**3GPP TSG-RAN WG4 Meeting #112 R4-2413409**

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

**Agenda item:** 8.22.5

**Source:** Moderator (Huawei)

**Title:** Topic summary for [112][309] NR\_LPWUS

**Document for:** Information

# Introduction

This contribution summarizes the documents that are submitted to agenda 8.22.3 for RAN4#112 and it concentrates on the following aspect.

* Topic #1: On BS RF requirements for LP-WUS/WUR

# Topic #1: On the BS RF requirement for LP-WUS

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2411094 | CATT | ***Proposal 1: For manufacture declaration on LP-WUS power boosting, RAN4 to specify minimum power boosting level in core specs together with manufacturer declaration in the conformance test specification, i.e., Option 2, for the sake of making most of LP-WUS in reality.******Proposal 2: Define EPRE ratio between LP-WUS and NR signals instead of power dynamic range.******Proposal 3: Introduce the definition of LP-WUS power boosting as: The LP-WUS power boosting is the difference between the average power of LP-WUS REs (which occupy certain REs within a NR transmission bandwidth configuration and the average power NR REs (the NR carrier excluding the LP-WUS REs).******Proposal 4: RAN4 to introduce the maximum allowed power degradation as one of the core requirements for LP-WUS power boosting, i.e., Option 1, for the sake of guaranteeing NR network performance.******Proposal 5: RAN4 not to set a restriction on applicable BS types for LP-WUS.******Proposal 6: RAN4 to consider 3dB as a starting point as the minimum requirements for different channel bandwidths for different channel bandwidths.******Observation: The cap for LP-WUS power boosting may vary with different channel bandwidths if introducing the maximum allowed power degradation.******Proposal 7: Do not introduce a universal cap for LP-WUS power boosting when specifying the maximum allowed power degradation.*** |
| R4-2411231 | Huawei, HiSilicon | ***Proposal 1: EPRE ratio has the merit that power boosting declaration for LP-WUS does not vary with different CBWs, which can be considered as basis for definition of LP-WUS dynamic range/power boosting. The proposed definition could be:******The LP-WUS RB power dynamic range (or LP-WUS power boosting) is the difference between the average power of an LP-WUS RE (averaged power per RE based on all LP-WUS REs within a NR transmission bandwidth configuration) and the average power of a non-LP-WUS RE (averaged power from all REs from the NR carrier excluding the LP-WUS REs).******Proposal 2: It is proposed to limit power boosting of LP-WUS, if supported, to larger channel BWs which has less impact on coverage of NR signal. Specific CBW can be determined with inputs from operators on the tolerable degradation for NR power in terms of single RB or EPRE.******Proposal 3: It is proposed to specify 3dB as minimum level for LP-WUS power boosting but with 6dB as upper bound given the larger impact on NR available transmission power.******Proposal 4: All possible BS types could be considered for LP-WUS, which are relevant to the supported operating bands.*** ***Proposal 5: OTA based 1-O requirements should not be considered for LP-WUS.******Proposal 6: Unwanted emissions requirements of SEM and spurious emissions should be considered for transmitted signal with LP-WUS and NR in the same carrier.*** ***Proposal 7: Transmitted signal quality requirements should be defined for LP-WUS, FFS whether measurements could be waived.***  |
| R4-2411733 | CMCC | ***Proposal 1: Not to set restriction on applicable BS types to support LP-WUS.******Proposal 2: it’s suggested to also define multi-band requirements at gNB side for LP-WUS.******Observation 1: RAN1 listed several schemes to improve the coverage of Msg3, and power boosting has not yet been decided to be used.******Proposal 3: CBW for MR should not be limited.******Proposal 4: Set the LP-WUS power boosting a complete manufacture declaration feature.*** |
| R4-2411894 | ZTE | ***Observation 1: NR power deboosting is not the only factor that impacts LP-WUS power boosting level. Another important issue is that the location of LP-WUS RBs in the carrier may also impact the LP-WUS power boosting level in other aspects, such as out-of-band emissions.******Observation 2: There is a risk of not meeting the ACLR requirement when WUS is located at edge of the carrier and the transmit power of LP-WUS is boosted.******Observation 3: A minimum value requirement for LP-WUS power boosting cannot be used in all the cases and it is difficult to set different requirements for different cases, because the boundaries of different cases are vague.******Observation 4: Traditional EVM requirements may not work for LP-WUS with envelope detection and time-domain correlation.******Proposal 1: Use concept of LP-WUS dynamic range/power boosting in Option 1: The LP-WUS RB power dynamic range (or LP-WUS power boosting) is the difference between the average power of LP-WUS REs (which occupy certain REs within a NR transmission bandwidth configuration and the average power over all REs (from both LP-WUS and the NR carrier containing the LP-WUS REs).******Proposal 2: Not to set a minimum limitation or a maximum limitation for LP-WUS power boosting.******Proposal 3: Set the LP-WUS power boosting a complete manufacture declaration feature, including whether supporting LP-WUS power boosting and the supported boosting level.******Proposal 4: There is no need to set new output RF spectrum emission requirements for the mixed LP-WUS and NR signal. Legacy output RF spectrum emission requirements for NR should be reused and should not be relaxed for the existence of LP-WUS, even with LP-WUS power boosting.******Proposal 5: RAN4 should further study how to evaluate transmission signal quality in time domain and/or in frequency domain, e.g., OOK energy precision for envelope detection, for time-domain correlation, and frequency-domain EVM requirements for frequency-domain correlation.******Proposal 6: Propose to use BS Type 1-C as applicable BS type.*** |
| R4-2412062 | vivo | ***Proposal 1: RAN4 should define a min power boosting level in core specification which is based on optional manufacture declaration.******Proposal 2: RAN4 LP-WUS power boosting definition can reuse the NR RB power dynamic range as much as possible meanwhile consider the fact that the assumption in RAN1 of 3dB or 6dB means the EPRE ratio.******Proposal 3: There is no need to preclude any CBW.*** ***Proposal 4: RAN4 should evaluate the NR throughput impact due to in-band LP-WUS power boosting. The min value can be decided based on reasonable threshold of NR performance degradation.*** |
| R4-2412595 | Nokia | ***Proposal 1: The core requirement for the dynamic range for LP-WUS/LP-SS shall be specified the same as 64QAM, i.e., 0 dB, and BS manufacturers should be allowed to declare the supported LP-WUS power boosting level.******Proposal 2: The definition of LP-WUS dynamic range/power boosting in RAN4#110bis approved WF R4-2406140 should continue to be used to avoid potential confusion among the various requirements related to power boosting.******If proposal 1 is agreed, then:******Proposal 3: There is no need to preclude small CBW for LP-WUS power boosting.******Proposal 4: There is no need to set restriction on applicable BS types for LP-WUS.******Proposal 5: There is no need to cap the LP-WUS power boosting.******Proposal 6: There is no need to adjust other requirements like UEM, ACLR and EVM, and the same LP-WUS/LP-SS power boosting requirement and declaration can be applicable to multi-band BS.*** |
| R4-2412974 | Ericsson | ***Observation 1: 3 dB power boosting is possible if CP-OFDM symbol used for LP-WUS generation is QPSK modulation.******Observation 2: 3 dB power boosting is applied to BS type 1-C, 1-H and 1-O in test model TM1.2.******Observation 3: Power boosting declaration only applies for BS type 1-C.******Proposal-1: Limit the power boosting for LP-WUS to 3 dB for BS type 1-C.******Observation 4: No test model for power boosting is defined for FR2 and power boosting capability cannot be assumed for FR2 BS.******Proposal-2: RAN4 should allow dynamic range requirements based on existing specification for OOK-1 waveform.******Observation 5: For overlaid LP-WUS signal, RAN4 investigate further after RAN1 make further progress.******Proposal-3: The power boosting of the LP-WUS is up to manufacture declaration.******Proposal-4: No other RF requirement than the dynamic range should be specified for LP-WUS.*** |

## Open issues summary

### Sub-topic 1-1 On dynamic range for LP-WUS

**Issue 1-1: Manufacture declaration on LP-WUS**

* Proposals
	+ Proposal 1: Set the LP-WUS power boosting a complete manufacture declaration feature, including whether supporting LP-WUS power boosting and the supported boosting level*.* (ZTE, CMCC, Nokia)
	+ Proposal 2: Minimum power boosting level in core specification together with manufacturer declaration in the conformance test specification. (CATT, vivo, Ericsson, Huawei)
* Recommended WF
	+ TBA

**Issue 1-2: Concept of LP-WUS dynamic range/power boosting**

* Proposals
	+ Option 1: Introduce EPRE ratio to define LP-WUS power boosting, since it has the merit that power boosting does not vary with different CBWs. (CATT, Huawei, [vivo])
		- Option 1-1: ***The LP-WUS power boosting is the difference between the average power of LP-WUS REs (which occupy certain REs within a NR transmission bandwidth configuration and the average power NR REs (the NR carrier excluding the LP-WUS REs).*** (CATT)
		- Option 1-2: ***The LP-WUS RB power dynamic range (or LP-WUS power boosting) is the difference between the average power of an LP-WUS RE (averaged power per RE based on all LP-WUS REs within a NR transmission bandwidth configuration) and the average power of a non-LP-WUS RE (averaged power from all REs from the NR carrier excluding the LP-WUS REs).*** (Huawei)

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| *Moderator: Followings are reproduced from* ***R4-2411094*** *for information*The relationship between EPRE ratio and power dynamic range is illustrated by the following equation where $δ\_{LP}$ is the power dynamic range and $α$ is the EPRE ratio:$δ\_{LP}$=$\frac{N\_{RB}∙α}{N\_{LP\\_RB}∙α+(N\_{RB}-N\_{LP\\_RB})}$ The two tables below indicate how a fixed EPRE is associated with power dynamic ranges, and how a fixed power dynamic range is associated with different EPRE values respectively for different channel bandwidth assuming WUS occupies 5MHz.Table – 1 Power dynamic range for LP-WUS

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| EPRE ratio (dB) | CBW 10MHz  | CBW 20MHz | CBW 30MHz | CBW 40MHz | CBW 50MHz |
| +3dB | 1.3 dB | 2.1 dB | 2.4 dB | 2.5 dB | 2.6 dB |
| +6dB | 2.1 dB | 3.7 dB | 4.4 dB | 4.7 dB | 4.9 dB |
| +9dB | 2.5 dB | 4.4 dB | 5.3 dB | 5.8 dB | 6.1 dB |

Table – 2 EPRE ratio for LP-WUS

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Power dynamic range (dB) | CBW 10MHz  | CBW 20MHz | CBW 30MHz | CBW 40MHz | CBW 50MHz |
| +3dB | 14.3 | 4.6 | 3.9 | 3.6 | 3.5 |
| +6dB | N/A | 17.3 | 9.5 | 8.2 | 7.6 |
| +9dB | N/A | N/A | 19.1 | 12.4 | 10.9 |

It could be observed that for some channel bandwidths, power dynamic range values may not be achievable at all. Actually EPRE ratio is also used in RAN1 discussion. |

* + Option 2: Adopt following definition rather than introduce EPRE ratio. (ZTE, Nokia)
		- ***The LP-WUS RB power dynamic range (or LP-WUS power boosting) is the difference between the average power of LP-WUS REs (which occupy certain REs within a NR transmission bandwidth configuration) and the average power over all REs (from both LP-WUS and the NR carrier containing the LP-WUS REs)*.**
* Recommended WF
	+ TBA

**Issue 1-3: Whether to preclude small CBW for consideration of LP-WUS power boosting**

* Proposals
	+ Proposal 1: Preclusion on small CBW respective to different power boosting level and/or power degradation on NR signal can be considered for LP-WUS power boosting.
		- Proposal 1-1: Also introduce the maximum allowed power degradation as one of the core requirements for LP-WUS power boosting. (CATT)
		- Proposal 1-2: Operator inputs on the tolerable power degradation can be considered for the determination on the CBW to be precluded. (Huawei)

|  |
| --- |
| *Moderator: Followings are reproduced from* ***R4-2411094*** *for information*Fig. 1, Power degradation threshold for validating EPRE ratio and channel bandwidth for power boostingThe power degradation $∆ $could be calculated as:$$∆=1+\frac{(α-1)N\_{LP\\_RB}}{N\_{RB}}$$ |

* + Proposal 2: No need to preclude any CBW. (CMCC, vivo)
		- Proposal 2-1: Only if the LP-WUS power boosting can be defined as dynamic range where the level is up to manufacturer declaration and 0dB as minimum core requirement. (Nokia)
* Recommended WF
	+ TBA

**Issue 1-4: On applicable BS type for LP-WUS**

* Proposals
	+ Proposal 1: Not to set restriction on applicable BS types to support LP-WUS. (Huawei, CATT, CMCC)
		- Proposal 1-1: Only if the LP-WUS power boosting can be defined as dynamic range where the level is up to manufacturer declaration and 0dB as minimum core requirement. (Nokia)
	+ Proposal 2: Adopt type 1-C as applicable BS type and FFS other BS types. (ZTE, Ericsson)
* Recommended WF
	+ Check if all available BS types can be considered for LP-WUS due to the support of LP-WUS is optional and the power boosting level could be up to manufacturer declaration.
	+ Check whether only conductive based BS RF requirements should be defined for LP-WUS.
		- For 1-C and 1-H, only defining conductive based requirements, if no need to define TRP requirement
		- Not to define 1-O requirements

**Issue 1-5: On minimum value for LP-WUS power boosting**

* Proposals
	+ If power boosting will be defined as EPRE ratio.
		- Proposal 1: Use 3dB as minimum requirement. (CATT, Huawei)
	+ If power boosting will be defined as dynamic range.
		- Proposal 2: Based on existing specification for OOK-1 waveform, the core requirement for the dynamic range should be limited to 3dB. (Ericsson)
	+ Proposal 3: Not to introduce minimum value for LP-WUS power boosting. (ZTE, Nokia)
* Recommended WF
	+ TBA

**Issue 1-6: Whether a cap for LP-WUS power boosting should be considered**

* Proposals
	+ Proposal 1: Yes, because impact on NR signal available transmission power should be considered.
		- Proposal 1-1: 3dB. (Ericsson)
		- Proposal 1-2: 6dB. (Huawei)
	+ Proposal 2: Not to introduce maximum value for LP-WUS power boosting. (ZTE, Nokia, CATT)
* Recommended WF
	+ TBA

### Sub-topic 1-2 Other considerations apart from power boosting for LP-WUS

**Issue 1-7: Unwanted emissions**

* Proposals
	+ Proposal 1: No need to consider ACLR, but unwanted emissions requirements of SEM and spurious emissions should be considered for transmitted signal with LP-WUS and NR in the same carrier. (Huawei)
	+ Proposal 2: No need to introduce new output spectrum emission requirements. Instead, legacy ones should be reused and no relaxation w or w/o LP-WUS power boosting. (ZTE, Nokia)
	+ Proposal 3: No other RF requirement than the dynamic range should be specified for LP-WUS. (Ericsson)
* Recommended WF
	+ Check if reuse legacy unwanted emissions requirements of SEM and spurious emissions for LP-WUS can be acceptable.

**Issue 1-8: Transmitted signal quality**

* Proposals
	+ Proposal 1: Transmitted signal quality requirements should be defined for LP-WUS, FFS whether measurements could be waived. (Huawei)
	+ Proposal 2: RAN4 should further study how to evaluate transmission signal quality in time domain and/or in frequency domain, e.g., OOK energy precision for envelope detection, for time-domain correlation, and frequency-domain EVM requirements for frequency-domain correlation. (ZTE)
	+ Proposal 3: No need to adjust EVM requirements. (Nokia)
	+ Proposal 4: No other RF requirement than the dynamic range should be specified for LP-WUS. (Ericsson)
* Recommended WF
	+ TBA.

**Issue 1-9: Multi-band operation**

* Proposals
	+ Option 1: The same LP-WUS/LP-SS power boosting requirement and declaration can be applicable to multi-band BS. (Nokia, CMCC)
	+ Option 2: Others.
* Recommended WF
	+ TBA.