we can discuss the coverage, the NF is highly dependent on SNR and coverage target. Suggest further discuss this issue*

*MTK: if we can clearly state the NF range for different architecture with different coverage target, then would be OK.*

*Apple: for coverage issue, there is no RAN1 consensus on LP-WUS coverage. The power consumption is related to RRM measurement, we can not discuss target coverage this stage.*

*Nokia: it is beneficial to define NF for different LP-WUR. Achievable NF of each architecture is helpful.*

***Agreements:***

**In SI phase, RAN4 do not need to define NF for LP-WUR.**

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

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

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

***Discussions:***

*E///: the 6dB under discussing is only for existing BS. For WI phase, we can discuss a potential new requirements for BS.*

*Nokia: the 6dB power boosting for whole WUS signal is not OK to us.*

*QC: not clear about the concern from Nokia*

*Apple: suggest to capture power boosting for two cases, one is for legacy BS, one is for new BS implementation.*

*QC: corner case of BS implementation should not preclude the power boosting of WUS signal.*

*E///: agree with Nokia, the output power can not beyond the declared Power value of BS. But for new BS requirements in WI, may consider new power level depends on discussion. For existing BS, same view with Nokia.*

*MTK: from UE side, this power boosting of LP-WUS is very valuable.*

*Nokia: there will be power pulling of 3db, is this 6dB power boosting additionally?*

*QC: the power boosting is dependent on RAN1 waveform decision.*

*Nokia: 2dB is max value we can accept.*

*Sony: from UE implementation perspective, the WUS power boosting is important. We can conclude the power boosting is possible and needed. For specific value can be WI phase.*

*Apple: we support to keep 6dB in [ ]. Add statement of smaller value that is for legacy BS.*

*Huawei: we support 6dB in [ ] as SI outcome. The final value is related to number of WUS RBs, can be discussed in WI phase.*

*MTK: 6dB in [] is good outcome of SI. For 2dB, this belongs to the range, can be declared by BS manufacture. For a smaller value, would be difficult to define.*

*Nokia: NB IoT only 1RB. WUS has large bandwidth.*

*Huawei and E///: not need to specifically state some BS can not reach the highest power boosting level, this power boosting is already based on BS declaration.*

*vivo: power pulling is simulated in RAN1, related to specific waveform type. Not necessary to put it here. Further discuss the relationship with power pulling is OK to us.*

*E///: power pulling is not clear to the group. RAN4 has not discussed it, we suggest not to capture this in the outcome.*

***Agreements:***

* + **Consider [0~6dB] for LP-WUS power boosting as SI outcome, further discuss in WI for specific value.**
    - **The condition of power boosting can be further discussed in WI phase.**
    - **The number [0~6] is aligned with RAN1 assumption.**

Nokia: disagree with the numbers.

Qualcomm: this is a range and will be decided according to conditions in the future.

Nokia: the number comes from RAN1. There is no analysis to justify the number.

Moderator: not only for this issue, also for other issue, companies did the simulation and provided the results. Accordingly RAN4 captured the outcome as observations.

Apple: it is beneficial to have power boosting at gNB.

Nokia: we are not against the power boosting. If there is analysis, please show us the tdoc where the number comes from.

Moderator: 0~6dB comes from RAN1.

Nokia: Do we preclude the higher number, like 7dB? Do we take the WiFi and local BS into account?

Moderator: the current values are based on the discussions. If we figured out the higher number which can be used, we are OK to have such value.

Qualcomm: we are happy to consider higher value. This is linked to base station type.

Huawei: We cannot accept the higher values. The condition includes the possible RB numbers and others. There will be limitation.

Nokia: The values comes from RAN1. RAN1 does not do analysis.

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

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

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

***Offline discussion outcome: the sensitivity will be discussed based on Rel-19 scope. No need specific agreements here.***

**Issue 1-4-2: LP-WUR test cases**

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

***Offline discussion outcome: this has been agreed last meeting.***

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

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

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

***Offline discussion outcome: Encourage more study on phase noise impacts in future.***

# Topic #2: TPs to RAN1 TR

## Companies’ contributions summary

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

## Open issues summary

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

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

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

***Offline discussion outcome: revise the TP, update with minor refined wording.***

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

* Proposals6
  + **Proposal 1: Update the guard RB interpretation based on outcome of issues in 1-1. Proposals in** **R4-2318975, R4-2320085, R4-2320643, and R4-2320547 can be considered. (Moderator)**
* Recommended WF
  + TBA

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

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

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

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

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



(case 1: WUS within large NR channel)



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

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



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

***Offline discussion outcome: revise the TP, remove the 5MHz restrictions in Figure 7.1.2.1-1 and 7.1.2.1-2.***

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

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

***Offline discussion outcome: the above content is more related to RAN1 scope, not need to be captured in RAN4 part.***

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

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

***Offline discussion outcome: the ADC content needs refined wording.***

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

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

***Offline discussion outcome: Coverage aspects are mainly RAN1 scope, not need to be captured as RAN4 part. High-level description of NF vs power consumption may be captured in TR.***