**3GPP TSG-RAN WG4 Meeting # 112 draft R4-2412834**

Maastricht, Netherlands,19 – 23 Aug, 2024

**Agenda item:** 8.20.4

**Source:** Moderator (Huawei)

**Title:** Topic summary for [112][132] FS\_Ambient\_IoT\_solutions\_part2

**Document for:** Information

# Introduction

The thread [112][132] FS\_Ambient\_IoT\_solutions\_part2 is on Rel-19 SI for Study on solutions for Ambient IoT in NR (RP-240826).

In previous meetings, the following WFs was agreed: R4-2410597 (RAN4 #111).

The summary covers contributions submitted under the agenda items including:

8.20.3 RF requirement impact

8.20.3.1 Ambient IoT BS

8.20.3.2 Ambient IoT device

8.20.3.3 Intermediate note (UE)

# Topic #1: A-IoT System Parameters

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| R4-2413282 | Huawei | RAN4 to study the necessity of channel raster for Ambient RF requirement. If needed, it is proposed to reuse the enhanced channel raster (i.e. 10 kHz) |
| R4-2411768 | CMCC | Proposal 1: it’s suggested to define one unified set of system parameter for A-IoT BS, A-IoT intermediate UE and devices.Proposal 2: it’s suggested to only choose band n8 as example band.Proposal 3: no need to define transmission bandwidth requirements in RAN4.Observation 1: Intra-A-IoT system guard RB is mainly used to reduce or even avoid interference for device FDM operation case or for A-IoT reader FDM operation case. Such interference would be even worse if reader or device have bad frequency accuracy performance.Proposal 4: RAN4 further discuss the candidate channel bandwidth for all three spectrum deployment modes. For standalone mode, it seems 5MHz bandwidth is enough based on current assumed data rate and modulation scheme. For other two spectrum deployment mode, the channel bandwidth also seems necessary as common concept which may be used by reader.Proposal 5: RAN4 further discuss whether any guard band is needed or not to avoid interference between A-IoT system and NR/LTE system. * For guard-band spectrum deployment mode, guard band can be in any granularity.
* For in-band spectrum deployment mode, guard band could help to enhance current Tx leakage and Rx selectivity performance and detailed value can wait for co-existence results.

Proposal 6: syn raster is not applicable for all three spectrum deployment mode. For guard-band mode, the channel raster and channel spacing are not applicable. For in-band mode, the channel spacing is not applicable.* Standalone: channel raster, channel spacing
* In-band: channel raster
* Guard-band: N/A
 |

### Issue 1-1: System parameter

Agreement in RAN4#111

* RAN4 will define the D2R and/or R2D channel bandwidth and operating bands for A-IoT
	+ Wait for the conclusions from other WGs to discuss the detailed parameters.
	+ FFS on whether to have the same or different channel bandwidths for devices, BS and intermediate node
* Proposals:
	+ define one unified set of system parameter for A-IoT BS, A-IoT intermediate UE and devices. (R4-2411768, CMCC)
* Recommended WF
	+ Define a single set of system parameter for A-IoT Reader and devices.
	+ The following table can be discussed

|  |
| --- |
| **System parameter for A-IoT** |
| System parameter | Operating band | Band n8 as example band  |
| Channel bandwidth | Transmission bandwidth configuration | NA (R4-2411768, CMCC) |
| channel bandwidth | Standalone: 5MHz bandwidth is enough based on current assumed data rate and modulation scheme. In-band/ guard-band: may be needed.  |
| Channel arrangement | Channel spacing | Standalone： ApplicableIn-band/ Guard-band：NA |
| Channel raster | Standalone/ In-band：Applicable (R4-2411768, CMCC)Guard-band：NA （R4-2411768, CMCC) If needed, reuse the enhanced channel raster (i.e. 10 kHz)（R4-2413282, Huawei） |
| Synchronization raster | NA |
| Minimum receiver bandwidth | Discuss whether needed considering the spectrum of backscattering signal（R4-2408093, vivo） |
| Guard band/Guard RB | discuss whether any guard band is needed or not (R4-2411768, CMCC) |

# Topic #2: A-IoT BS

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| [**R4-2411084**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411084.zip) | CATT | A-IoT BS feasibility and requirementsObservation 1: If SBFD SI analysis approach is used, required CW cancellation capability is up to 150 dB for 33 dBm CW power level.Proposal 1: How CW impacts AIoT reader Rx BB DEMOD performance needs some evaluation or assumption for the feasibility study.For the AIoT BS RF requirements, preliminary views from our side are provided in Table 2 to Table 4. |
| **[R4-2411766](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411766.zip)** | CMCC | Discussion on A-IoT BS RF requirementsProposal 1: it’s suggested to use micro cell type/MR BS as baseline but further discuss whether reader could support other BS class besides MR.Proposal 2: it’s suggested to focus on 1-C reader BS type at first and further discuss the necessity of 1-H reader BS type.Proposal 3: MR A-IoT BS could reuse current transmit output power and max output power of 1-C MR BS.Proposal 4: RE power control dynamic range may needs to be updated since now only OOK modulation is supported at reader side.Proposal 5: total power dynamic range needs to be updated accordingly based on conclusion of channel bandwidth and SCS. Proposal 6: current gNB frequency error is enough for reader if assuming no FDM operations between readers.Observation 1: if reader support FDM operation and carrier bandwidth is much less, more strict frequency error requirement may be needed. Proposal 7: in RAN4, it’s suggested to focus on single carrier operation mode for reader at first and FDM reader operation as low priority.Observation 2: RFID spec use RF envelop related parameters to evaluate ASK signal transmission quality requirement, e.g. modulation depth, RF envelop ripple, RF plusewidth etc.Proposal 8: RAN4 could refer to RFID RF envelop related parameters to define signal transmission quality requirement as starting point, i.e. modulation depth, RF envelop ripple, RF plusewidth.Proposal 9: it’s suggested to define transient period related requirements for A-IoT reader. Details value can refer to RFID rise/fall time.Proposal 10: RAN4 further discuss whether settling time as defined in RFID spec is needed or not to evaluate RF envelop ripple characteristics.Proposal 11: if finally approve that A-IoT reader support multiple-RAT, IBE equivalent requirement needs to be defined.Proposal 12: unwanted emission related requirements are based on co-existence evaluation. For spurious emission related requirements, it seems reasonable to reuse current gNB requirements.Observation 3: due to very narrow bandwidth of CW interference signal, RAN4 needs to further discuss whether 1dB desense self-interference cancellation target is still applicable or not.Observation 4: for CW outside topology, RAN4 needs some typical spatial isolation assumption before conclude whether to/ how to reflect self-interference by RF requirements.Proposal 13: ICS requirement is needed if reader support multi-RAT or device support FDM operation. Proposal 14: ACS requirement is based on co-existence evaluation for single RAT scenario, i.e. existing gNB and reader doesn’t share same hardware scenario.Observation 6: IMD product of multi-tone CW is much hard to be suppressed and filter solution may not work considering there is frequency overlapping between IMD products and wanted data. Proposal 15: RAN4 should wait for RAN1 CW signal design conclusion and then decide whether/how to consider the IMD product of multiple-tone CW when defining Rx requirements for reader.Proposal 16: blocking related requirements of A-IoT BS is based on co-existence evaluation. It’s noted we should consider FDM operation between devices if RAN1 has approved such operation.Proposal 17: for CW outside of topology, it seems only max output power and spurious emission requirement is applicable. For out of band emission, if we assume almost perfect performance since single tone is assumed, there is no need for such requirements.  |
| **[R4-2412065](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412065.zip)** | vivo | Discussion on the RF requirement of AIoT BSProposal 1: The definition of power boosting should be clarified first if AIoT BS does not share hardware with legacy NR.Proposal 2: For the case that AIoT BS and legacy NR share same hardware, the power boosting related work in RAN4 can be started after the co-existence evaluation and RAN1 coverage study. Observation 1: The RF requirement of AIoT BS will be impacted by different spectrum usage.Proposal 3：It is suggested to discuss whether different sets of requirements need to be defined for AIoT BS based on different spectrum usage.  |
| [**R4-2412698**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412698.zip) | ZTE Corporation, Sanechips | Discussion on RF requirement of Ambient IoT BSProposal 1: for D1T1 deployment scenario, at least the transmitter RF requirement for R2D transmission should be specified and FFS for RF requirement of CW signal transmission since the CW signal waveform might be out of 3GPP scope.Proposal 2: for D1T1 deployment scenario, detection performance for backscattering signal e.g. OOK signal should be specified and the capability of rejecting CW signals from its own transmitter or other aggressor BS’s transmitter should be considered as well. Proposal 3: further discuss the applicability of the existing RF requirement for in-band /guard band A-IoT BS with the shared RF hardware (e.g. option 2-1 in D1T1 deployment scenario) and potential new RF requirements for A-IoT BS e.g. power boosting Proposal 4: please check the initial analysis for RF requirement of A-IoT BS in D1T1 in table 1.  |
| [**R4-2412968**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412968.zip) | Ericsson | A-IoT BS RF overviewProposal-1:The existing NR and LTE BS specifications should be starting point.Proposal-2: OFDM based transmitter should be baseline for R2D.Proposal-3: RAN4 wait RAN1 further progress on the D2R waveform.Observation 1 The legacy local BS definition could be applied when CWT is outside topologyProposal-4: Further study on the CW signal and concurrent A-IoT signal receiving impact on receiver RF requirement for outside topology.Proposal-5: Further study needed for the CW inside topology impact on the BS RF.Proposal-6:Wait the coexisting study for the ACLR and ACS impact on BS RF.Proposal-7:Wait RAN1 progress on CW suppression discussion for inside topology. |
| [**R4-2413282**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2413282.zip) | Huawei, HiSilicon | RF requirements for Ambient IoT BSProposal 1: RAN4 to study the necessity of channel raster for Ambient RF requirement. If needed, it is proposed to reuse the enhanced channel raster (i.e. 10 kHz)Proposal 2: It is proposed to define BS type 1-C for Ambient-IoT indoor scenarios.Proposal 3: The existing rated output power limits for NR Medium range BS is applicable to Ambient IOT BS for D1T1 deployment scenarios.Proposal 4: it is proposed to define RF envelope mask as the transmit signal quality requirement.Proposal 5: no need to define transmitter intermodulation for A-IOT BSProposal 6: IoT due the residual CW interference should be considered when define RX reference sensitivityProposal 7: existing out-of-band blocking requirement is applicablea summary for TX part is captured in below Table |

## Open issues summary

### Issue 2-1: start point

**Agreement in RAN4#110bis:**

**Issue 2-1-1: deployment scenarios for D1T1 (from R4-2410567)**

Option 1-1: Legacy NR gNB are outdoor macro gNB while AIoT reader/CW/devices are all indoors. Legacy NR UE is only allowed outdoors.

Option 1-2: Legacy NR gNB are outdoor macro gNB while AIoT reader/CW/devices are all indoors. Legacy NR UE is indoor accessing to outdoor NR marco gNB

Option 2-1: Legacy NR gNB are co-located with AIoT reader and CW. All of NR and AIoT BS/UE/Reader/Device/CW are indoors. AIoT reader /CW and Legacy gNB share same hardware

Option 2-2: Legacy NR gNB are co-located with AIoT reader and CW. All of NR and AIoT BS/UE/Reader/Device/CW are indoors. AIoT reader /CW and Legacy NR gNB do not share same hardware. (less limitation on the power boosting)

**Agreement:**

* RAN4 to first evaluate co-existence for deployment scenario of option 1-1 and 1-2, and further study option 2-1 and 2-2.

Agreement in RAN4#111:

Agreement:

* The existing NR BS RF requirement framework can be used as starting point for A-IoT BS.
	+ FFS on the detailed requirements.
* Proposals:
	+ Proposal 1: The existing NR and LTE BS specifications should be starting point. (R4-2412968, Ericsson）
	+ Proposal 2: It is suggested to discuss whether different sets of requirements need to be defined for AIoT BS based on different spectrum usage. (R4-2412065, vivo)
	+ Proposal 3: Further discuss the applicability of the existing RF requirement for in-band /guard band A-IoT BS with the shared RF hardware (e.g. option 2-1 in D1T1 deployment scenario) and potential new RF requirements for A-IoT BS e.g. power boosting. (R4-2412698, ZTE)
* Recommended WF
	+ Priority impact on non-co-located scenarios (option 1-1 and 1-2), and FFS for potential new RF requirements for option 2-1.

### Issue 2-2: A-IoT BS class and BS type

* Proposals:
	+ Proposal 1: Use micro cell type/MR BS as baseline but further discuss whether reader could support other BS class besides MR. (R4-2411769, CMCC)
	+ Proposal 2: 1/C and 1/H
		- Option 1: focus on 1-C reader BS type at first and further discuss the necessity of 1-H reader BS type. (R4-2411769, CMCC)
		- Option 2: define BS type 1-C for Ambient-IoT indoor scenarios. （R4-2413282, Huawei）
* Recommended WF
	+ BS class: Use Micro-BS as baseline in SI stage (reference to SID RP-240826).
	+ BS type: Priority A-IoT BS type 1-C, FFS for 1-H.

### Issue 2-4: TX

Agreement in RAN4#111:

Agreement:

* Use the following table as starting point for RF requirements impact study. The table is for information.

|  |
| --- |
| **RF Requirement for A-IoT BS- TX part** |
| TX requirement  | Transmit output power | Maximum output power |  |
| Output power dynamic |  |
| Transmit ON/OFF power |  |
| Transmission times |  |
| Transmit signal quality | Frequency error |  |
| EVM |  |
| TAE |  |
| Unwanted emissions | Occupied bandwidth |  |
| SEM |  |
| ACLR |  |
| Operating band unwanted emissions |  |
| Transmitter spurious emissions |  |
| Transmitter intermodulation |  |

* Proposals:
	+ Proposal 1: OFDM based transmitter should be baseline for R2D. (R4-2412968, Ericsson)
* Recommended WF
	+ The following table can be discussed for AIoT device RX RF requirement

|  |
| --- |
| **RF Requirement for A-IoT BS- TX part** |
| TX requirement  | Base station output power | Option 1: MR A-IoT BS reuse current transmit output power and max output power of 1-C MR BS. (R4-2411769, CMCC; R4-2413282, Huawei)Option 2: To follow the FR1 MR and LA BS output power limitation and power accuracy requirement; (R4-2412698, ZTE) |
| Output power dynamic | RE power control dynamic range | Option 1: NA. The power boosting for BS support both Ambient IOT and NR can be discussed in future release. (R4-2413282, Huawei）Option 2: define power boosting for OOK signal might be needed for in-band/guard band operation for hardware share; (R4-2412698, ZTE; R4-2412065, vivo; R4-2411769, CMCC) |
| Total power dynamic range | need to be updated accordingly based on conclusion of channel bandwidth and SCS. (R4-2411769, CMCC) |
| Transmit ON/OFF power | Option1: some transition period might be needed for the switch between R2D signal transmission and CW transmission in D1T1-A1 and D1T1-A2. (R4-2412698, ZTE)Option 2: It is a TDD requirements and not applicable to Ambient IOT BS. (R4-2413282, Huawei） |
| Transmitter transient period | Requirement necessary（R4-2411085, CATT）define transient period related requirements for A-IoT reader. Details value can refer to RFID rise/fall time. (R4-2411769, CMCC)RAN4 further discuss whether settling time as defined in RFID spec is needed or not to evaluate RF envelop ripple characteristics. (R4-2411769, CMCC) |
| Transmission times | Not applicable. (R4-2413282, Huawei） |
| Transmit signal quality | define RF envelope mask as the transmit signal quality requirement. (R4-2413282, Huawei） |
| Transmit signal quality | Frequency error | Requirement necessary（R4-2411085, CATT）Reused from NR BS (R4-2413282, Huawei; R4-2412698, ZTE, R4-2411769, CMCC） |
| EVM | Option 1: Requirement necessary（R4-2411085, CATT）Option 2: refer to RFID RF envelop related parameters to define signal transmission quality requirement, such as:1. modulation depth, RF envelop ripple, RF plusewidth. (R4-2411769, CMCC)
2. RF envelope mask (R4-2413282, Huawei）
3. power stability or power accuracy for OOK ON signal and OOK OFF signal, power difference between OOK ON and OOK OFF (R4-2412698, ZTE)
 |
| TAE | Not needed for R2D signal transmission or CW signal transmission. （R4-2411085,CATT; R4-2412698, ZTE, R4-2413282, Huawei; R4-2411085, CATT） |
| Unwanted emissions | Occupied bandwidth | Requirement necessary（R4-2411085, CATT）The legacy OBW requirement could be reused for A-IoT BS (R4-2412698, ZTE) |
| ACLR | Depends on co-existence study (R4-2412698, ZTE; R4-2413282, Huawei ; R4-2412968, Ericsson; R4-2411085, CATT) |
| IBE | if finally approve that A-IoT reader support multiple-RAT, IBE equivalent requirement needs to be defined. (R4-2411769, CMCC) |
| Operating band unwanted emissions | depends on coexistence study (R4-2412698, ZTE; R4-2411769, CMCC; R4-2411085, CATT; R4-2413282, Huawei) |
| Transmitter spurious emissions | Requirement necessary（R4-2411085, CATT）Existing spurious emission requirement is applicable (R4-2413282, Huawei; R4-2412698, ZTE; R4-2411769, CMCC） |
| Transmitter intermodulation | For 900M: not needed (R4-2413282, Huawei; R4-2412698, ZTE）For 2GHz: FFS (R4-2412698, ZTE) |

### Issue 2-5: RX

Agreement in RAN4#111:

Agreement:

* Use the following table as starting point for RF requirements impact study. The table is for information.

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| --- |
| **RF Requirement for A-IoT BS- RX part** |
| RX requirement | Reference sensitivity  |  |
| Dynamic range  |  |
| In-channel selectivity |  |
| Adjacent Channel Selectivity |  |
| In-band blocking |  |
| Out-of-band blocking |  |
| Receiver intermodulation |  |
| Narrowband intermodulation |  |
| Rx spurious emission |  |
| Receiver intermodulation |  |

* Proposals:
	+ RAN4 wait RAN1 further progress on the D2R waveform. (R4-2412968, Ericsson)
* Recommended WF
	+ The following table can be discussed for A-IoT BS RX RF requirement

Table 1. The initial analysis for RF requirement of A-IoT BS in D1T1.

|  |  |
| --- | --- |
|  | **RF Requirement for A-IoT BS- RX part** |
| TX requirement | Reference sensitivity level | The REFSENS requirement might be not based on the throughput metric and it should be dependent on the miss detection ratio and false alarm detection ratio instead if without any HARQ-ACK feedback. In addition, the impacts on CW signal transmission should be also taken into account especially for D1T1-A2. (R4-2412698, ZTE)IoT due the residual CW interference should be considered when define RX reference sensitivity (R4-2413282, Huawei） |
| Dynamic range  | Similar analysis for REFSENS requirement. IoT level could be further discussed in the WI phase. (R4-2412698, ZTE)Requirement necessary（R4-2411085, CATT）FFS (R4-2413282, Huawei） |
| In-channel selectivity | FFS whether requirement necessary（R4-2411085, CATT）ICS requirement is needed if reader support multi-RAT or device support FDM operation. (R4-2411769, CMCC)We don’t see the necessity to have this requirement for standalone A-IoT BS or in-band/guard band operation with the individual RF hardware similar as standalone NB-IoT ICS requirement. (R4-2412698, ZTE)NA (R4-2413282, Huawei） |
| Adjacent Channel Selectivity | depends on coexistence study. (R4-2412698, ZTE; R4-2413282, Huawei; R4-2412968, Ericsson; R4-2411769, CMCC; R4-2411085, CATT) |
| Blocking requirement | This depends on co-existence study. (R4-2412698, ZTE)blocking related requirements of A-IoT BS is based on co-existence evaluation. It’s noted we should consider FDM operation between devices if RAN1 has approved such operation. (R4-2411769, CMCC) |
| In-band blocking | FFS whether requirement necessary（R4-2411085, CATT）（The scenario needs more discussion. ）need more study after ACS is defined (R4-2413282, Huawei） |
| Narrow-band blocking | Requirement not necessary （R4-2411085, CATT） |
| Out-of-band blocking | FFS whether requirement necessary（R4-2411085, CATT）（The scenario needs more discussion. ）Reuse the -15dBm CW signal as interference signal of OOBB requirement. For f\_OOBB requirement, this could be further discussed once we have more clear assumption on A-IoT BS. (R4-2412698, ZTE)Existing out-of-band blocking requirement is applicable (R4-2413282, Huawei） |
| Receiver intermodulation | This is somehow similar as Tx intermodulation requirement. (R4-2412698, ZTE)FFS whether requirement necessary（R4-2411085, CATT）（The scenario needs more discussion. ） |
| Narrowband intermodulation | FFS whether requirement necessary（R4-2411085, CATT; R4-2413282, Huawei）（The scenario needs more discussion. ） |
| Rx spurious emission | The legacy receiver spurious emission requirement could be applicable. (R4-2412698, ZTE; R4-2413282, Huawei)Requirement necessary（R4-2411085, CATT） |
| Receiver intermodulation | RAN4 should wait for RAN1 CW signal design conclusion and then decide whether/how to consider the IMD product of multiple-tone CW when defining Rx requirements for reader. (R4-2411769, CMCC)FFS (R4-2413282, Huawei） |

### Issue 2-6: CW for D1T1

Agreement in RAN4#111:

Agreement:

* To further investigate output power, emission requirements for CW node
	+ FFS for other requirements.
* Proposals:
	+ Proposal 1: for CW outside of topology, it seems only max output power and spurious emission requirement is applicable. For out of band emission, if we assume almost perfect performance since single tone is assumed, there is no need for such requirements. (R4-2411769, CMCC)
	+ Proposal 2: for D1T1 deployment scenario, FFS for RF requirement of CW signal transmission since the CW signal waveform might be out of 3GPP scope. (R4-2412698, ZTE)
	+ Proposal 3: for D1T1 deployment scenario, detection performance for backscattering signal e.g. OOK signal should be specified and the capability of rejecting CW signals from its own transmitter or other aggressor BS’s transmitter should be considered as well. (R4-2412698, ZTE)
	+ Proposal 3: Further study on the CW signal and concurrent A-IoT signal receiving impact on receiver RF requirement for outside topology. (R4-2412968, Ericsson)
	+ Proposal 4: Further study needed for the CW inside topology impact on the BS RF. (R4-2412968, Ericsson)
* Recommended WF
	+ TBA
	+ The following table can be discussed

(from R4-2411769, CMCC if not noted)

|  |  |
| --- | --- |
| requirement | Applicable or not |
| Operation bands | Single FDD DL or UL bands |
| Channel bandwidth related requirements | NA |
| Channel arrangement related | NA |
| Output power | Applicable. Further check the power limitFor CW uses the UL spectrum in 900 MHz band, 26 dBm used for NR UE and 33 dBm for GSM should be considered. (R4-2413282, Huawei）MPR/A-MPR not applicableConfigured output power, not applicable |
| Output power dynamic range | Minimum output power: NAON/OFF time mask: may not applicablePower control: NA |
| Transmit signal quality | Frequency error: NATransmit modulation quality: NAIf phase noise or emissions should be defined FFS. (R4-2411085, CATT) |
| RF spectrum emission | Occupied bandwidth: NAOut of band emission: not applicable if we assume CW nodes have almost perfect out of band emission?Spurious emission: current may still applicable to meet regulatory requirementTransmit inter-modulation: applies at least for inside topology case |

# Topic #3: AIoT device

## Companies’ contributions summary

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| **T-doc number** | **Company** | **Proposals / Observations** |
| [**R4-2411072**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411072.zip) | CATT | Discussion on AIoT device RF requirementProposal 1: Separate the RF requirements discussions for passive and active devices.Proposal 2: The same set of RF requirements, maybe with different specific levels, can be considered for Device 1 and Device 2a.Proposal 3: Only define OTA requirements for Device 1 and Device 2a.Proposal 4: The number of requirements for Device 1 and Device 2a should be as small as possible to limit the costs.Proposal 5: The following requirements are to be defined for Device 1 and Device 2a.Radiated powerReference sensitivity (the name can be discussed further)Unwanted emissionsProposal 6: No ACS and blocking requirements for device 1 and device 2a.Observation: Discussion for device 2b RF requirements is too premature at current stage.Proposal 7: For Device 2b RF requirement discussion, the deployment assumption and system requirement should be decided first. Then the baseline RF architecture should be decided. |
| [**R4-2411537**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411537.zip) | Sony | Further considerations on the ambient IoT device implementation and RF aspectObservation 1: From the RF perspective, the reception part of the R2D link in AIoT devices can be leveraged from the ED-based LP-WUS receiver. Observation 2: The RF-ED envelope detector lacks frequency selectivity. Observation 3: If multiple bands or different RB allocations need to be supported in the R2D link, using RF BPF in AIoT devices may not be feasible due to the complexity and power consumption limits.Observation 4: even under single band operation, if the R2D link may happen both in the DL and UL spectrum due to the reader can be either BS or intermediate UE, it will also be hard to implement any RF BPFs.Observation 5: the performance of the R2D link may still be acceptable without any RF BPF, considering LP filter in the BB, the potential guard RB, and also the limited coverage target. Observation 6: For the D2R link, the AIoT device 2b might be similar to the UL of legacy IoT devices but with lower transmission power and reduced availability due to the energy harvesting and power consumption constraint. Observation 7: For device types 1 and 2a, its transmission performance depends not only on the design of AIoT devices but is also highly impacted by the design of the CW and the corresponding transmission node.Observation 8: The maximum out power of device type 1 could be in the range of -20 to -10 dBm, while about -10 dBm to 0 dBm for device 2a. Observation 9: A small frequency shift (a few MHz) can be used to separate the backscattering signal from the CW signal to improve the SINR on the reader, while a larger frequency shift (tens or hundreds MHz) can be used to separate the CW and the backscattering signals on different bands or the same FDD band but different UL/DL spectrum. Observation 10: The frequency translation range of the backscattering signal needs to be studied under the power consumption limitation.Proposal 1: Assuming no RF BPF filter for at least device type 1 when discussing the RF performance of AIoT devices type 1, FFS on device type 2b and 2a. Proposal 2: Considering the 3rd order Butterworth filter as a starting point for the BB LPF.Proposal 3: Considering 1-bit ADC for device type 1 and 4-bit ADC for devices 2a and 2b. Proposal 4: the maximum output power of device type 2b can be specified similarly to legacy UEs, and a new power class with a significantly lower power level than existing ones may need to be specified accordingly. Proposal 5: The maximum output power and power class of device types 1 and 2a can be defined based on the reflection gain of the device and the maximum input power level it can tolerate from the CW. Proposal 6: RAN4 shall further study the maximum input power level of CW of device types 1 and 2a and the maximum gain if the reflection amplifier applies. Proposal 7: the output power dynamic requirements should also be specified for device type 2b. Proposal 8: There might be no need to define power control requirements and the ON/OFF time masks for AIoT devices type 1 and type 2a.Proposal 9: Re-use the -50 dBm transmit off power and -40 dBm Minimum output power for all device types Proposal 10: The transmit-off power of the backscattering devices should be defined as the emission level when no CW is illuminated on the devices. FFS on what the CW power level should be for minimum output power for devices type 1 and type 2a.Proposal 11: Transmit signal quality requirements and output RF spectrum emission requirements shall be specified for all AIoT device types.Proposal 12: RAN4 shall study the feasibility and necessity of frequency shift function for device type 2a and investigate its impact on frequency accuracy. Proposal 13: the OTA test should be taken as the baseline for at least ambient IoT devices 1 and 2a. Proposal 14: RAN4 shall study how CW signal and energy source should be provided in the test system |
| [**R4-2411768**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411768.zip) | CMCC | Discussion on A-IoT device RF requirementsProposal 7: as starting point, it’s suggested to discuss RF requirements separately for three device types. Proposal 8: for device 1, taking RFID RF requirements as reference which only define output power and unwanted emission requirements. Besides, REFSENSE requirement is also needed.Proposal 9: at least for transmit signal quality related requirement, RAN4 should wait for RAN1 conclusion of how to achieve small frequency shift in baseband and/or FDM(A) among devices.Proposal 10: if RAN4 only simulate in-band spectrum mode, RAN4 further discuss whether/how to define out of band emission requirement. Proposal 11: REFSENSE and max input level needs to be separately defined for different devices types. Proposal 12: RAN4 needs to further discuss the out of band blocking performance based on RF architecture discussion.Proposal 13: For device 2b, it’s suggested to use UE RF framework as baseline and further discuss whether certain relaxation is needed or not. |
| [**R4-2411867**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411867.zip) | Spreadtrum Communications | Discussion on RF requirements impact for ambient IoT deviceProposal 1: Some initial views about TX RF requirements for A-IoT devices in Table1.Proposal 2: With the ultra-low complexity and cost, the test cost of Device1 should be reduced as much as possible.Proposal 3: Some initial views about RX RF requirements for A-IoT devices in Table2.Proposal 4: Conducted conformance test is feasible for all A-IoT devices, but testing cost needs to be considered.Proposal 5: How to simplify existing OTA test method needs to be further studied. |
| [**R4-2412066**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412066.zip) | vivo | Discussion on the RF requirement of AIoT deviceObservation 1: It is important to identify which requirements are indeed necessary for device, which can help reduce the cost of device.Observation 2: For device 1 from Tx requirement perspective:The device does not support power control, so power control related requirement is not needed, e.g., power control accuracy, minimum output powerThere is no LO in Tx chain, so LO related requirement is not needed, e.g., carrier leakageWhen the device is in OFF state, it will still reflect the incoming signal since the impedance is unmatched, so the transmit OFF power seems meaningless for such deviceThe Tx intermodulation product is mainly produced by PA. Since there is no PA for device 1, such requirement seems also not needed. Observation 2: For device 1 from Rx requirement perspective:In the co-existence study, the receiver bandwidth of device 1 is assumed the same as system channel bandwidth, which means ACS/ASCS is not available.The RF envelope detection is used and there is no LNA and mixer are assumed, so the Rx intermodulation should not be important for such receiver. Proposal 1: The following requirements are considered removed for device 1:Transmit OFF power; Minimum output power; Power control requirement; Carrier leakage; Tx intermodulation; ACS; ASCS; Receiver intermodulationProposal 2: The following requirements are considered removed for device 2a:Transmit OFF power; Minimum output power; Power control requirement; ACS; ASCSProposal 3: For device 2b, the RF requirement for NB-IoT can be considered as starting point.Observation 3: The traditional EVM define the modulation quality for QAM signal in frequency domain, but the OOK waveform need a metric in time domain.Proposal 4: It is suggested to discuss how to define the modulation quality for OOK waveform in time domain in SI, e.g., the power ratio between ON symbol and OFF symbol. |
| [**R4-2412699**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412699.zip) | ZTE Corporation, Sanechips | Discussion on RF requirement of Ambient IoT deviceProposal 1: specify different sets of RF requirement for Ambient IoT Device 1, Device 2a and Device 2b; Proposal 2: specify the RF requirement (e.g. Tx and Rx, ACS, ASCS etc requirements) for A-IoT device;Proposal 3: treat the reception of CW signals as part of Rx requirements for Ambient IoT Device 1, Device 2a.Proposal 4: please find the initial analysis for RF requirement of Ambient IoT device in Table 1. |
| [**R4-2412972**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412972.zip) | Ericsson | AIoT UE RF overviewObservation 1 As the RF ED architecture does not provide in-band selectivity.Observation 2 There should not be a RF BPF if the same A-IoT device should talk to BS and UE as intermediate node.Observation 3 The system parameter of channel bandwidth needs to be discussed.Proposal-1: Clarify whether the same A-IoT UE can communicate to either A-IoT BS or UE as intermediate node.Proposal-2: The UL backscatter signal power level in relation to the received power are aspects specific to the A-IoT and needs further discussion in future meetings.Proposal-3: EH sensitivity can be studied in study phase.Proposal-4: OTA RF requirement should be discussed for A-IoT UE equipped with an antenna. |
| [**R4-2413030**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2413030.zip) | Huawei, HiSilicon | On the RF requirements for Ambient IoT DeviceObservation 1: It is challenging for devices to achieve consistent RF performances across the whole frequency range of an operating band due to the simplistic-transceiver design target. As a result, frequency-dependent relaxation in performance requirements is expected for a A-IoT device to support a given operating band.Observation 2: The definition of channel bandwidths based on multiple PRBs or sub-carriers should be considered for A-IoT devices.Observation 3: The minimum input SNR for a RF envelope detector is required to be around 7.5dB, given that the RF BW=10MHz and target SNR=15dB.Observation 4: For the Rx sensitivity for device 2a/2b, the effect of 1/f noise of the BB amplifier needs to be further considered.Observation 5: To meet the 10mv threshold voltage of the comparator, the input power to the RF envelope detector (implemented by 10-stage rectifiers) is at least -36dBm.Proposal 1: For device receivers based on RF envelop detector and comparator, the effects of both target SNR and the threshold voltage should be considered when determining the Rx sensitivity.Proposal 2: For A-IoT device Rx RF requirements, consider to define maximum input level, interference rejection (to wideband interferer) in addition to Rx sensitivity. |
| [**R4-2413321**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2413321.zip) | Qualcomm Incorporated | Energy harvesting considerationsProposal 1: RAN4 shall study device energy harvesting capabilityProposal 2: RAN4 shall study how device energy harvesting capability can be included in the requirementsProposal 3: RAN4 should study how the availability of energy harvesting signal impacts device behavior |
| [**R4-2413455**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2413455.zip) | LG Electronics UK | Discussion on Ambient IoT Device RF requirement impactObservation 1: The transmit output power of device1 is dependent on the ambient-IoT reader power.Proposal 1: For device1, It is necessary to clarify insertion loss of each block.Proposal 2: For device1, there is no need to define Transmit OFF power and power control requirement.Proposal 3: For device2a, it is necessary to wait conclusion for device structure from RAN1Proposal 4: Adjacent channel leakage ratio (ACLR) will be defined based on the co-existence simulation results. And spurious emission should meet regulatory requirement. Proposal 5: For Rx requirement, The ACS and ASCS will be defined based on co-existence simulation. |

## Open issues summary

### Issue 3-1: General

* Proposals:
	+ Proposal 1: Specify different RF requirement for Ambient IoT Device 1, Device 2a and Device 2b; (R4-2411072, CATT ;R4-2412699, ZTE; R4-2411768, CMCC)
	+ Proposal 2: Device 1/2a
		- for device 1, taking RFID RF requirements as reference which only define output power and unwanted emission requirements. Besides, REFSENSE requirement is also needed. (R4-2411768, CMCC)
		- The number of requirements for Device 1 and Device 2a should be as small as possible to limit the costs. (R4-2411072, CATT)
		- The same set of RF requirements, maybe with different specific levels, can be considered for Device 1 and Device 2a. (R4-2411072, CATT)
		- Only define OTA requirements for Device 1 and Device 2a. (R4-2411072, CATT)
	+ Proposal 3: Device 2b:
		- For Device 2b RF requirement discussion, the deployment assumption and system requirement should be decided first. Then the baseline RF architecture should be decided. (R4-2411072, CATT)
		- For device 2b, it’s suggested to use UE RF framework as baseline and further discuss whether certain relaxation is needed or not. (R4-2411768, CMCC)
		- For device 2b, the RF requirement for NB-IoT can be considered as starting point. （R4-2412066, Vivo）
	+ Proposal 4:Clarify whether the same A-IoT UE (Moderator : refer to device here?) can communicate to either A-IoT BS or UE as intermediate node.（Ericsson, R4-2412972）
* Recommended WF
	+ TBA

### Issue 3-2: RF impairments

* Proposals:
	+ Proposal 1: The UL backscatter signal power level in relation to the received power are aspects specific to the A-IoT and needs further discussion in future meetings. （Ericsson, R4-2412972）
	+ Proposal 2: RAN4 shall further study the maximum input power level of CW of device types 1 and 2a and the maximum gain if the reflection amplifier applies. (R4-2411537, Sony)
	+ Proposal 3: at least for transmit signal quality related requirement, RAN4 should wait for RAN1 conclusion of How to achieve small frequency shift in baseband and/or FDM(A) among devices. (R4-2411768, CMCC)
	+ Proposal 4: Assuming no RF BPF filter for at least device type 1 when discussing the RF performance of AIoT devices type 1, FFS on device type 2b and 2a. (R4-2411537, Sony)
	+ Proposal 5: Considering the 3rd order Butterworth filter as a starting point for the BB LPF. (R4-2411537, Sony)
	+ Proposal 6: Considering 1-bit ADC for device type 1 and 4-bit ADC for devices 2a and 2b. (R4-2411537, Sony)
	+ Proposal 7: For device1, it is necessary to clarify insertion loss of each block. (R4- 2413455, LGE)
* Recommended WF
	+ TBA

### Issue 3-3: TX(D2R)

Agreement in RAN4#111:

Agreement:

* Use the following table as starting point for RF requirements impact study. The table is for information.
	+ Encourage companies to provide views on RF requirements impact for different device types.

|  |
| --- |
| **RF Requirement for A-IoT device- TX part** |
| Tx requirement  | Transmit output power | Maximum output power |  |
| Output power dynamic | Transmit OFF power |  |
| Transmit time mask |  |
| Minimum output power |  |
| Power control requirement |  |
| Transmit ON/OFF power | Transmit OFF power |  |
| ON/OFF time mask |  |
| Transmit signal quality | Frequency error |  |
| EVM |  |
| In band emissions  |  |
| Carrier leakage |  |
| Output RF spectrum emissions | Occupied bandwidth |  |
| SEM |  |
| ACLR |  |
| Spurious emissions |  |
| Transmit intermodulation |  |

* Proposals:

 Proposal 1: if RAN4 only simulate in-band spectrum mode, RAN4 further discuss whether/how to define out of band emission requirement. (R4-2411768, CMCC)

* Recommended WF
	+ The following table can be discussed for AIoT device TX RF requirement:

|  |
| --- |
| **RF Requirement for A-IoT device- TX part** |
| TX requirement  | Transmit output power | Maximum output power | defined Radiated power for Device 1 and Device 2a (R4-2411072, CATT)For device type 2b, a similar approach as legacy UEs can be used to define its maximum output power. **Device 1:**Not for device 1（R4-2412066, Vivo）Device 1: consider -20 to -10 dBm as a starting point (R4-2411537, Sony)For device 1: transmit output power up to CW, need to meet the coverage target of 10 meters and regulatory requirement (R4-2411867, Spreadtrum; R4-2412699, ZTE)**Device 2a:**Device 2a: All three kinds of device have different output power level. RAN4 further discuss how to define power class based on different device type and architecture. (R4-2411768, CMCC)Device 2a: consider -10 to 0 dBm as a starting point (R4-2411537, Sony)For device 2a: transmit output power up to CW, need to meet the coverage target of 10 meters and regulatory requirement (R4-2411867, Spreadtrum; R4-2412699, ZTE)**Device 2b:**Device 2b: need to define max output power, PC3 as a starting point (R4-2411867, Spreadtrum) Device 2b: maximum output power should be specified agnostic with the input CW power. (R4-2412699, ZTE)Device 2b: A bit lower power level as device 2a (-10 dBm to -5 dBm dBm) might be a starting point (R4-2411537, Sony) |
| Output power dynamic |  | Device 2a: NA (R4-2411768, CMCC)Device 2b: need to be specified. (R4-2411537, Sony) |
| Output power dynamic | Transmit OFF power | For all device types, consider the same level as NR and LTE, e.g., -50 dBm.For the backscattering type of the device, this power level can be defined as the emission level from the device when there is no incoming CW signal. (R4-2411537, Sony)**Device 1:**Not for device 1（R4-2412066, Vivo; R4-2411867, Spreadtrum; R4- 2413455, LGE）**Device 2a:**Not for device 2a（R4-2412066, Vivo）For device 2a: Need to define (R4-2411867, Spreadtrum)**Device 2b:**For device 2b: Need to define (R4-2411867, Spreadtrum) |
| Transmit time mask | It may not be necessary for backscattering types of AIoT device (1 and 2a), but it is only specified for the CW node.Needs to be specified for device 2b. (R4-2411537, Sony)Repeated with transmit ON/OFF time mask (R4-2411867, Spreadtrum) |
| Minimum output power | Consider the same level as NR and LTE for all AIoT device types, e.g., -40 dBm. Further study should be conducted on the corresponding CW power level in this case. (R4-2411537, Sony)This requirement might be still needed. e.g. with -45dBm as lowest input power and 9/12/15dBi backscattering gain for Device 1 and 2a. (R4-2412699, ZTE)**Device 1:**For device 1: Need to define, to ensure that signal is not submerged by noise (R4-2411867, Spreadtrum)**Device 2a:**Not for device 2a（R4-2412066, Vivo）For device 2a: need to define minimum output power (R4-2411867, Spreadtrum)**Device 2b:**For device 2b: need to define minimum output power (R4-2411867, Spreadtrum) |
| Power control requirement | **Device 1:**not necessary for device 1 (R4-2411537, Sony; R4-2412699, ZTE; R4-2412066, Vivo; R4-2411867, Spreadtrum)**Device 2a:**NA for device 2a (R4-2411768, CMCC; R4-2412066, Vivo; R4-2411867, Spreadtrum)**Device 2b:**Needs to be specified for device 2b. (R4-2411537, Sony; R4-2412699, ZTE)Need to define, legacy UE requirements as a starting point (R4-2411867, Spreadtrum) |
| Transmit ON/OFF power | ON/OFF time mask | **Device 1:**not necessary for device 1 (R4-2407523, CATT; R4-2411867, Spreadtrum)**Device 2a:**not necessary for device 2a (R4-2411867, Spreadtrum)**Device 2b:**Need to define for device 2b (R4-2411867, Spreadtrum) |
| Transmit signal quality | Frequency error | This could be further discussed based on the some practical measurement results for it. (R4-2412699, ZTE)**Device 1:**For device 1: No need to consider carrier frequency error. Need to consider sample frequency error. (R4-2411867, Spreadtrum)**Device 2a:**For device 2a: No need to consider carrier frequency error. Need to consider sample frequency error. (R4-2411867, Spreadtrum)The frequency shift function of device 2a needs to be studied, as it may affect the frequency accuracy of the performance. (R4-2411537, Sony) Device 2a: wait for modulation scheme conclusion (R4-2411768, CMCC)**Device 2b:**For device 2b: Need to define, consider CFO (R4-2411867, Spreadtrum)The frequency shift function of device 2a needs to be studied, as it may affect the frequency accuracy of the performance. (R4-2411537, Sony) |
| EVM | Device 2a: wait for modulation scheme conclusion (R4-2411768, CMCC)EVM for backscattering OOK signal is not needed since OOK signal is not mapped by the legacy constellation, instead it’s reflected in the envelope level as following. The power stability or power accuracy for OOK ON signal and OOK OFF signal is important and also power difference between OOK ON and OOK OFF is essential to ensure the tag OOK detection performance. (R4-2412699, ZTE)Need to define (R4-2411867, Spreadtrum)It is suggested to discuss how to define the modulation quality for OOK waveform in time domain in SI, e.g., the power ratio between ON symbol and OFF symbol. （R4-2412066, Vivo） |
| In band emissions (IBE) | Needed (R4-2411768, CMCC)**For device 1**: No need to consider image suppression, just need to consider general requirement (R4-2411867, Spreadtrum)**For device 2a**: If device2a support large shift, image suppression need to consider; general requirement need to consider (R4-2411867, Spreadtrum)**For device 2b**: The legacy UE requirement as a starting point (R4-2411867, Spreadtrum) |
| Carrier leakage | **Device 1:** no need to define（R4-2412066, Vivo; R4-2411867, Spreadtrum）**Device 2a:** may be needed based on the design of small frequency shift in baseband (R4-2411768, CMCC)no need to define (R4-2411867, Spreadtrum)**Device 2b:** the legacy carrier leakage requirement as a starting point (R4-2411867, Spreadtrum) |
| Output RF spectrum emissions | Occupied bandwidth | depends on chip rate (R4-2411867, Spreadtrum) |
| SEM | This depends on the outcome of coexistence study and regulatory requirement as part of input. (R4-2412699, ZTE; R4-2411867, Spreadtrum) |
| ACLR | depends on co-existence study (R4-2411867, Spreadtrum; R4- 2413455, LGE; R4-2411537, Sony) |
| Spurious emissions | The legacy transmitter spurious emission requirement could be used as starting point. (R4-2412699, ZTE)depends on co-existence study and related regulatory requirements (R4-2411867, Spreadtrum; R4- 2413455, LGE) |
| Unwanted emissions | Define Unwanted emissions for Device 1 and Device 2a (R4-2411072, CATT)For device 1, taking RFID RF requirements as reference which only define output power and unwanted emission requirements. Besides, REFSENSE requirement is also needed. (R4-2411768, CMCC) |
| Transmit intermodulation | at 900MHz is not needed. FFS for other frequency e.g. 2GHz. (R4-2409598, ZTE) (R4-2412699, ZTE)**Device 1:**Not for device 1（R4-2412066, Vivo）Need to consider CW with two tone intermodulation (R4-2411867, Spreadtrum)**Device 2a:** For device 2a: Need to consider CW with two tone intermodulation (R4-2411867, Spreadtrum)**Device 2b:** For device 2b: Need to consider intermodulation (R4-2411867, Spreadtrum) |

### Issue 3-4: RX(R2D)

Agreement in RAN4#111:

Agreement:

* Use the following table as starting point for RF requirements impact study. The table is for information.
	+ Encourage companies to provide views on RF requirements impact for different device types.

|  |
| --- |
| **RF Requirement for A-IoT device- RX part** |
| RX requirement | Reference sensitivity |  |
| Maximum input power |  |
| ACS |  |
| ASCS |  |
| In-band blocking |  |
| Out-of-band blocking |  |
| Receiver intermodulation |  |
| Rx spurious emission |  |

* Proposals:
	+ treat the reception of CW signals as part of Rx requirements for Ambient IoT Device 1, Device 2a. (R4-2412699, ZTE)
* Recommended WF
	+ The following table can be discussed for AIoT device RX RF requirement:

|  |  |
| --- | --- |
|  | **RF Requirement for AIoT device- RX part** |
| RX requirement | Reference sensitivity | Define Reference sensitivity for different AIoT device types (R4-2411072, CATT; R4-2411537, Sony; R4-2411768, CMCC)For device receivers based on RF envelop detector and comparator, the effects of both target SNR and the threshold voltage should be considered when determining the Rx sensitivity.（R4- 2413030, Huawei）The REFSENS requirement might be not based on the throughput metric and it should be dependent on the miss detection ratio and false alarm detection ratio instead if without any HARQ-ACK feedback. e.g. -45dBm. (R4-2412699, ZTE)For device 1: Refer to co-existence simulation parameters (e.g.,-36dBm) (R4-2411867, Spreadtrum)For device 2a /b: Refer to RAN1’s LLS result, the traditional sensitivity formula as a starting point (R4-2411867, Spreadtrum) |
| Maximum input power | different maximum input power levels can be specified for different types of devices. (R4-2411537, Sony; R4- 2413030, Huawei)At least the following two aspects need to be considered:1)Maximum input power for CW signal with measurement metric as backscattering output power which might be covered by Maximum output power/Output to input power gain within A-IoT carrier; 2)Maximum input power for R2D signal reception e.g. with OOK signal detection with measurement metric as miss detection ration and false alarm detection ratio; (R4-2412699, ZTE)For device 1/2a: Need to consider to meet the dynamic range of envelop detection (R4-2411867, Spreadtrum)For device 2a: Necessary and may needs to be separately defined for different devices types. (R4-2411768, CMCC)For device 2b: Legacy UE requirement as a starting point (R4-2411867, Spreadtrum) |
| ACS  | depends on co-existence study (R4-2411867, Spreadtrum; R4- 2413455, LGE; R4-2412699, ZTE;)No ACS and blocking requirements for device 1 and device 2a. (R4-2411072, CATT)different sizes of guard band/RB may be considered for different device types. (R4-2411537, Sony)Not for **device 1**（R4-2412066, Vivo）For **device 2a:** For standalone, FFS and details based on architecture. (R4-2411768, CMCC)Not for device 2a（R4-2412066, Vivo） |
| ACSC | depends on coexistence study. (R4-2412699, ZTE; R4-2411867, Spreadtrum; R4- 2413455, LGE)different sizes of guard band/RB may be considered for different device types. (R4-2411537, Sony)No ACS and blocking requirements for device 1 and device 2a. (R4-2411072, CATT)Not for **device 1**（R4-2412066, Vivo）Not for **device 2a**（R4-2412066, Vivo） |
| In-band blocking | Depends on coexistence study. (R4-2412699, ZTE; R4-2411867, Spreadtrum; R4-2411537, Sony)For device 2a: necessary (R4-2411768, CMCC) |
| Out-of-band blocking | reuse the -15dBm CW signal as interference signal of OOBB requirement (R4-2412699, ZTE)Depends on coexistence study. (R4-2411867, Spreadtrum; R4-2411537, Sony)For **device 2a**: Further discuss the out of band blocking performance based on RF architecture discussion (R4-2411768, CMCC) |
| Receiver intermodulation | The analysis is somehow similar as Tx intermodulation requirement. (R4-2412699, ZTE)Not necessary (R4-2407523, CATT)Not for device 1（R4-2412066, Vivo）Need to consider CW intermodulation (R4-2411867, Spreadtrum) |
| Rx spurious emission | The legacy receiver spurious emission requirement might be needed for R2D reception and backscattering signal transmission with CW signal as input at antenna connector. (R4-2412699, ZTE)For **device 2a**: to meet regulatory requirement (R4-2411768, CMCC)depends on co-existence study and related regulatory requirements (R4-2411867, Spreadtrum) |
| Spurious response | For **device 2a**: The same analysis as out of band blocking. ( Further discuss the out of band blocking performance based on RF architecture discussion (R4-2411768, CMCC))This might be needed for R2D reception only. For backscattering transmission requirement, receiver spurious response requirement is not relevant anymore. (R4-2412699, ZTE) |

### Issue 3-5: testability

Agreement in RAN4#111:

Agreement:

* FFS on whether conducted conformance test is feasible for AIOT devices.
* FFS on OTA test method, performance metric, etc.
* Proposals:
	+ Proposal 1: With the ultra-low complexity and cost, the test cost of Device1 should be reduced as much as possible. (R4-2411867, Spreadtrum)
	+ Proposal 2: Conducted conformance test is feasible for all A-IoT devices, but testing cost needs to be considered. (R4-2411867, Spreadtrum)
	+ Proposal 3: How to simplify existing OTA test method needs to be further studied. (R4-2411867, Spreadtrum)
	+ Proposal 4: OTA RF requirement should be discussed for A-IoT UE equipped with an antenna. （Ericsson, R4-2412972）
* Recommended WF
	+ Conducted conformance test is feasible, but testing cost needs to be considered

### Issue 3-6: Energy harvesting

【Background】

According to RAN plenary agreement below, the EH waveform design is out of SI scope, but EH can be discussed for potential impact of energy harvesting on device availability for transmission and reception procedures.

**Proposal 2 (endorsed)**

* Confirm that study of design of energy harvesting signal/waveform is out of SI scope in Rel-19
* The potential impact of energy harvesting on device availability for transmission and reception procedures can be considered for the study [RAN2, RAN1]
* Duration of one device’s unavailability due to charging by energy harvesting can be assumed up to several tens of seconds
	+ Note: this value can be revisited in future RAN plenary meetings, if necessary
	+ TR 38.848 clause 5.6 statement on latency remains the case with respect to a single device, i.e.: “*NOTE: The time for charging the Ambient IoT device storage (if present) is not included in the latency defined above. Time for energy harvesting, charging, etc. is regarded as an implementation issue only.*”
* No SID revision is necessary
* Proposals:
	+ Proposal 1: RAN4 shall study device energy harvesting capability (Qualcomm, R4-2413321)
	+ Proposal 2: RAN4 shall study how device energy harvesting capability can be included in the requirements (Qualcomm, R4-2413321)
	+ Proposal 3: RAN4 should study how the availability of energy harvesting signal impacts device behavior (Qualcomm, R4-2413321)
* Recommended WF
	+ According to SID and RAN1 agreement, can wait for RAN2 and RAN1 progress on energy harvesting

# Topic #4: Intermediate node （UE）

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| [**R4-2411085**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411085.zip) | CATT | A-IoT intermediate UE feasibility and requirementsObservation 1: If SBFD SI analysis approach is used, required CW cancellation capability is up to 142 dB for 23 dBm CW power level.Proposal 1: How CW impacts AIoT reader Rx BB DEMOD performance needs some evaluation or assumption for the feasibility study. |
| [**R4-2411769**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411769.zip) | CMCC | Discussion on A-IoT intermediate UE RF requirementsProposal 1: intermediate UE should following current UE RF requirements when it connect to controlling gNB.Proposal 2: it’s suggested to separately testing intermediate UE when it acts like UE and when it acts like reader even if certain RF requirements are the same.Proposal 3: for intermediate UE band specific RF requirement analysis, it’s suggested to only use n8(900MHz) as example band. Proposal 4: max supported power class per band of intermediate UE is only limited to PC3 as baseline.Proposal 5: no minimum output power nor power control requirement are needed for intermediate UE.Proposal 6: it’s suggested to define transient period related requirements for A-IoT reader. Details value can refer to RFID rise/fall time.Proposal 7: RAN4 further discuss whether settling time as defined in RFID spec is needed or not to evaluate RF envelop ripple characteristics.Observation 1: RFID spec use RF envelop related parameters to evaluate ASK signal transmission quality requirement, e.g. modulation depth, RF envelop ripple, RF plusewidth etc.Proposal 8: RAN4 could refer to RFID RF envelop related parameters to define signal transmission quality requirement as starting point, i.e. modulation depth, RF envelop ripple, RF plusewidth. Besides, the RF requirements for BS reader and UE reader can be the same.Observation 2: It seems current legacy IBE requirements of UE still applies for intermediate UE.Proposal 9: it’s suggested to assume that legacy IBE requirements of UE still applies for intermediate UE as starting point.Observation 3: current co-existence evaluation only focus on in-band spectrum deployment mode but there is no interference analysis for adjacent carrier spectrum deployment mode.Proposal 10: for ACLR requirement* + Once final co-existence evaluation show that A-IoT system could co-exist with NR system for in-band spectrum mode, then we can conclude legacy UE ACLR requirement applies for A-IoT UE reader.
	+ But if certain interference occurs for in-band spectrum deployment mode, further evaluation is needed for corresponding interference case. But we can leave such analysis to work phase to define corresponding requirements.

Observation 4: ICS requirement needs to wait for co-existence evaluation. Guard RB will help to improve IBE/ICS performance but will reduce spectrum utilization. Observation 5: due to very narrow bandwidth of CW interference signal, RAN4 needs to further discuss whether 1dB desense self-interference cancellation target is still applicable or not.Observation 6: for CW outside topology, RAN4 needs some typical spatial isolation assumption before conclude whether to/ how to reflect self-interference by RF requirements.Proposal 11: for ACS requirement* + Once final co-existence evaluation show that A-IoT system could co-exist with NR system for in-band spectrum mode, then we can conclude legacy UE ACS requirement applies for A-IoT UE reader.
	+ But if certain interference occurs for in-band spectrum deployment mode, further evaluation is needed for corresponding interference case. But we can leave such analysis to work phase to define corresponding requirements.

Observation 7: IMD product of multi-tone CW is much hard to be suppressed and filter solution may not work considering there is frequency overlapping between IMD products and wanted data. Proposal 12: RAN4 should wait for RAN1 CW signal design conclusion and then decide whether/how to consider the IMD product of multiple-tone CW when defining Rx requirements for reader.Proposal 13: for CW outside of topology, it seems only max output power and spurious emission requirement is applicable. For out of band emission, if we assume almost perfect performance since single tone is assumed, there is no need for such requirements.  |
| [**R4-2411868**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2411868.zip) | Spreadtrum Communications | Discussion on RF requirements impact for intermediate node (UE)Proposal 1: Some initial views about TX RF requirements for A-IoT intermediate UE in Table1.Proposal 2: Some initial views about RX RF requirements for A-IoT intermediate UE in Table2.Proposal 3: Higher CW output power can be considered (e.g., 26dBm or 29dBm).Proposal 4: Unwanted emissions caused by intermodulation products of CW need to be further studied.Proposal 5: CW and the intermodulation products of CW for D2T2 interference cancellation ability need to be further studied. |
| [**R4-2412067**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412067.zip) | vivo | Discussion on the RF requirement of intermediate UEObservation 1: The NR system require a more powerful hardware compared to AIoT system, so for a intermediate UE supports both AIoT and NR, if some NR requirements are verified and show enough performance, it may not be necessary to check it again from AIoT requirement perspective.Proposal 1: It is suggested to identify which requirements of AIoT can be waived if they are already verified in NR for intermediate UE.Observation 2: When the CW is in UL spectrum, an additional Rx chain in UL is needed which may have impact on the requirement design.Proposal 2: It is suggested to discuss the UE architecture assumption when CW is in the UL spectrum, and whether different requirements should be defined for different spectrum usage of CW.Proposal 3: The requirements of intermediate UE to transmit or receive NR and AIoT signal simultaneously are not considered in SI unless there are clear feedback from RAN1.Proposal 4: For the maximum output power and spurious emission of CW, the NR requirement can be the starting point. Observation 3: The phase noise of CW may overlap with D2R which impact on the D2R receive performance.Proposal 5: It is suggested to discuss whether the phase noise of CW need to be restricted by RF requirement. |
| [**R4-2412700**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412700.zip) | ZTE Corporation, Sanechips | Discussion on RF requirement of Intermediate node (UE)Proposal 1: specify the Tx and Rx requirement for intermediate UE in addition to RF requirements for the legacy Uu link. |
| [**R4-2412971**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2412971.zip) | Ericsson | A-IoT UE as intermediate node RF overviewProposal-1:The existing NR UE specification should be starting point.Proposal-2: OFDM based transmitter should be baseline for R2D.Proposal-3: RAN4 wait RAN1 further progress on the D2R waveform.Proposal-4:The tolerance of CW signal within the same channel of the backscattered signal as interferer needs to be further studied.Proposal-5: Further study needed for the CW inside topology impact on the UE RF when UE is intermediate node.Proposal-6: RAN4 wait RAN1 further progressing on the CW signal suppression capability. |
| [**R4-2413322**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2413322.zip) | Qualcomm Incorporated | CW cancellation capabilityObservation 1: Intermediate node CW cancellation circuitry processing accuracy is in the order of 1.5-4 %. Observation 2: Intermediate node realistic analogue domain CW cancellation capability is at most 50 dB and more likely typical value is closer to less than 40 dB. Observation 3: Intermediate node feasible CW cancellation capability is approximately 70-80 dB. And made one proposal:Proposal: RAN4 to study methods and feasable values for CW cancellation in Intermediate node. |

## Open issues summary

### Issue 4-1: start point

* Proposals:
	+ Proposal 1: The existing NR UE specification should be starting point for intermediate UE.（Ericsson, R4-2412971; CMCC, R4-2411769）
	+ Proposal 2: specify the Tx and Rx requirement for intermediate UE in addition to RF requirements for the legacy Uu link. (ZTE, R4-2412700）
	+ Proposal 3: separately testing intermediate UE when it acts like UE and when it acts like reader even if certain RF requirements are the same. （CMCC, R4-2411769）
	+ Proposal 4: identify which requirements of AIoT can be waived if they are already verified in NR for intermediate UE.（vivo, R4-2412067）
	+ Proposal 5: The requirements of intermediate UE to transmit or receive NR and AIoT signal simultaneously are not considered in SI unless there are clear feedback from RAN1. （vivo, R4-2412067）
* Recommended WF
	+ The existing NR UE requirements can be used as starting point for A-IoT intermediate UE.

### Issue 4-2: TX

Agreement in RAN4#111:

Agreement:

* Use the following table as starting point for RF requirements impact study. The table is for information.

|  |
| --- |
| **RF Requirement for A-IoT intermediate UE- TX part** |
| TX requirement | Maximum output power  |  |
| Output power dynamics |  |
| Transmit ON/OFF power |  |
| Transmitted signal quality |  |
| Transmission times |  |
| Occupied bandwidth |  |
| Tx intermodulation |  |
| ACLR |  |
| Operating band unwanted emissions  |  |
| Transmitter spurious emissions |  |

* Proposals:
	+ OFDM based transmitter should be baseline for R2D. （Ericsson, R4-2412971）
* Recommended WF
	+ The following table can be discussed for AIoT itermediate UE Tx RF requirement:

|  |  |
| --- | --- |
|  | **RF Requirement for AIoT intermediate UE- TX part**  |
| TX requirement | Maximum output power  | max supported power class per band of intermediate UE is only limited to PC3 as baseline.（R4-2411769, CMCC; ZTE, R4-2412700）Refer to RAN1’s LLS result, take a large value between RAN1’s LLS result and legacy UE.（R4-2411868, Spreadtrum） |
| Output power dynamics | Option 1: no minimum output power nor power control requirement are needed for intermediate UE. (R4-2411769, CMCC）Option 2: Minimum output power：The legacy UE requirement as a starting point（R4-2411868, Spreadtrum）Power boosting for OOK signal might be needed（ZTE, R4-2412700; R4-2411868, Spreadtrum） |
| Transmit ON/OFF power | some transition period might be needed for the switch between R2D signal transmission and CW transmission in D2T2. or switch between R2D signal transmission, CW transmission and other eMBB transmission in in-band/guard band scenario under the shared RF architecture.（ZTE, R4-2412700）it’s suggested to define transient period related requirements for A-IoT reader. Details value can refer to RFID rise/fall time. (R4-2411769, CMCC）RAN4 further discuss whether settling time as defined in RFID spec is needed or not to evaluate RF envelop ripple characteristics. (R4-2411769, CMCC）Transmit OFF power :The legacy UE requirement as a starting point(e.g., -50dBm) （R4-2411868, Spreadtrum） |
| Transmit ON/OFF time mask | The legacy UE requirement as a starting point（R4-2411868, Spreadtrum） |
| Transmitted signal quality | Frequency error | Frequency error ：Requirement necessary (CATT, R4-2411085）The legacy UE of frequency error as a starting point（R4-2411868, Spreadtrum）The legacy UE transmit frequency error requirement could be reused for A-IoT intermediate node. (R4-2412700, ZTE) |
| EVM | EVM：Requirement necessary, AIoT waveform is different with NR, new requirement and test approach is needed.（CATT, R4-2411085）Refer to RFID RF envelop related parameters to define signal transmission quality requirement, such as:1) modulation depth, RF envelop ripple, RF plusewidth. Besides, the RF requirements for BS reader and UE reader can be the same (R4-2411769, CMCC)2)power stability or power accuracy for OOK ON signal and OOK OFF signal, power difference between OOK ON and OOK OFF (R4-2412698, ZTE) |
| Transmission times | The definition needs further clarification（R4-2411868, Spreadtrum） |
| Occupied bandwidth | The legacy UE OBW requirement could be reused for A-IoT intermediate node;（ZTE, R4-2412700）Requirement necessary (CATT, R4-2411085）Wait for RAN1 progress on R2D（R4-2411868, Spreadtrum） |
| Spectrum emission mask | Requirement necessary (CATT, R4-2411085） |
| Transmitterintermodulation | The legacy UE transmitter intermodulation requirement is somehow agnostic to certain bands, therefore from our understanding, the legacy Tx intermodulation requirement is still applicable for Ambient intermediate node which is somehow different from A-IoT BS and A-IoT device.（ZTE, R4-2412700）FFS whether requirement necessary, IMD scenario needs more discussion.（CATT, R4-2411085）The legacy UE requirement as a starting point（R4-2411868, Spreadtrum） |
| IBE | it’s suggested to assume that legacy IBE requirements of UE still applies for intermediate UE as starting point. (R4-2411769, CMCC） |
| ACLR | Depends on co-existence study（R4-2411868, Spreadtrum; ZTE, R4-2412700; R4-2411769, CMCC） |
| Operating band unwanted emissions  | Depends on co-existence study and regulatory requirements（R4-2411868, Spreadtrum; ZTE, R4-2412700） |
| Transmitter spurious emissions | Reuse the legacy transmitter spurious emission requirement（ZTE, R4-2412700; R4-2411868, Spreadtrum） |

### Issue 4-3: RX

Agreement in RAN4#111:

Agreement:

* Use the following table as starting point for RF requirements impact study. The table is for information.

|  |
| --- |
| **RF Requirement for A-IoT intermediate UE- RX part** |
| RX requirement | Reference sensitivity |  |
| Maximum input power |  |
| ICS |  |
| ACS |  |
| In-band blocking |  |
| Out-of-band blocking |  |
| Receiver intermodulation |  |
| Rx spurious emission |  |

* Proposals:
	+ RAN4 wait RAN1 further progress on the D2R waveform. （Ericsson, R4-2412971）
* Recommended WF
	+ The following table can be discussed for A-IoT itermediate UE RX RF requirement:

|  |  |
| --- | --- |
|  | **RF Requirement for A-IoT intermediate UE- RX part** |
| RX requirement | Reference sensitivity power level  | The REFSENS requirement might be not based on the throughput metric and it should be dependent on the miss detection ratio and false alarm detection ratio instead if without any HARQ-ACK feedback.（ZTE, R4-2412700）In addition, the impacts on CW signal transmission should be also taken into account especially for D2T2. （ZTE, R4-2412700）For D2T2-A2 deployment scenarios, some self interference on Ambient intermediate node should be taken into account.（ZTE, R4-2412700）Requirement necessary (CATT, R4-2411085）The legacy UE requirement as a starting point, but need to consider CW interference cancellation and R2D waveform (R4-2411868, Spreadtrum） |
| Maximum input power | Similar analysis for backscattering signal should be specified with measurement metric as miss detection ratio or false alarm detection ratio.（ZTE, R4-2412700）Requirement necessary (CATT, R4-2411085）The legacy UE requirement as a starting point (R4-2411868, Spreadtrum） |
| ICS | FFS whether Requirement necessary（CATT, R4-2411085）Depends on co-existence study (R4-2411868, Spreadtrum） |
| ACS | This depends on further coexistence study.（ZTE, R4-2412700）Requirement necessary (CATT, R4-2411085）Proposal 11: for ACS requirement* + Once final co-existence evaluation show that A-IoT system could co-exist with NR system for in-band spectrum mode, then we can conclude legacy UE ACS requirement applies for A-IoT UE reader.
	+ But if certain interference occurs for in-band spectrum deployment mode, further evaluation is needed for corresponding interference case. But we can leave such analysis to work phase to define corresponding requirements. (R4-2411769, CMCC）

Depends on co-existence study (R4-2411868, Spreadtrum） |
| In-band blocking | FFS whether Requirement necessary（CATT, R4-2411085）Depends on co-existence study (R4-2411868, Spreadtrum） |
| Out-of-band blocking | FFS whether Requirement necessary（CATT, R4-2411085）Depends on co-existence study (R4-2411868, Spreadtrum）Don’t see the reason not to reuse the -15dBm CW signal as interference signal of OOBB requirement. For f\_OOBB requirement, this could be further discussed once we have more clear assumption on A-IoT intermediate node. （ZTE, R4-2412700） |
| Narrow band blocking | Not needed（CATT, R4-2411085） |
| Blocking requirement | depends on coexistence study.（ZTE, R4-2412700） |
| Receiver intermodulation | This is somehow similar as Tx intermodulation requirement.（ZTE, R4-2412700）Requirement necessary (CATT, R4-2411085）The legacy UE requirement as a starting point (R4-2411868, Spreadtrum） |
| Receiver spurious response  | This might be needed for D2R reception only.（ZTE, R4-2412700） |
| Rx spurious emission | The legacy UE receiver spurious emission requirement could be applicable.（ZTE, R4-2412700）Requirement necessary (CATT, R4-2411085）The legacy UE requirement as a starting point (R4-2411868, Spreadtrum） |

### Issue 4-4: CW for D2T2

Agreement in RAN4#111:

Agreement:

* To further investigate output power, emission requirements for CW node
	+ FFS for other requirements.
* Proposals:
	+ Proposal 1: How CW impacts AIoT reader Rx BB DEMOD performance needs some evaluation or assumption for the feasibility study. （CATT, R4-2411085）
	+ Proposal 12: RAN4 should wait for RAN1 CW signal design conclusion and then decide whether/how to consider the IMD product of multiple-tone CW when defining Rx requirements for reader. (R4-2411769, CMCC）
	+ for CW outside of topology, it seems only max output power and spurious emission requirement is applicable. For out of band emission, if we assume almost perfect performance since single tone is assumed, there is no need for such requirements. (R4-2411769, CMCC）
	+ Unwanted emissions caused by intermodulation products of CW need to be further studied. (R4-2411868, Spreadtrum）
	+ Proposal 5: CW for D2T2 interference cancellation ability and MSD need to be further studied. (R4-2411868, Spreadtrum）
	+ Proposal 4: For the maximum output power and spurious emission of CW, the NR requirement can be the starting point. (( vivo, R4-2412067))
	+ Proposal 5: It is suggested to discuss whether the phase noise of CW need to be restricted by RF requirement. ( vivo, R4-2412067)
	+ The tolerance of CW signal within the same channel of the backscattered signal as interferer needs to be further studied. （Ericsson, R4-2412971）
	+ Further study needed for the CW inside topology impact on the UE RF when UE is intermediate node. （Ericsson, R4-2412971）
	+ RAN4 wait RAN1 further progressing on the CW signal suppression capability. （Ericsson, R4-2412971）
	+ Proposal: RAN4 to study methods and feasable values for CW cancellation in Intermediate node. （）[R4-2413322](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_112/Docs/R4-2413322.zip),QC)
	+ Proposal 2: It is suggested to discuss the UE architecture assumption when CW is in the UL spectrum, and whether different requirements should be defined for different spectrum usage of CW. （vivo, R4-2412067）
* Recommended WF
	+ The following table can be discussed for CW node RF requirement

|  |
| --- |
| **RF Requirement for CW node** (if not noted, from R4-2408946, CMCC） |
| requirement | Applicable or not |
| Operation bands | Single FDD DL or UL bands(R4-2411769, CMCC） |
| Channel bandwidth related requirements | NA (R4-2411769, CMCC） |
| Channel arrangement related | NA (R4-2411769, CMCC） |
| Transmitter power 或output power | Applicable. Further check the power limit(R4-2411769, CMCC）MPR/A-MPR NA (R4-2411769, CMCC）Configured output power, NA (R4-2411769, CMCC）Output power ：Requirement necessary (CATT, R4-2411085）Higher CW output power can be considered (e.g., 26dBm or 29dBm). (R4-2411868, Spreadtrum） |
| Output power dynamic range | Minimum output power: NA (R4-2411769, CMCC）ON/OFF time mask: may NA (R4-2411769, CMCC）Power control: NA (R4-2411769, CMCC） |
| Transmit signal quality | Frequency error: NA (R4-2411769, CMCC）Transmit modulation quality: NA (R4-2411769, CMCC）CW signal quality：FFS, If phase noise or emissions should be defined FFS.（CATT, R4-2411085） |
| RF spectrum emission | Occupied bandwidth: NA (R4-2411769, CMCC）Out of band emission: not applicable if we assume CW nodes have almost perfect out of band emission? (R4-2411769, CMCC）Spurious emission: current may still applicable to meet regulatory requirement (R4-2411769, CMCC）Transmit inter-modulation: applies at least for inside topology case (R4-2411769, CMCC） |