**3GPP TSG-RAN WG4 Meeting # 109 draft R4-2408946**

Chicago, US, November 13 – 17, 2023

**Agenda item:** 10.13.4

**Source:** Moderator (Huawei)

**Title:** Topic summary for [111][135] FS\_Ambient\_IoT\_solutions\_part2

**Document for:** Information

# Introduction

The thread [111][135] FS\_Ambient\_IoT\_solutions\_part2 is on Rel-19 SI for Study on solutions for Ambient IoT in NR (RP-240826).

The summary covers contributions submitted under the agenda items including:

10.13.3 RF requirement impact

10.13.3.1 Ambient IoT BS

10.13.3.2 Ambient IoT device

10.13.3.3 Intermediate note (UE)

# Topic #1: A-IoT System Parameters

## Companies’ contributions summary

### Issue 1-1: System parameter

* Proposals:
	+ Ambient IoT device is equipped with 1TX and 1RX. RX diversity is FFS. (R4-2407717, Spreadtrum)
* Recommended WF
	+ The following table can be the starting point

|  |
| --- |
| RF Requirement for AIoT BS |
| System parameter | Operating band | Band n8 as example band in SI （R4-2408093, vivo）other FDD bands less than or equal to 2GHz should be considered (R4-2407717, Spreadtrum) |
| Channel bandwidth | Transmission bandwidth configuration | Same as NR for in-band operation（R4-2408093, vivo）180 kHz, FFS larger bandwidth for higher data rate |
| Guard band | Same as NR for in-band operation（R4-2408093, vivo）Guard-band between AIoT and NR/LTE, as well as between FDMed AIoT systems (R4-2408238, China Telecom) |
| Occupied bandwidth | The legacy UE OBW requirement could be reused for A-IoT intermediate node; （R4-2409599, ZTE） |
| Minimum receiver bandwidth | RAN4 discuss whether this requirement is needed considering the spectrum of backscattering signal（R4-2408093, vivo） |
| Guard RB | Whether or not define Guard RBOption 1: define minimum guard RB between A-IoT and NR（R4-2407822, Xiaomi; R4-2407522, CATT）Option 2: If we define guard RB at device side for in-band mode, then it seems there is no need to define guard RB requirements at reader side. (R4-2408217, CMCC) |

# Topic #2: A-IoT BS

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| [**R4-2407522**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407522.zip) | CATT | Discussion on RF requirements of A-IoT BS**Observation 1: A-IoT BS potential Tx requirements are shown in Table 1, the requirements only consider device 1 and device 2a.****Observation 2: A-IoT BS potential Rx requirements are shown in Table 2, the requirements only consider device 1 and device 2a.****Proposal 1: The minimum guard RB between A-IoT and NR needs to be analyzed.** |
| [**R4-2407822**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407822.zip) | Xiaomi | Discussion on the RF impact of Ambient IoT BS**Proposal 1: The Tx requirement of the Ambient IoT BS for R2D can reuse NR gNB’s requirements as starting point.****Proposal 2: RAN4 need to at least define the transmission power and related transmission emission limitation for CW waveform based on single-tone for Ambient IoT BS no matter it is transmitted inside or outside.****Proposal 3: RAN4 can consider the Rx requirements for Ambient IoT BS similar with those for NR gNB, the detail value can further discuss.****Proposal 4: Guard RB between NR signalling and D2R signalling and ASCS requirements for Ambient IoT BS need to consider for in-band/guard-band operation.** |
| [**R4-2408093**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408093.zip) | vivo | Discussion on the RF requirement for AIoT BS**Proposal 1:** It is suggested that success rate is used as performance metric for Rx requirement definition for AIoT BS.**Proposal 2:** The following table can be the starting point for AIoT BS RF requirement discussion:

|  |
| --- |
| RF Requirement for AIoT BS |
| System parameter | Operating band | Band n8 as example band in SI |
| Channel bandwidth | Transmission bandwidth configuration | Same as NR for in-band operation |
| Guard band | Same as NR for in-band operation |
| Minimum receiver bandwidth | RAN4 discuss whether this requirement is needed considering the spectrum of backscattering signal |
| Tx requirement  | Transmit output power | Maximum output power | 33 dBm/200kHz for frequency <900MHz;36 dBm/400kHz for frequency>900MHz; |
| Output power dynamic | RAN4 need to discuss whether the power boosting is necessary and what is the feasible boosting value. |
| Transmit signal quality | Frequency error | ±10 ppm |
| EVM | FFS, ASK/PSK are considered |
| Output RF spectrum emissions | Occupied bandwidth | Same as NR BS |
| SEM | SEM in [2] as starting point |
| ACLR | Depends on co-existence study |
| SE | SE in [2] as starting point |
| Rx requirement  | RAN4 should first discuss and decide what metric will be used to represent the Rx performance, e.g., 10% BLER, 90% success rate, etc. |

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| [**R4-2408217**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408217.zip) | CMCC | Discussion on A-IoT BS RF requirements**Observation 1: RF energy sources or energy harvesting of the tag are not in scope of the study.****Proposal 1: it’s suggested to study following two operation modes for in-band spectrum deployment mode at current stage and wait for power boosting requirements discussion to further check whether only option 2 is allowed or not.** * **Option 1: A-IoT reader for topology 1 could share the same hardware with existing gNB**
* **Option 2: A-IoT reader for topology 1 doesn’t share the same hardware with existing gNB**

**Proposal 2: LLS is required to evaluate required power boosting level for reader of topology 1.** **Observation 2: if we define guard RB at device side for in-band mode, then it seems there is no need to define guard RB requirements at reader side.** **Proposal 3: IBE and ICS requirements are needed for A-Iot reader and detailed value could be based on co-existence analysis.****Proposal 4: further discuss whether reader could support other cell type besides micro cell.****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.****Observation 5: 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 5: 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 6: for CW outside of topology, it seems only max output power and spurious emission requirement is applicable. The same RF framework applies for both topology 1 and topology 2.** |
| [**R4-2408237**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408237.zip) | China Telecom | Consideration on RF requirements for Ambient IoT BS**Observation 1: Waveform design in RAN1 may introduce some hardware upgrade and new RF requirements.****Observation 2: Ambient IoT device has poor reception sensitivity, which may impact on the coverage.****Proposal 1:** **Pre****fer to reuse existing BS equipment with some minor hardware upgrade. To minimize changes to existing BS equipment, traditional BS RF requirements can be used as baseline for ambient IoT BS, and some new requirements regarding new characteristics of aIoT can be introduced.** |
| [**R4-2409093**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2409093.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. |
| [**R4-2409407**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2409407.zip) | Huawei, HiSilicon | RF requirements for Ambient IoT BS**Proposal 1**: Ambient IOT BS shall transmit in FDD downlink operating band.**Proposal 2:** in rel-19, RAN4 specify the RF requirement for BS only support Ambient IOT. BS support multiple RAT can be discussed in future release.**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:** the maximum transmit power of 33 dBm and 38 dBm for micro-BS are recommended for the evaluations.**Proposal 5:** For co-existence study, the following simplified antenna pattern is proposed,

|  |  |  |
| --- | --- | --- |
| Vertical angle | Internal Antenna | External Antenna |
| -45 ≤ θ ≤ 45 | 2 dBi | 6 dBi |
| Others | -1 dBi | 0 dBi |

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| [**R4-2409597**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2409597.zip) | ZTE Corporation, Sanechips | Discussion on RF requirement of Ambient IoT BS**Proposal 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, EVM requirements for OOK signal etc. **Proposal 4**: please check the initial analysis for RF requirement of A-IoT BS in D1T1 in table 1. |

## Open issues summary

### Issue 2-1: start point

* Proposals:
	+ Three companies propose that the existing NR BS requirements should be as starting point for A-IoT BS.（R4-2407822,Xiaomi；R4-2408237,China Telecom；R4-2409093,Ericsson）
	+ Further study on the CW signal and concurrent A-IoT signal receiving impact on receiver RF requirement for outside topology. (R4-2409093,Ericsson)
* Recommended WF
	+ The existing NR BS requirements can be used as starting point for A-IoT BS.

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

* Proposals:
	+ Option 1: A-IoT BS type is micro-BS as described in the SID RP-240826
	+ Option 2: Further discuss whether reader could support other cell type besides micro cell. (R4-2408217, CMCC)
* Recommended WF
	+ TBA

### Issue 2-3: Single RAT or Multi-RAT

Background：

The WF last meeting R4-2406714 agreed that：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.

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)

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.

* Proposals:
	+ Option 1: In Rel-19, only support Ambient IOT. BS support multiple RAT can be discussed in future release.（R4-2409407,Huawei）
	+ Option 2: Multi-RAT: A-IoT BS may share the same hardware with existing gNB (R4-2408217, CMCC)
* Recommended WF
	+ RAN4 to first evaluate Single RAT AIOT BS, and further study multi-RAT AIOT BS

### Issue 2-4: TX

* Recommended WF
	+ TBA

|  |  |  |  |
| --- | --- | --- | --- |
| Tx requirement  | Transmit output power | Maximum output power | 33 dBm/200kHz for frequency <900MHz;36 dBm/400kHz for frequency >900MHz;（R4-2408093,Vivo）The existing rated output power limits for NR Medium range BS is applicable to Ambient IOT BS for D1T1 deployment scenarios. (R4-2409407, Huawei)To follow the FR1 MR and LA BS output power limitation and power accuracy requirement; （R4-2409597, ZTE） |
| Output power dynamic | RAN4 need to discuss whether the power boosting is necessary and what is the feasible boosting value.LLS is required to evaluate required power boosting level for reader of topology 1. (R4-2408217, CMCC) |
| Transmit ON/OFF power | The transmit ON-OFF power is only limited for TDD bands, however A-IoT BS might need to send the R2D signal and CW signal in the sequential way, then some transition period might be needed for the switch between R2D signal transmission and CW transmission in D1T1-A1 and D1T1-A2. （R4-2409597, ZTE） |
| Transmission times | RAN4 needs further analysis(R4-2407522, CATT) |
| Transmit signal quality | Frequency error | ±10 ppm |
| EVM | FFS, ASK/PSK are considered |
| TAE | not needed for R2D signal transmission or CW signal transmission.  |
| Output RF spectrum emissions | Occupied bandwidth | Same as NR BS |
| SEM | SEM in [2] as starting point |
| Tx intermodulation | Based on some operator’s initial feedback on 900MHz indoor deployment, it seems that general Tx intermodulation requirement for A-IoT BS operating at 900MHz is not needed. FFS for other frequency e.g. 2GHz. |
| ACLR | Depends on co-existence study |
| IBE | IBE based on co-existence analysis. (R4-2408217, CMCC) |
| Operating band unwanted emissions | This depends on outcome of coexistence evaluation |
| Transmitter spurious emissions | SE in [2] as starting point；（R4-2408093,Vivo）The legacy transmitter spurious emission requirement could be reused since this is coming from the ITU regulatory definition.（R4-2409597, ZTE） |

### Issue 2-5:RX

* Recommended WF
	+ TBA

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

|  |
| --- |
| **Rx part** |
| 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. （R4-2409597, ZTE）In addition, the impacts on CW signal transmission should be also taken into account especially for D1T1-A2. RAN4 should first discuss and decide what metric will be used to represent the Rx performance, e.g., 10% BLER, 50% success rate, etc. ( R4-2408093,Vivo) |
| Dynamic range  | Similar analysis for REFSENS requirement. IoT level could be further discussed in the WI phase.  |
| In-channel selectivity | This depends on further coexistence studyNo need 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. (R4-2409597,ZTE） |
| Adjacent Channel Selectivity | This depends on further coexistence study.  |
| Blocking requirement | This depends on further coexistence study.  |
| OOBB | 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 BS.  |
| Receiver intermodulation | This is somehow similar as Tx intermodulation requirement.  |
| Narrowband intermodulation |  |
| Rx spurious emission | The legacy receiver spurious emission requirement could be applicable.  |
| IMD | 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. (R4-2408217, CMCC) |

### Issue 2-5 CW

* Proposals:
	+ max output power, spurious emission both topology 1 and topology 2, inside or outside ( R4-2408217,CMCC; R4-2407822, Xiaomi)
	+ Further study on the CW signal and concurrent A-IoT signal receiving impact on receiver RF requirement for outside topology. (R4-2409093, Ericsson)
	+ 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. (R4-2409597, ZTE)
* Recommended WF
	+ TBA

# Topic #3: AIoT device

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| [**R4-2407411**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407411.zip) | Sony | Preliminary considerations on the ambient IoT device implementation and RF aspect**Observation 1: The transmission and reception parts of the AIoT device need to be considered for the co-existence study and RF requirements. Meanwhile, the energy harvesting, and storage part may affect the capability, availability, and testability of the AIoT reception and transmission.** **Observation 2: From the RF perspective, the reception part design of the AIoT device can be leveraged from the envelope detector-based LP-WUS receiver design but with a smaller coverage target.** **Observation 3: The RF-ED envelope detector is poor in frequency selectivity.** **Observation 4: For the transmission part, the AIoT device 2b function might be similar to legacy IoT devices but with lower capability due to the energy harvesting and power consumption constraint.** **Observation 5: 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 6: 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 7: The frequency translation range of the backscattering signal needs to be studied under the power consumption limitation.****Proposal 1: RAN4 shall study if there is any impact due to the energy harvesting/storage on the co-existence, RF performance, and testability of AIoT devices.** **Proposal 2: RAN4 shall study how to accommodate RF-ED receivers for R2D link.** **Proposal 3: The power consumption limitation needs to be considered when RAN4 discusses the RF architecture and performance of the AIoT devices.** **Proposal 4: The usage of reflection amplifier and frequency shift technology for backscattering communication needs to be investigated in RAN4 in order to set a reasonable assumption for ambient IoT devices for the co-existence simulation and for deriving the RF requirements.** **Proposal 5: RAN4 shall create a common understanding of the feasible implementations of different device types before proceeding further with co-existence and RF work.****Proposal 6: The reception requirement framework of LP-WUS can be taken as a starting point to define the requirements framework for AIoT reception.** **Proposal 7: For device 2b, the transmission requirements for legacy IoT devices can be taken as a starting point with the possibility of a new power class.** **Proposal 8: The transmission performance of backscattering devices can be defined with respect to an input CW signal.** |
| [**R4-2407523**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407523.zip) | CATT | Discussion on RF requirements of A-IoT device**Observation 1: Potential Tx requirements of device 1 or device 2a are shown in Table 1.** **Proposal 1: Input signal power range requirement of CW2D Rx is necessary.****Observation 2: Potential R2D Rx requirements of device 1 or device 2a are shown in Table 2.****Observation 3: It’s very challenging to design good performance narrow-bandwidth RF bandpass filters with LC.****Proposal 2: The feasibility and the performance for the RF BPF filter before the RF envelope detector should be studied in RAN4.****Proposal 3: The following assumptions should be aligned for the RF BPF filter study:****Operating frequency, cutoff frequency, performance assumption, etc.** |
| [**R4-2407588**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407588.zip) | Qualcomm Incorporated | A-IoT device study and RF requirements aspects **Proposal 1: RAN4 to study what kind of spectral confinement requirements could be placed for A-IoT device.** **Observation 1: Applicable terminology for the A-IoT backscattering device transmission should be unified in RAN4 discussions** **Observation 2: RAN4 can use the boundary of Occupied bandwidth, *B*occ,D2R as a starting point for the study for requirements for spectral confinement of A-IoT device transmissions****Proposal 2: RAN4 should study realistic implementations and impact of their components to the spectral purity of the signal****Observation 3: RAN1 may not study impact of realistic design and its impairments to signal characteristics****Observation 4: For FDM operation for same reader with single CW, the frequency domain positions for the two transmission from two different A-IoT device need to be defined in relation to the same CW.****Proposal 3: RAN4 to study how to test a backscattering device, considering OTA methods and feasibility for conducted testing** |
| [**R4-2407717**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407717.zip) | Spreadtrum Communications | Discussion on RF requirements impact for ambient IoT device**Observation 1: RF BPF and BB LPF exist depending on whether they meet RF requirements or not.****Proposal 1: System bandwidths needs to be further discussed in RAN4.****Proposal 2: other FDD bands less than or equal to 2GHz should be considered.****Proposal 3: Ambient IoT device is equipped with 1TX and 1RX. RX diversity is FFS.****Proposal 4: SFO impact for RF requirements need to be considered.****Proposal 5: ADC bits impact for RF requirements need to be considered.****Proposal 6: one or multiple sets of requirements for devices to define needs to study.****Proposal 7: REFSENS and NF for different devices need to be studied.****Observation 2: The transmission power of device 1 is determined by CW and the distance with CW.****Proposal 8: Reflection amplification gain of device 2a and max power of device 2b need to be further discussed.** |
| [**R4-2407823**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407823.zip) | Xiaomi | Discussion on the RF impact of Ambient IoT device**Proposal 1: At least below Tx requirements need be considered for different devices as shown in Table 2-1:**Table 2-1 the possible Tx requirements for Ambient IoT devices

|  |  |
| --- | --- |
| Requirements | Devices |
| power class | device 1, device 2a and device 2b |
| power control | device 2b |
| Output power dynamics | device 2b |
| Transmit signal quality | device 1, device 2a and device 2b |
| Emission  | device 1, device 2a and device 2b |

The output power need define for these three devices, how many power class need define can be further discussed. And the power control is needed only for device 2b.**Proposal 2: The MOP need be defined for these three devices, how many power class should be defined can further discuss.****Proposal 3: The power control is needed only for device 2b.****Proposal 4: For the devices based on backscatter modulator, RAN4 need discuss how to evaluate the backscattering signal quality and related emission.****Proposal 5: At least below Rx requirements need be considered for different devices as shown in Table 2-2:** Table 2-2 The possible Rx requirements for Ambient IoT devices

|  |  |
| --- | --- |
| Requirements | Devices |
| REFSENS | device 1, device 2a and device 2b |
| Maximum input power | device 2a and device 2b with LNA |
| ACS or ASCS | device 1, device 2a and device 2b |
| Blocking | device 1, device 2a and device 2b |

**Proposal 6: RAN4 need specify different REFSENs requirements for these three devices based on RF envelop detection.** |
| [**R4-2408094**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408094.zip) | vivo | Discussion on the RF requirement for AIoT device**Proposal 1:** In SI, the RF requirement for device 1/2a can be prioritized.**Observation 1:** The conducted conformance testing may not feasible for AIoT device.**Proposal 2:** RAN4 to discuss whether conducted conformance testing is still feasible for AIoT device. If not, it is suggested to define radiated requirement for device.**Proposal 3:** It is suggested that success rate is used asperformance metric for Rx requirement definition for AIoT device.**Proposal 4:** The following table can be the starting point for AIoT device RF requirement discussion:

|  |
| --- |
| RF Requirement for AIoT device |
| System parameter | Operating band | Band n8 as example band in SI |
| Channel bandwidth | Transmission bandwidth configuration | 180 kHz, FFS larger bandwidth for higher data rate |
| Guard band | FFS |
| Minimum receiver bandwidth | RAN4 need to discuss whether this requirement is need considering the feasibility of RF filter |
| Tx requirement  | Transmit output power | Maximum output power | -25 dBm/100kHz for frequency <900MHz;-18 dBm/100kHz for frequency>900MHz;FFS whether/how to convert radiated requirement to conducted requirement  |
| Output power dynamic | Transmit OFF power | Same as NR, -40 dBm |
| Transmit time mask | FFS following requirement:Transmit-to-Receive Turn-Around Time;Receive-to-Transmit Turn-Around Time;Transmit Power-On Ramp; |
| Transmit signal quality | Frequency error | FFS |
| EVM | FFS, ASK/PSK are considered |
| IBE | FFS |
| Output RF spectrum emissions | Occupied bandwidth | Same as NR |
| SEM | Unwanted emission in [2] as starting point |
| ACLR | Depends on co-existence study |
| SE | Unwanted emission in [2] as starting point |
| Rx requirement  | RAN4 should first discuss and decide what metric will be used to represent the Rx performance, e.g., BLER, success rate, etc. |

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| **[R4-2408220](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408220.zip)** | CMCC | Discussion on A-IoT device RF requirements**Proposal 1: as starting point, it’s suggested to discuss RF requirements separately for three device types.****Proposal 2: it’s suggested to only choose band n8 as example band.****Proposal 3: 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 4: no need to define transmission bandwidth RF requirement in RAN4.****Proposal 5: RAN4 further discuss the guard RB value range in study phase based on co-existence for in-band spectrum deployment mode of device 2a.** **Proposal 6: RAN4 further discuss whether any guard band is needed or not for guard-band spectrum deployment mode. Guard frequency can be in any granularity.**1715594282153**Proposal 7: 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 8: 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**

**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: if large shifter has been studied, further check the spurious emission at specific frequency where harmonic occurs.****Proposal 12: REFSENSE and max input level needs to be separately defined for different devices types.** **Proposal 13: at least for standalone, ACS is needed. Further discuss for in-band and guard-band spectrum deployment mode.****Proposal 14: RAN4 needs to further discuss the out of band blocking performance based on RF architecture discussion.****Proposal 15: For device 2b, it’s suggested to use UE RF framework as baseline and further discuss whether certain relaxation is needed or not.** |
| [**R4-2408238**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408238.zip) | China Telecom | Consideration on RF requirements for Ambient IoT device**Proposal 1: Energy harvesting requirements for ambient IoT device should be defined in RAN4, e.g., energy harvesting sensitivity or activation threshold.****Proposal 2: The requirements of UL backscattering signal power for device 1/device 2a should be discussed.****Observation 1: The RF architecture of ambient IoT device is still under discussion, and can be different in implementation.****Proposal 3: Traditional Tx/Rx requirements should also be considered, and RAN4 should have a common understanding on the architecture and capability of ambient IoT device before discussing RF requirements.****Observation 2: The definition of transmission bandwidth and occupied bandwidth for D2R should also be utilized in RAN4.** **Proposal 4: The design of guard-band between AIoT and NR/LTE, as well as between FDMed AIoT systems should be discussed in RAN4.** |
| [**R4-2408817**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408817.zip) | OPPO | further discussion on the regulation and Device requirements**Observation 1: Different receiver architecture may lead to different method to derive REFSENS requirement.****Proposal 1: The REFSENS requirement for device needs to consider different receiver architecture.****Proposal 2: Use 1% misdetection rate as performance metric for evaluation and can be further used in REFSENS requirement deriving.** |
| [**R4-2409097**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2409097.zip) | Ericsson | A-IoT 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: 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-2: EH sensitivity can be studied in study phase.Proposal-3: OTA RF requirement should be discussed for A-IoT UE equipped with an antenna. |
| [**R4-2409598**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2409598.zip) | ZTE Corporation, Sanechips | Discussion on RF requirement of Ambient IoT device**Proposal 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. |
| [**R4-2409646**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2409646.zip) | Huawei, HiSilicon | Discussion on RF requirements for Ambient IoT devices**Proposal 1: RAN4 to study the RF requirements on operating bands, channel bandwidth and channel arrangement for ambient IoT devices, which can be common to both devices and readers.****Proposal 2: RAN4 to consider the ultra-low complexity and power consumption of ambient IoT devices when defining the applicable RF requirements on the expected performances.****Proposal 3: Different Tx/Rx RF requirements may be applied to Device 1/2a/2b based on Tx/Rx capabilities.****Proposal 4:** **RAN4 to study the Tx RF requirements on transmit power, transmit signal quality (for device 2b) and output RF spectrum emissions for ambient IoT devices.****Proposal 5: Special care is needed on how to define the requirements on the output RF spectrum emissions if the backscattered transmission is in the DL spectrum of an FDD band.****Proposal 6:** **RAN4 to study the Rx RF requirements on reference sensitivity, max input level (device 2a/2b), adjacent channel selectivity and blocking characteristics for ambient IoT devices.****Proposal 7: RAN4 to study the testability of the RF requirements for ambient IoT devices, including test method, performance metric, etc.** |

## Open issues summary

### Issue 3-1 General:

* Proposals:
	+ Specify different RF requirement for Ambient IoT Device 1, Device 2a and Device 2b;( R4- 2409646, Huawei; R4-2407717, Spreadtrum; R4-2409598, ZTE)
	+ For device 2b, the transmission requirements for legacy IoT devices can be taken as a starting point with the possibility of a new power class. (R4-2407411, Sony)
	+ The transmission performance of backscattering devices can be defined with respect to an input CW signal. (R4-2407411, Sony)
	+ The reception requirement framework of LP-WUS can be taken as a starting point to define the requirements framework for AIoT reception.( R4-2407411, Sony)
* Recommended WF
	+ Specify different RF requirement for Ambient IoT Device 1, Device 2a and Device 2b

### Issue 3-2 RF impairments:

* Proposals:
	+ Proposal 1: The feasibility and the performance for the RF BPF filter before the RF envelope detector should be studied in RAN4.( R4-2407523, CATT)
	+ Proposal 2: The following assumptions should be aligned for the RF BPF filter study:Operating frequency, cutoff frequency, performance assumption, etc. (R4-2407523, CATT)
	+ Proposal 3: There should not be a RF BPF if the same A-IoT device should talk to BS and UE as intermediate node.( R4-2409097, Ericsson)
	+ Proposal 4: SFO impact for RF requirements need to be considered.( R4-2407717, Spreadtrum)
	+ Proposal 5: ADC bits impact for RF requirements need to be considered. R4-2407717, Spreadtrum)
	+ Proposal 6: The usage of reflection amplifier and frequency shift technology for backscattering communication needs to be investigated in RAN4 in order to set a reasonable assumption for ambient IoT devices for the co-existence simulation and for deriving the RF(R4-2407411, Sony)
	+ Proposal 7: Reflection amplification gain of device 2a and max power of device 2b need to be further discussed.(R4-2407717, Spreadtrum)
	+ Proposal 8:RAN4 should study realistic implementations and impact of their components to the spectral purity of the signal(R4-2407588,QC)
	+ Proposal 9:Device backscatter loss is needed to be analysed.( R4-2407523, CATT)
* Recommended WF
	+ TBA

### Issue 3-3: TX

* Recommended WF
	+ The following table can be disussed for AIoT device RF requirement discussion:

|  |  |  |  |
| --- | --- | --- | --- |
| Tx requirement  | Transmit output power | Maximum output power | -25 dBm/100kHz for frequency <900MHz;-18 dBm/100kHz for frequency>900MHz;FFS whether/how to convert radiated requirement to conducted requirement ;The requirements of UL backscattering signal power for device 1/device 2a should be discussed.( R4-2408238, China Telecom)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.( R4-2409097,Ericsson)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.( [R4-2408220](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408220.zip) ,CMCC)For Device 1 and 2a, from our understanding, it is highly dependent on maximum input power of CW signal and its backscattering gain according to its input CW signal e.g. 9dBi, 12dBi or 15dBi etc.(R4-2409598, ZTE)For Device 2b, since it is capable of transmitting signal without any backscattering, then maximum output power should be specified agnostic with the input CW power. (R4-2409598, ZTE) |
| Output power dynamic | Transmit OFF power | Same as NR, -40 dBm |
| Transmit time mask | FFS following requirement:Transmit-to-Receive Turn-Around Time;Receive-to-Transmit Turn-Around Time;Transmit Power-On Ramp;This might need more discussions since A-IoT device or cheap tag might don’t have capability to switch ON-OFF by itself at least for Device 1 and 2a. (R4-2409598, ZTE) |
|  | Minimum output power | 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.For minimum output power for Device 2b, this need more discussions. (R4-2409598, ZTE) |
|  | Power control requirement | For Device 1 and 2a, power control requirement might be not needed similar as repeater-Fwd link requirement. For Device 2b, this needs further discussions and might be also not needed since the legacy requirement is defined for open-loop PRACH transmission and close loop PUSCH/PUCCH transmission based on DL RSRP measurement during the connected mode. (R4-2409598, ZTE) |
| Transmit signal quality | Frequency error | transmit signal quality (for device 2b);According to how the D2R signal is generated, not necessary to define these requirements(for device 1,2a)This could be further discussed based on the some practical measurement results for it. (R4-2409598, ZTE) |
| EVM | FFS, ASK/PSK are consideredtransmit signal quality (for device 2b)( R4-2407523\_CATT)According to how the D2R signal is generated, not necessary to define these requirements(for device 1,2a)EVM requirement for backscattering signal is needed with CW signal as input. (R4-2409598, ZTE) |
| IBE | FFS |
| Carrier leakage | may be needed based on the design of small frequency shift in baseband |
|  | Transmit OFF power | According to how the D2R signal is generated, not necessary to define these requirements(for device 1,2a) |
|  | ON/OFF time mask | According to how the D2R signal is generated, not necessary to define these requirements(for device 1,2a) |
|  | Power Control | According to how the D2R signal is generated, not necessary to define these requirements(for device 1,2a) |
| Output RF spectrum emissions | Occupied bandwidth | Same as NR |
| SEM | Unwanted emission in [2] as starting point;RAN4 can use the boundary of Occupied bandwidth, Bocc,D2R as a starting point for the study for requirements for spectral confinement of A-IoT device transmissions(R4-2407588,QC) |
| ACLR | Depends on co-existence studyNot necessary(for device 1,2a) ( R4-2407523\_CATT) |
| Spurious emissions | Unwanted emission in [2] as starting point;Out of band emission: at least for standalone, it’s needed. For in-band and guard-band spectrum deployment mode, FFS how to define such requirements. ([R4-2408220](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408220.zip) ,CMCC)needed to meet regulatory requirement. if large frequency shifter is considered for device 2a, RAN4 should further check the spurious emission at specific frequency where harmonic occurs. ([R4-2408220](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408220.zip) ,CMCC) |
|  |  | Transmit intermodulation | Not necessary;Based on some operator’s initial feedback on 900MHz indoor deployment, it seems that general Tx intermodulation requirement for A-IoT UE operating at 900MHz is not needed. FFS for other frequency e.g. 2GHz.(R4-2409598, ZTE) |

### Issue 3-4: RX

* Recommended WF
	+ The following table can be disussed for AIoT device RX RF requirement discussion:

|  |
| --- |
| **Rx part** |
| REFSENS | 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.(R4-2409598, ZTE)Use 1% misdetection rate as performance metric for evaluation and can be further used in REFSENS requirement deriving.( R4-2408817,OPPO)RAN4 should first discuss and decide what metric will be used to represent the Rx performance, e.g., BLER.（R4-2408094 ,Vivo）Necessary and needs to be separately defined for different devices types.（[R4-2408220](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408220.zip) ,CMCC） |
| Maximum input power | At least the following two aspects need to be considered: .(R4-2409598, ZTE)1. Maximum input power for CW signal with measurement metric as backscattering output power;
2. Maximum input power for R2D signal reception e.g. with OOK modulation with measurement metric as miss detection ration and false alarm detection ratio;

Necessary and may needs to be separately defined for different devices types. （[R4-2408220](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408220.zip) ,CMCC）Only for device 2a and device 2b with LNA (R4-2407823, Xiaomi) |
| ACS and ACSC | First of all, this depends on further coexistence study. In addition, based on the illustrated diagrams for Device 1 and 2a, the BB LPF is needed, then some ACS and ACSC requirement is also supposed to be essential to verify its RF performance. (R4-2409598, ZTE) |
| Inband blocking | This depends on further coexistence study. (R4-2409598, ZTE)In-band blocking: necessary（[R4-2408220](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408220.zip) ,CMCC） |
| Out-of-band blocking | Don’t see the reason not to reuse the -15dBm CW signal as interference signal of OOBB requirement since the A-IoT device is also supposed to be nearby with other normal UEs operating in other frequency ranges. In addition, as shown in illustration diagrams for Device 1 and 2a, the RF BPF is also needed, then the OOBB requirement is also supposed to be essential to verify its RF performance. .(R4-2409598, ZTE)Out of band blocking: Further discuss the out of band blocking performance based on RF architecture discussion（[R4-2408220](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408220.zip) ,CMCC） |
| RX IMD | The analysis is somehow similar as Tx intermodulation requirement. .(R4-2409598, ZTE)Not necessary (R4-2407523, CATT) |
| 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. .(R4-2409598, ZTE)Not necessary (R4-2407523, CATT) |
| Rx spurious response requirement | This might be needed for R2D reception only. For backscattering transmission requirement, receiver spurious response requirement is not relevant anymore. (R4-2409598, ZTE)Not necessary (R4-2407523, CATT) |
|  | Input signal power range requirement of CW2D Rx is necessary.( R4-2407523, CATT) |
| Others | treat the reception of CW signals as part of Rx requirements for Ambient IoT Device 1, Device 2a.(R4-2409598, ZTE) |

### Issue 3-5: testability

* Proposals:
	+ A-IoT BS is micro-BS RAN4 to study the testability of the RF requirements for ambient IoT devices, including test method, performance metric, etc.( R4- 2409646, Huawei)
	+ OTA RF requirement should be discussed for A-IoT UE equipped with an antenna.( R4-2409097, Ericsson)
	+ RAN4 to study how to test a backscattering device, considering OTA methods and feasibility for conducted testing (R4-2407588, QC)
	+ RAN4 to discuss whether conducted conformance testing is still feasible for AIoT device. If not, it is suggested to define radiated requirement for device. (R4-2408094, vivo)
* Recommended WF
	+ TBA

### 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:
	+ RAN4 shall study if there is any impact due to the energy harvesting/storage on the co-existence, RF performance, and testability of AIoT devices.( R4-2407411, Sony)
	+ Energy harvesting requirements for ambient IoT device should be defined in RAN4, e.g., energy harvesting sensitivity or activation threshold.( R4-2408238, China Telecom)
	+ EH sensitivity can be studied in study phase.( R4-2409097, Ericsson)
* Recommended WF
	+ According to SID and RAN1 agreement, energy harvesting is not a common objective for RAN4

# Topic #4: Intermediate node （UE）

## Companies’ contributions summary

|  |  |  |
| --- | --- | --- |
| **T-doc number** | **Company** | **Proposals / Observations** |
| [**R4-2407524**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407524.zip) | CATT | Discussion on RF requirements of A-IoT intermediate node**Observation 1: A-IoT intermediate node potential Tx requirements are shown in Table 1, the requirements only consider device 1 and device 2a.****Observation 2: A-IoT intermediate node potential Rx requirements are shown in Table 2, the requirements only consider device 1 and device 2a.****Proposal 1: The RF requirements for the links working simultaneously need discussion according to the different DL/UL spectrum usage for A-IoT.** |
| [**R4-2407587**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407587.zip) | Qualcomm Incorporated | Intermediate node role in A-IoT system and study considerations**Observation 1: If Uu link and A-IoT are on same band or channel, Ran4 needs to discuss the co-ex aspects.** **Observation 2: If a UE can use DL spectrum to transmit should be confirmed from regulatory aspect.** **Observation 3: In order to study intermediate node requirements, the TAG behaviour and requirements should be well understood**.  |
| [**R4-2407718**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407718.zip) | Spreadtrum Communications | Discussion on RF requirements impact for intermediate node (UE)**Proposal 1: System bandwidths for R2D and D2R need to be further discussed in RAN4.****Proposal 2: the transmission power of CW and R2D needs to be further studied.****Proposal 3: interference cancellation ability and Maximum Sensitivity Degradation (MSD) need to be further studied.****Proposal 4: Power boosting for intermediate node (UE) by macro BS needs to be further studied.** |
| [**R4-2407824**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2407824.zip) | Xiaomi | Discussion on the RF impact of intermediate UE**Proposal 1: The Tx requirement of the intermediate UE for R2D can reuse NR UE’s requirements as starting point.****Proposal 2: RAN4 need to at least specify the MOP and related transmission emission limitation for CW waveform based on single-tone for intermediate UE if it need transmit CW for D2R backscattering.****Proposal 3: At least following Rx requirements need to specify for intermediate UE:*** **REFSENS**
* **Maximum input power**
* **ACS/ASCS**
* **Guard RBs for in-band/guard-band operation.**
* **ICS**
* **Blocking**
 |
| [**R4-2408095**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408095.zip) | vivo | Discussion on the RF requirement for intermediate UE**Proposal 1:** RAN4 discuss whether 50% success rate is also used for Rx requirement definition for AIoT BS.**Proposal 2:** The following table can be the starting point for AIoT device RF requirement discussion:

|  |
| --- |
| RF Requirement for AIoT device |
| System parameter | Operating band | Band n8 as example band in SI |
| Channel bandwidth | Transmission bandwidth configuration | 180 kHz, FFS larger bandwidth for higher data rate |
| Guard band | FFS |
| Minimum receiver bandwidth | RAN4 need to discuss whether this requirement is need considering the feasibility of RF filter |
| Tx requirement  | Transmit output power | Maximum output power | -25 dBm/100kHz for frequency <900MHz;-18 dBm/100kHz for frequency>900MHz;FFS whether/how to convert radiated requirement to conducted requirement  |
| Output power dynamic | Transmit OFF power | Same as NR, -40 dBm |
| Transmit time mask | FFS following requirement:Transmit-to-Receive Turn-Around Time;Receive-to-Transmit Turn-Around Time;Transmit Power-On Ramp; |
| Transmit signal quality | Frequency error | FFS |
| EVM | FFS, ASK/PSK are considered |
| IBE | FFS |
| Output RF spectrum emissions | Occupied bandwidth | Same as NR |
| SEM | Unwanted emission in [2] as starting point |
| ACLR | Depends on co-existence study |
| SE | Same as NR |
| Rx requirement  | RAN4 should first discuss and decide what metric will be used to represent the Rx performance, e.g., BLER, success rate, etc. |

 |
| [**R4-2408221**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408221.zip) | CMCC | Discussion on A-IoT intermediate UE RF requirements**Proposal 1: for intermediate UE band specific RF requirement analysis, it’s suggested to use n8(900MHz) as example band. Other example bands are not precluded.** **Proposal 2: max supported power class per band is only limited to upper bound as specified in current R18 spec, i.e. no need to consider PC1.5 for FDD bands in study phase.****Observation 1: It seems current legacy IBE requirements of UE still applies for intermediate UE.****Proposal 3: it’s suggested to assume that legacy IBE requirements of UE still applies for intermediate UE as starting point.****Proposal 4: it’s suggested to wait for co-existence analysis conclusion before define ICS requirement for intermediate UE when topology 2 reader using UL/DL spectrum for receive.****Observation 2: guard RB will help to improve IBE/ICS performance but will reduce spectrum utilization. It’s suggested to take care of this guard RB 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.****Observation 5: 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 5: 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 6: for CW outside of topology, it seems only max output power and spurious emission requirement is applicable. The same RF framework applies for both topology 1 and topology 2.** |
| [**R4-2408239**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408239.zip) | China Telecom | Consideration on RF requirements for Intermediate Node**Observation 1: The D2R waveform can be very different and is still under discussion in RAN1, and it may have impact on the design of the receiver, which will introduce new receiver requirements.****Proposal 1: RF requirements for traditional NR UE can be used as baseline for intermediate node, while new RF characteristics related to waveform need more input from RAN1.****Proposal 2: Suggest to consider high power immediate node if necessary.** |
| [**R4-2408818**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2408818.zip) | OPPO | further discussion on the regulation and UE requirements**Proposal 1: For 900MHz band, the FCC part 15 and ETSI EN 302 208, EN 300 220-2 can be considered from regulation perspective to derive the UE RF requirement.****Proposal 2: for 2.4GHz band, the FCC part 15 and ETSI EN 300 328 , EN 300 440 can be considered from regulation perspective to derive the UE RF requirement.****Proposal 3: The regulations for RFID can be a reference to be captured in the SI TR for further information.** |
| [**R4-2409096**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2409096.zip) | Ericsson | AIoT 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. |
| [**R4-2409599**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2409599.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. |
| [**R4-2409647**](https://www.3gpp.org/ftp/TSG_RAN/WG4_Radio/TSGR4_111/Docs/R4-2409647.zip) | Huawei, HiSilicon | Discussion on RF requirements for intermediate UE**Proposal 1: RAN4 to study the RF requirements on operating bands, channel bandwidth and channel arrangement for the intermediate UE node, which can be common to both readers and devices.****Observation 1: An intermediate UE needs to transmit R2D in either UL spectrum or DL spectrum of an FDD band. Both options are under consideration.****Observation 2: If CW is also provided by the intermediate UE, it will be transmitted in the UL spectrum.****Proposal 2: RAN4 to consider spectrum usage (UL or DL) for transmission and signal characteristics (R2D or CW) when defining Tx RF requirements for intermediate UEs.****Proposal 3:** **RAN4 to consider spectrum usage (UL or DL) for reception and CW interference when defining Rx RF requirements for intermediate UEs.** |

## Open issues summary

### Issue 4-1: start point

* Proposals:
	+ Three companies propose that the existing NR UE requirements should be as starting point for A-IoT intermediate UE.（R4-2407824,Xiaomi；R4-2408946,CMCC；R4-2408239,China Telecom ；R4-2409096,Ericsson）
	+ For 900MHz band, the FCC part 15 and ETSI EN 302 208, EN 300 220-2 can be considered from regulation perspective to derive the UE RF requirement.（R4-2408818,OPPO）
	+ for 2.4GHz band, the FCC part 15 and ETSI EN 300 328 , EN 300 440 can be considered from regulation perspective to derive the UE RF requirement. （R4-2408818,OPPO）
	+ The regulations for RFID can be a reference to be captured in the SI TR for further information. （R4-2408818,OPPO）
* Recommended WF
	+ The existing NR UE requirements can be used as starting point for A-IoT intermediate UE.

### Issue 4-2: TX

* Recommended WF
	+ The following table can be disussed for AIoT itermediate UE Tx RF requirement discussion:

|  |
| --- |
| **Tx part** |
| Maximum output power  | In last RAN4 meeting, it was agreed to use the UL spectrum for R2D transmission, therefore from our understanding, we could use the FDD PC3 as starting point for Ambient intermediate node transmission by reusing the same LPAMid module within UE. （R4-2409599, ZTE）In addition, for CW transmission, it’s still not clear to use DL or UL spectrum for transmission, its maximum transmission power could be further discussed later on. （R4-2409599, ZTE）max supported power class per band is only limited to upper bound as specified in current R18 spec, i.e. no need to consider PC1.5 for FDD bands in study phase.（R4-2408946,CMCC）Suggest to consider high power immediate node if necessary.（R4-2408239,China Telecom）Follow NR UE power class（R4-2408095,Vivo） |
| Output power dynamics | Some power boosting for OOK signal might be needed for in-band/guard band operation of A-IoT service if A-IoT intermediate node share the same hardware with legacy eMBB transmission in other PRBs e.g. sharing the same LPAMid module; （R4-2409599, ZTE）FFS following requirement: （R4-2408095,Vivo）Transmit-to-Receive Turn-Around Time;Receive-to-Transmit Turn-Around Time;Transmit Power-On Ramp;Transmit Power-Down RampPower boosting for intermediate node (UE) by macro BS needs to be further studied. （R4-2407718,Spreadtrum） |
| Transmit ON/OFF power | The transmit ON-OFF power is only limited for TDD bands, however A-IoT intermediate node might need to send the R2D signal and CW signal in the sequential way, then 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. （R4-2409599, ZTE） |
| Transmitted signal quality | The legacy UE transmit frequency error requirement could be reused for A-IoT intermediate node. （R4-2409599, ZTE）EVM for OOK signal should be defined accordingly. （R4-2409599, ZTE）Frequency error：±10 ppm（R4-2408095,Vivo）EVM：FFS, ASK/PSK are considered（R4-2408095,Vivo）IBE：FFS whether new IBE is needed since the SEM in [2] is more stringent（R4-2408095,Vivo） |
| Transmission times | RAN4 needs further analysis（R4-2407524,CATT） |
| OBW | The legacy UE OBW requirement could be reused for A-IoT intermediate node; （R4-2409599, ZTE） |
| Tx intermodulation | 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. （R4-2409599, ZTE） |
| ACLR | This depends on further coexistence study. （R4-2409599, ZTE） |
| Operating band unwanted emissions  | This depends on outcome of coexistence evaluation （R4-2409599, ZTE） |
| Transmitter spurious emissions | The legacy transmitter spurious emission requirement could be reused since this is coming from the ITU regulatory definition. （R4-2409599, ZTE） |

### Issue 4-3: RX

* Recommended WF
	+ The following table can be disussed for AIoT itermediate UE Tx RF requirement discussion:

|  |
| --- |
| **Rx part** |
| REFSENS | 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. （R4-2409599, ZTE）In addition, the impacts on CW signal transmission should be also taken into account especially for D2T2. （R4-2409599, ZTE）For D2T2-A2 deployment scenarios, some self interference on Ambient intermediate node should be taken into account. （R4-2409599, ZTE）RAN4 discuss whether 50% success rate is also used for Rx requirement definition for AIoT BS.（R4-2408095,Vivo）interference cancellation ability and Maximum Sensitivity Degradation (MSD) need to be further studied.（R4-2407718,Spreadtrum） |
| Maximum input power | Similar analysis for backscattering signal should be specified with measurement metric as miss detection ratio or false alarm detection ratio. （R4-2409599, ZTE） |
| ICS | it’s suggested to wait for co-existence analysis conclusion before define ICS requirement for intermediate UE when topology 2 reader using UL/DL spectrum for receive.（R4-2408946,CMCC） |
| ACS | This depends on further coexistence study. （R4-2409599, ZTE） |
| Blocking requirement | This depends on further coexistence study. （R4-2409599, ZTE） |
| OOBB | 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. （R4-2409599, ZTE） |
| RX IMD | This is somehow similar as Tx intermodulation requirement. （R4-2409599, ZTE）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. （R4-2408946,CMCC） |
| Rx spurious emission | The legacy UE receiver spurious emission requirement could be applicable. （R4-2409599, ZTE） |
| Receiver spurious response  | This might be needed for D2R reception only. （R4-2409599, ZTE） |
| others | The tolerance of CW signal within the same channel of the backscattered signal as interferer needs to be further studied.（R4-2409096,Ericsson）;Further study needed for the CW inside topology impact on the UE RF when UE is intermediate node.（R4-2409096,Ericsson）The RF requirements for the links working simultaneously（NR link and A-IoT link） need discussion according to the different DL/UL spectrum usage for A-IoT.（R4-2407524,CATT）If Uu link and A-IoT are on same band or channel, Ran4 needs to discuss the co-ex aspects. （R4-2407587,QC） |

### Issue 4-4: CW

* Recommended WF
	+ TBA （From R4-2408946, CMCC）

|  |  |
| --- | --- |
| requirement | Applicable or not |
| Operation bands | Single FDD DL or UL bands |
| Channel bandwidth related requirements | Not applicable |
| Channel arrangement related | Not applicable |
| Transmitter power | Applicable. Further check the power limitMPR/A-MPR not applicableConfigured output power, not applicable |
| Output power dynamic range | Minimum output power: not applicableON/OFF time mask: may not applicablePower control: not applicable |
| Transmit signal quality | Frequency error: not applicableTransmit modulation quality: not applicable |
| RF spectrum emission | Occupied bandwidth: not applicableOut 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 |