**3GPP TSG RAN WG1#117 R1-2405438**

**Fukuoka City, Fukuoka, Japan, May 20th – 24th, 2024**

**Agenda Item: 9.4.2.4**

**Source: Moderator (Spreadtrum Communications)**

**Title: FL summary#1 on CW waveform characteristics for A-IoT**

**Document for: Discussion and decision**

# Introduction

This feature lead summary (FLS) concerns the Rel-19 study item (SI) on solutions for Ambient IoT (Internet of Things) in NR [1]. The detailed objectives can be seen in appendix (section 9.2). This Rel-19 WGs level study item was preceded by a Rel-18 RAN study item [2, 3] and a Rel-19 SA1 study item [4, 5].

The final CW (carrier wave) FLS in last RAN1 meeting can be found in [6], and the discussion in RAN#103 can be found in [7]. The achieved agreements in previous meetings are attached in section 9.3. The agreements achieved in this meeting will be added in section 9.4.

The **Contact Information** for 9.4.2.4 is attached in section 9.1, please feel free to update the contact info, if any.

This document summarizes contributions [8]-[40] submitted to agenda item 9.4.2.4, i.e., discussion on the characteristics of carrier-wave waveform for a carrier wave provided externally to the Ambient IoT device. The section arrangement and numbering in this document based on the submitted contributions, the issues that included in the previous agreements or have been discussed extensively are placed at the front. If the summary missed or misunderstood companies’ views, FL apologizes for that, and companies can feel free to contact with FL or correct the position/views in the summary.

The issues in this document are tagged and color coded with High Priority or Medium Priority or Low priority. The issues that were in the focus of this round of the discussion are tagged **FL1.**

Follow the naming convention in this example:

* *..* *characteristics for A-IoT -v000.docx*
* *..* *characteristics for A-IoT -v001-CompanyA.docx*
* *..* *characteristics for A-IoT -v002-CompanyA-CompanyB.docx*
* *..* *characteristics for A-IoT -v003-CompanyB-CompanyC.docx*

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# CW waveform

## Characteristics of CW waveforms

In the previous meeting, it was agreed to study single-tone unmodulated sinusoid waveform and multiple unmodulated single-tone waveform (section 9.3). For these waveforms, several characteristics was considered for the study.

|  |
| --- |
| Agreement  Study at least the following characteristics of unmodulated single-tone and multiple unmodulated single-tone CW waveforms for backscattering:   * For D2R   + Reception performance   + Spectrum utilization of backscattered signal corresponding to the CW waveforms * CW interference suppression at D2R receiver   + Including complexity and CW cancellation capability value/range (if any)   + For scenarios ’A1’, ’A2’ and ’B’ * Relative complexity of CW generation |

For multiple unmodulated single-tone waveform, it was agreed that two unmodulated single-tones as a starting point. Section 2.1.1 to 2.1.4 discuss the above characteristics for single-tone unmodulated sinusoid waveform and two unmodulated single-tone waveform.

### D2R reception performance [Open]

Contribution [8], [9], [10], [12], [13], [14], [16], [18], [21], [23], [24], [26], [27], [30], [33], [34] discussed D2R reception performance for single-tone unmodulated sinusoid waveform and two unmodulated single-tones waveform. The general views or qualitative analysis are captured in the following table.

**Table 2.1.1-1 Qualitative analysis for D2R reception performance (Single-tone vs. Two single-tones)**

|  |  |  |
| --- | --- | --- |
| **Characteristics** | **Single-tone unmodulated sinusoid waveform** | **Two unmodulated single-tones** |
| D2R reception performance | * Suffered from deep fading in frequency [8] [12] [16] [18] [21] [33] | * Higher frequency diversity and robust in frequency selective frequency channel [8] [9] [10] [12] [13] [14] [16] [18] [21] [23] [24] [26] [27] [30] [33] [34] |

In addition to the above, several contributions provided simulation results. The performance gain and corresponding parameters are captured below.

**Table 2.1.1-2 Quantitative analysis for D2R reception performance (Single-tone vs. Two single-tones)**

|  |  |  |
| --- | --- | --- |
| **Contributions** | **Gain** | **Part of parameters or conditions\*** |
| [8] | 5dB | FSK, TDL-A 150 ns, Tone gap: 1.65 MHz, 10%BER |
| [10] | 3dB | Every tone has same transmission power and all received by device |
| [12] | 3dB | OOK, TDL-A 150 ns, 10% BLER, Tone gap: >6.7 MHz, two tones are equally shared the total transmit power, 1Rx |
| [16] | 3dB | OOK, TDL-A 100 ns, Tone gap: 1.2MHz, ideal suppression of the multi-tone interference |
| [21] | 6 dB | OOK, TDL-C 30ns, Tone gap: 7MHz, 1Rx, 1% BER |
| [24] | 3dB | OOK, TDL-A 30ns, Tone gap: 90KHz, 10% BLER |
| [34] | 6dB | FSK, TDL-A 300ns, Tone gap: 600KHz, 1% BLER |
| [35] | 5dB or 8dB | BPSK, TDL-A 30ns or150ns, Tone gap: 2.16MHz, 1% BLER |
| Note: Parameters here are for reference, details can be found in corresponding contributions. | | |

Contribution [10] observed that for the case of 2 Rx antennas, almost no frequency diversity gain at 10% BLER and ~4dB gain at 1% BLER. In addition, in the multi-path channel with short delay spread (e.g., 10 ns-level), the frequency diversity gain for multiple unmodulated single-tone waveform is expected to be obviously reduced [10].

Based on the above, at least the observations mentioned by the majority can be captured firstly. Therefore, the following proposal is considered.

**FL1 High Priority Proposal 2.1.1-1a: For D2R reception performance, at least the following observation is captured.**

* **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones provide higher frequency diversity gain in fading channel.**
  + **In general, ≥3dB gain can be observed (for 10% BLER or 1%BLER).**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Apple | Y |  |
| TCL | Y | Okay with this proposal. |
| OPPO | Yes with comments | The gap between 2 tones must be larger than coherent bandwidth:  **FL1 High Priority Proposal 2.1.1-1a: For D2R reception performance, at least the following observation is captured.**   * **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones with gap larger than coherent bandwidth provide higher frequency diversity gain in fading channel.**   + **In general, ≥3dB gain can be observed (for 10% BLER or 1%BLER).** |
| MTK | Comment | Similar view as OPPO. We are OK for the direction of this proposal. But we think actually without some specific assumptions, e.g., max channel delay spread, GB size, etc. it is hard to say ≥3dB gain can be observed for two unmodulated single-tones compared to single-tone unmodulated sinusoid waveform.  For example, as the simulation results shown in our paper, for TDL-A with DS = 300ns, if the GB between two unmodulated single-tones is only 75kHz, it is hard to observe a gain considering the GB is much less than the coherence BW of the channel.  So we suggest the following modifications  **FL1 High Priority Proposal 2.1.1-1a: For D2R reception performance, at least the following observation is captured.**   * **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones provide higher frequency diversity gain in fading channel.**   + **In general, ≥3dB gain can be observed for the case that the GB is comparable to the coherence bandwidth (for 10% BLER or 1%BLER).**     - **FFS other conditions for achieving the above observation if any.** |
| LGE | Y |  |
| NTT Docomo | Y |  |
| CEWiT |  | OK for the suggestion from Oppo. |
| xiaomi | Y |  |
| Huawei, HiSilicon | Comments | When discussing observations, we would not label them as a proposal but an observation, and hence would rephrase as follows (and also for the other observations in this section):  **FL1 High Priority Proposed~~al~~ Observation 2.1.1-1a: For D2R reception performance~~, at least the following observation is captured~~.**  While we agree with the direction of the observation, we would need to clarify that the performance gain takes place only if the frequency gap between the two tones is larger than the coherence bandwidth for the two unmodulated single-tone waveform.  For the bullet, we would like to make the observation clearer, by stating that the gain is seen at 1% BLER. |
| Panasonic | Y |  |
| Ericsson | Y | Though this observation is inline with our simulation result, there was no discussion on simulation assumption. We suggest the following qualitative observation.   * **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones provide higher frequency diversity gain in fading channel, depending on the frequency separation between the two tones.**   + **~~In general, ≥3dB gain can be observed (for 10% BLER or 1%BLER).~~**   A follow-up observation can be made by adding companies’ simulation assumptions. |
| FL2 | Based on the above, the following observation is considered.  **FL2 High Priority Proposed Observation 2.1.1-1b: For D2R reception performance,**   * **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones provide higher frequency diversity gain in fading channel, depending on the gap between the two tones.**   + **≥3dB gain can be observed for the case that the gap between tones is comparable to the coherence bandwidth (for 10% BLER or 1%BLER).** | |
| vivo | Y to FL2 proposal | |
| FL3 | After online discussion, the following qualitative observation is considered. Quantitative analysis will be discussed in **FL3 High Priority Question 2.1.1-1c’**.  **FL3 High Priority Proposed Observation 2.1.1-1c: For D2R reception performance,**  **Compared to single-tone unmodulated sinusoid waveform without frequency hopping, two unmodulated single-tones provide higher frequency diversity gain in fading channel, depending on the gap between the two tones.** | |
| Apple | Before drawing observation, FL please have a clear alignment on multi-tone definition, particularly whether the multi-tone is from CW node perspective, or D2R receiver point of view.  In our view, single tone frequency hopping is one special case of multi-tone. Also each CW node transmit single tone, and different CW node transmit different single tone, which is also multi-tone. Comparing to multitone by one CW node, two CW node transmit one tone each has 3dB power gain as well.  The clarification is needed for all remaining observations on multi-tone/single tone. | |
| Samsung | Generally fine with the FL’s proposal with slight modifications:  **FL3 High Priority Proposed Observation 2.1.1-1c: For D2R reception performance,**  **Compared to single-tone unmodulated sinusoid waveform without frequency hopping, two unmodulated single-tones provide higher frequency diversity gain in a fading channel, depending on the gap between the two tones and the channel’s coherence bandwidth.** | |

Based on the online discussion, for quantitative analysis, FL would like to ask companies whether simulation should be aligned among companies, if Yes, which parameters/conditions should be aligned.

**FL3 High Priority Question 2.1.1-1c’: For D2R reception performance, in addition to qualitative observation, whether quantitative analysis is needed. If Yes, whether/which simulation parameters/conditions should be aligned.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Samsung | Y | We think that a quantitative analysis is necessary to compare the candidates for CW and appropriately understand their pros and cons.  For this, we can have aligned assumptions as follows:   * Fading channel model * The choice of line coding * Power allocation between the two tones * Etc. |
|  |  |  |
|  |  |  |

### D2R spectrum utilization [Open]

Contribution [8], [9], [10], [12], [14], [16], [18], [21], [33] discussed D2R spectrum utilization for single-tone unmodulated sinusoid waveform and two unmodulated single-tone waveform. The views are captured in the following table.

**Table 2.1.2-1 Views for D2R spectrum utilization (Single-tone vs. Two single-tones)**

|  |  |  |
| --- | --- | --- |
| **Interpretations** | **Single-tone unmodulated sinusoid waveform** | **Two unmodulated single-tones** |
| D2R spectrum utilization part 1:  Required spectrum resources/BW | * Less bandwidth, shares the same bandwidth as the baseband signal[12] [16] [33] | * Require more spectrum resources [9] [16] [33] * Consumes N times the bandwidth of baseband signal[12] [14] |
| D2R spectrum utilization part 2:  Spectrum efficiency | * High spectrum efficiency, utilized bandwidth equals to baseband signal BW [10][12][16][18][21] | * Lower, as baseband signal is modulated into multiple carrier wave tone. [9] [10] [12] [18] [21][14] * Does not lead to a proportional reduction in spectrum utilization.[8] * If other signal cannot be transmitted within gap, spectrum efficiency decreases with the increasing gap size[12][19] |

Contribution [12] indicates that there is a trade-off between increased BW and diversity gain. Contribution [8] observed that a multi-tone carrier wave signal distributes energy across multiple tones, and overall power per frequency contribution from the backscattered transmission of a dual-tone carrier wave might be almost similar to that of single-tone carrier wave. Contribution [16] indicates that for the case there is less or no FDMed D2R, use multiple single tone can improved the spectrum utilization.

Based on the above, at least the observations mentioned by the majority can be captured firstly. Therefore, the following proposal is considered.

**FL1 High Priority Proposal 2.1.2-1a: For D2R spectrum utilization, at least the following observation is captured.**

* **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones will consume two times the bandwidth of baseband signal, which will lead to lower spectrum efficiency.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Apple | Need clarification | The device backscattering BW (over what spectrum the signal will be reflected) needs to be discussed and agreed. In our understanding, device with narrow backscattering BW is challenging for implementation. Therefore, depending on system BW, if D2R BW is wider, with single tone will not increase system capacity. |
| TCL | Y | Ok |
| OPPO | Yes |  |
| MTK | Y |  |
| LGE | Y |  |
| NTT Docomo | N | We agree that backscattered D2R on two single-tone will consume larger bandwidth than single-tone, however, we feel it does not equivalent to lower spectrum efficiency. |
| CEWiT | Y |  |
| xiaomi | Y |  |
| Huawei, HiSilicon | Yes | We agree with the observation. |
| Ericsson | No | The proposal confuses baseband bandwidth and RF bandwidth.  Spectrum efficiency or spectrum utilization is an RF concept rather than a baseband term. It is the spectrum utilized by both the wanted signal and unwanted emission, which power is above a threshold.  As observed in our contribution, if a threshold is drawn like the black line, the spectrum for backscattered transmission of a single-tone CW spans the range between two blue vertical lines, and that for two-tone CW the range between two purple lines.  Note that we include the frequency gap between two tones for the spectrum utilized for the latter. However, since each tone of 2-tone CW is transmitted with half power of that of single-tone CW, given the same transmission power of CW node, it requires smaller spectrum for the sidelobes to fall from their peaks to a level below the threshold, compared with the sidelobes of backscattered transmission of single-tone CW. With the two conflicting factors, it is hard to get a general conclusion that single-tone CW or multi-tone CW results in larger spectrum utilization.  Instead, we can draw a conclusion that the spectrum utilization of the two cases depends on factors, e.g., frequency gap between the two tones, power spectrum density used for spectrum utilization calculation. |
| **FL2/FL3** | Based on the above, the following is considered.  **FL2/FL3 High Priority Proposed Observation 2.1.2-1b: For D2R spectrum utilization**   * **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones will consume two times the bandwidth of baseband signal.** | |
| Futurewei |  | A question for clarification regarding the FL2 proposed observation: the frequency gap separating the two unmodulated single tones is excluded from the proposed observation? |
| vivo | OK to FL2 proposal. |  |
| Qualcomm |  | We suggest to also add the impact of guard band, which is needed between D2R backscattering per tone. For the concern on spectrum efficiency, we think it is mainly related with FDM, which can be clarified.  ‘…consume two times the bandwidth of baseband D2R signal and require guard band between the D2R backscattering signals per tone, which will lead to lower spectrum efficiency to use remaining spectrum for FDMed D2R’. |
| Samsung |  | The current proposal addresses spectrum utilization for D2R transmission. Therefore, the sub-bullet contents should also include a description of D2R transmission. However, to compare the bandwidth for D2R transmission, we first need to define it. For example, it could be defined as the bandwidth at which the signal power of the backscattered signal decreases below a certain level. |

### CW interference suppression at D2R receiver

Contribution [8], [9], [14], [15], [16], [18], [19], [20], [21], [23], [26], [28], [33], [38], [35], [34], [40] discussed CW interference suppression at D2R receiver. Based on the contributions and agreements, the issue include four parts

* Interference type at D2R receiver for CW transmission cases/scenarios
* Interference suppression for different interference type at D2R receiver
* Interference suppression for different CW waveforms at D2R receiver
* CW cancellation capability value/range

#### CW interference type at D2R receiver for CW transmission cases/scenarios [Open]

Contribution [8], [9], [14], [15], [16], [18], [19], [20], [21], [23], [26], [28], [33], [38], [35], [34], [40] shared views for CW interference types at D2R receiver for CW transmission cases/scenarios, the views are summarized below.

**Table 2.1.3.1-1: CW interference type at D2R receiver**

|  |  |  |  |
| --- | --- | --- | --- |
| **CW transmission cases** | **CW interference type at D2R receiver** | | |
| **‘A1’** | **‘B’** | **‘A2’** |
| Case 1-1: inside/DL | * Cross-link interference (CLI) [8] [14] [16] [19] [20][21] [26] [27] [35][40] | N/A | * Self-interference (SI) [8] [9][14][15] [16][18] [19] [20] [21] [23] [26] [28] [33][38] [35] [34] [40] |
| Case 1-2: inside/UL | * Cross-link interference (CLI) [8] [14] [16] [19] [20] [21] [27] [26] [40] | N/A | * Self-interference (SI) [8] [9] [14] [15] [16] [18] [19] [20] [21] [23] [26] [28] [33] [34] [35] [40] |
| Case 1-4: outside/UL | N/A | * Cross-link interference (CLI) [8] [14] [16] [19] [20] [21] [26] [27] [28] [35] [40] | N/A |
| Case 2-2: inside/UL | * Cross-link interference (CLI) [8] [14] [16] [19] [20] [21] [26] [35] [40] | N/A | * Self-interference (SI) [8] [9] [14] [15] [16] [18] [19] [20] [21] [23] [26] [28] [33] [34] [38][35] [40] |
| Case 2-3: outside/DL | N/A | * Cross-link interference (CLI) [8] [14] [16] [19] [20] [21] [26] [35] [40] | N/A |
| Case 2-4: outside/UL | N/A | * Cross-link interference (CLI) [8] [14] [16] [19] [18] [20] [21] [26] [28] [35] [40] | N/A |

Based on the above, it seems views on CW interference type at D2R receiver are converged, therefore, the following proposal is considered.

**FL1 High Priority Proposal 2.1.3.1-1a: For CW interference type at D2R receiver, at least the following observations are captured.**

* **For scenarios “B” and ‘A1’, the CW interference type at D2R receiver is cross-link interference.**
* **For scenarios “A2”, the CW interference type at D2R receiver is self-interference.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| Apple | Y |  |
| TCL | Y | Agree with this proposal. One issue is whether it need to discuss the clutter interference or not when CW node is configured indoor. But we are not sure whether clutter interference should be included in self-interference because similar suppressed methods with self-interference may be used for it. However, clutter interference suppression may need interference channel estimation like CLI. |
| OPPO | Yes |  |
| MTK | Y w/ comment | OK for the interference type captured in FL’s proposal.  In addition, in our view, for multi-tone case, cross-tone interference should be captured considering the non-linear operation at the device side (especially when the GB between multi-tone is small) |
| LGE | Y |  |
| NTT Docomo | Y |  |
| CEWiT | Y |  |
| xiaomi |  | We suggest to add the definition of the cross-link interference and the self-interference to align the understanding among companies. We prefer that the cross-link interference includes the interference between the CW and the NR signal, and the interference between the CW and the AIOT signal. So we make the following revision:  **FL1 High Priority Proposal 2.1.3.1-1a: For CW interference type at D2R receiver, at least the following observations are captured.**   * **For scenarios “B” and ‘A1’, the CW interference type at D2R receiver is cross-link interference.**   + Note: cross-link interference includes the interference between the CW and the NR signal, and the interference between the CW and the AIOT signal. * **For scenarios “A2”, the CW interference type at D2R receiver is self-interference.** |
| Huawei, HiSilicon | Yes | We think this observation is ok based on the agreed scenarios. |
| Panasonic | Y |  |
| Ericsson | Y |  |
| FL2/FL3 | Based on the above, the following is considered.  **FL2/FL3 High Priority Proposed Observation 2.1.3.1-1b: For CW interference type at D2R receiver**   * **For scenarios “B” and ‘A1’, the CW interference type at D2R receiver is cross-link interference.** * **For scenarios “A2”, the CW interference type at D2R receiver is self-interference.** | |
| Futurewei | FL2 suggestion is Ok. |  |
| vivo | OK to FL2 proposal |  |
| Samsung | Fine with FL2 proposal |  |

#### Interference suppression for different interference types at D2R receiver [Open]

Contribution [8], [9], [10], [12], [14], [15], [16], [17], [19], [21], [26], [28], [30], [33], [37] shared views on interference suppression for different interference types at D2R receiver. The views are summarized below.

**Table 2.1.3.2-1 Interference suppression for different interference types at D2R receiver**

|  |  |
| --- | --- |
| **Interference type** | **Interference suppression** |
| Self-interference | * Antenna isolation [9][10][14][16][19][26][30][37] * RF-IC suppression [8][16] [21] [30] * BB/IF self-interference cancellation [8] * BB filtering [16] [21][30] * Analog cancellation [10][19][30] * Digital cancellation[10][12][19] * Additional circulator or directional coupler[12][16] |
| Cross-link interference | * Antenna separation [10][12][19][30][37] * Analog cancellation[10][30] * Digital cancellation[10][19] * BB filtering [21][30] * Antenna design like polarization conversion [19] |

In addition to the above, contribution [8], [9], [14], [15], [17], [24], [28], [33], [34] think that frequency shift at device side would be beneficial to the interference suppression.

Contribution[11] propose that RAN1 to study if mitigation procedures/techniques based on existing tools (QCL relationship) in RAN1 specification can be used. Contribution [28] shares general views that interference can suppressed by hardware and/or algorithm implementations. Contribution [18] [26] also think that it should be up to BS or intermediate node implementation to handle self-interference. For direct interference, contribution [26] prefers to study possible solutions to compensate the interference. Contribution [8] thinks that synchronization between CWT and the reader needs to be studied.

Contribution [19] [28] pointed out that cross-link interference is weaker than self-interference. While contribution [9] thinks that interference cancellation may not be needed at the reader for CLI. Contribution [10][18][19][40]further indicates that the accuracy of channel estimation will impact the effect of the self-interference cancelation.

**FL1/FL3 Medium Priority Proposal 2.1.3.2-1a: For interference suppression for different interference types at D2R receiver, at least the following candidate techniques are captured.**

* **The following techniques can suppress the self-interference at D2R receiver:** 
  + Spatial domain cancellation: antenna isolation, additional circulator or directional coupler
  + Analog cancellation: RF-IC suppression, BB filtering, BB/IF self-interference cancellation
  + Digital cancellation: high pass filter, and/or spatial signalling processing
  + Frequency shift for PDRCH at device, if supported
* **The following techniques can suppress the cross-link interference at D2R receiver:** 
  + Spatial domain cancellation: antenna separation, antenna design
  + Analog cancellation: BB filtering, BB/IF interference cancellation
  + Digital cancellation: high pass filter, digital BB interference cancellation
  + Frequency shift for PDRCH at device, if supported

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| TCL | Y | Fine. We think the suppression techniques need to be further clarified. Circulator or directional coupler may be in analog cancellation? And BB filtering may be in digital cancellation? High pass filter can also used for analog domain. |
| OPPO | Comments | We suggest to use “D2R transmission” instead of “PDRCH” in the 4th sub-bullet in each bullet. |
| LGE |  | Same comment as OPPO. |
| xiaomi | Comments | For self-interference at D2R receiver, we prefer to add a method that configure the guard band between the CW and the backscattered uplink signal. Meanwhile, for the cross-link interference, we prefer to add a method that configure the guard band between the CW and AIOT signal (D2R or R2D). Meanwhile, it might be also feasible that rely on the gNB’s scheduling to avoid the simultaneous CW transmission and AIOT signal transmission.  so we make the following revision with blue part:   * **The following techniques can suppress the self-interference at D2R receiver:**    + Spatial domain cancellation: antenna isolation, additional circulator or directional coupler   + Analog cancellation: RF-IC suppression, BB filtering, BB/IF self-interference cancellation   + Digital cancellation: high pass filter, and/or spatial signalling processing   + Frequency shift for PDRCH at device, if supported   + Configure the guard band between the CW and the backscattered uplink signal. * **The following techniques can suppress the cross-link interference at D2R receiver:**    + Spatial domain cancellation: antenna separation, antenna design   + Analog cancellation: BB filtering, BB/IF interference cancellation   + Digital cancellation: high pass filter, digital BB interference cancellation   + Frequency shift for PDRCH at device, if supported   + configure the guard band between the CW and AIOT signal (D2R or R2D)   + Rely on the gNB’s scheduling |
| Huawei, HiSilicon | Yes, with comments | For both the main bullets, we do not prefer adding the frequency shift aspect since the feasibility of large frequency shift has not been ascertained in agenda 9.4.1.2.  For the RF interference cancellation for CLI, we need to make it clear that it requires the reader to reconstruct a local CW according to the received interference. |
| CEWiT | Comment | Ok with proposal. |
| Ericsson |  | Agree with OPPO. |
| vivo | Y w/ comment | For BB/IF self- interference seems belong to digital baseband suppression according to [8], which explains that ‘Note that BB/IF self-interference cancellation includes, for e.g., interference rejection combining and/or successive interference cancellation.’  In our understanding, IRC and SIC are usually considered as digital based band processing rather than analog domain suppression. |
| Qualcomm |  | For the subbullet “Frequency shift for PDRCH at device, if supported”, does it include small and large shift? We need shift anyway; otherwise, PDRCH and CW will be overlapping.  Not sure of the intention to list the schemes. Is it just up to implementation or need to consider potential spec impact? |
| s |  | For the cross-link interference, in addition to the current options, it may be possible to use transmission schemes (e.g., line coding) to achieve CW cancellation. Therefore, we would like to include this as an additional option. |

#### Interference suppression comparison for different CW waveforms at D2R receiver [Open]

Contribution [9], [14], [16], [18], [21], [23], [33], [34] compared interference suppression for different CW waveforms at D2R receiver. The views are summarized below.

**Table 2.1.3.3-1 Interference suppression comparison for different CW waveforms at D2R receiver**

|  |  |  |
| --- | --- | --- |
|  | **Single-tone unmodulated sinusoid waveform** | **Two unmodulated single-tones** |
| CW interference suppression | Lower complexity for interference suppression [12][14][16][18][21][23][33][34]  Easier to reconstruct the CW waveform [12][18]  High-pass filtering can be used in BB without *N*-cycle operation. [12] | Higher complexity for interference suppression [9][12][16][18][21][33]  More challenge to reconstruct the CW waveform [12][16][18]  High-pass filtering can be used in BB with *N*-cycle operation. [12][21]  Additional complexity on RFIC and high/bandpass filters [21][16] |

Contribution [12] observed that for reconstruction of local single-tone carrier-wave, hypothesis testing for only amplitude and initial phase can be used. While separate backscattered signal on each single-tone using RF narrowband band-pass filtering, requiring N RF chains. In addtion, Hypothesis testing with the risk that complexity increases with number of single-tone carriers (only suitable for 2 tones) [12]. Contribution [18] thinks that when CW is transmitted inside topology, the CW reconstruction for cancellation is up to implementation. In addition, contribution [12] indicated that considering modest complexity of D2R receiver at intermediate UE, it is recommended to support only the unmodulated single-tone waveform for external carrier-wave in Topology 2.

It seems majority observed that two unmodulated single-tones will lead to higher complexity for interference suppression. The following proposal is considered based on the above summary.

**FL1 High Priority Proposal 2.1.3.3-1a: For interference suppression for different CW waveforms at D2R receiver, at least the following observation is captured.**

* **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones will lead to higher complexity for interference suppression, e.g.,**
  + **More challenge to reconstruct the CW waveform for two unmodulated single-tones**
  + **Additional complexity on RFIC, high/bandpass filters**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Y/N** | | **Comments** |
| Apple |  | | We would like to clarify the case where each CW is single tone, but there are multiple CW nodes each transmitting different tones. In terms of interreference suppression, this is considered as multi-tones? |
| TCL | Y | | Ok. Agree with this proposal, however, it may start to discuss for two single-tone until the occupied and transmitted bandwidth of D2R signal is agreed. We think the suppressed methods for two single-tone at D2R received is decided by D2R bandwidth and the gap between two single-tone. |
| OPPO | Yes | |  |
| MTK | Y | |  |
| LGE | Y | |  |
| NTT Docomo | Y | |  |
| CEWiT | Y | |  |
| xiaomi | Y | |  |
| Huawei, HiSilicon | Yes | | We would like to remove the “e.g.” since the bullets actually describe the reasons for the high complexity for the 2 unmodulated single-tone waveform to perform IC.  There is a small typo – “challenge” should be replaced with “challenging”. |
| Panasonic | Y | |  |
| Ericsson | N | | Many interference cancellation methods are mentioned in Proposal 2.1.3.2-1a. We agree that for some methods, two-tone CW may be more complicated than single-tone CW. However, these methods may not be put into use. |
| FL2 | Based on the above. “e.g.” is removed.  **FL2 High Priority Proposed Observation 2.1.3.3-1b: For interference suppression for different CW waveforms at D2R receiver**   * **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones will lead to higher complexity for interference suppression,**    + **More challenging to reconstruct the CW waveform for two unmodulated single-tones**   + **Additional complexity on RFIC, high pass/bandpass filters** | | |
| Futurewei |  | FL2 suggestion is Ok. | |
| vivo |  | 1, Since the observation is made generally for single tone CW and two tone CW, without further distinguish mono-static and bi-static, and for bi-static case, the disadvantages regarding RF-IC and filters may not matters due to enough suppression can be achieved through spatial isolation.  2, we share similar question as ZTE mentioned during online discussion that, ‘More challenging to reconstruct the CW waveform’ seems further description of additional complexity on RF-IC, since RF-IC is to re-construct the CW interference for cancellation at receiver.  Hence, we suggest the following revision.  **FL2 High Priority Proposed Observation 2.1.3.3-1b: For interference suppression for different CW waveforms at D2R receiver**   * **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones will lead to higher complexity for interference suppression, if following methods are used.**   + **Additional complexity on RFIC, i.e., More challenging to reconstruct the CW waveform for two unmodulated single-tones**   + **Additional complexity on ~~RFIC,~~  high pass/bandpass filters** | |
| FL3 | Companies are invited provide comments on the latest version from online discussion. Constructive suggestions and wording improvements are highly welcomed.  **FL3 High Priority Proposed Observation 2.1.3.3-1c: For interference suppression complexity for different CW waveforms at D2R receiver,**   * **Compared to single-tone unmodulated sinusoid waveform without frequency hopping, two unmodulated single-tones:**   + **Is more complex to reconstruct the CW waveform for two unmodulated single-tones**   + **Requires additional complexity on RF interference cancellation and/or [highpass]/bandpass filters** | | |
|  |  | |  |
|  |  | |  |
|  |  | |  |

#### Interference suppression capability [Open]

Contribution [8], [10], [11], [12], [19], [21] discussed interference suppression capability

Contribution [8] observed reader's ability for CW cancellation can vary depending on whether the CW is a single-tone or multi-tone waveform, and proposed to study CW interference cancellation modeling considering the different scenarios (D1T1/D2T2-A1/A2/B), CW waveform (single-tone or multi-tone), and frequency shift applied by the device. The initial modeling proposed by [8] are as follows

* A2 (monostatic): CW cancellation = Spatial isolation + RF-IC suppression + BB/IF self-interference cancellation
* A1/B (bistatic): CW cancellation = CW2R pathloss + beam nulling + RF-IC suppression + BB/IF self-interference cancellation

Contribution [21] share similar views as contribution [8], and shared interference cancellation table (below). It can be seen that interference suppression capability includes three parts: Spatial separation or circulator, RF-IC and digital baseband processing. The total cancellation capability in [8] is, 110-140dB (for A2) and 140dB(for A1/B).

**Table 2.1.3.4-1 CW interference suppression capability for A2 and A1/B [21]**

|  |  |  |
| --- | --- | --- |
| **required CW interference suppression (dB)** | **monostatic BSC (i.e., A2)** | **bi-static BSC (i.e., A1/B)** |
| **Part 1**: Spatial separation or circulator | Less Spatial separation, 10-30dB | large spatial separation, 60dB (10m) |
| **Part 2**: RF-IC | RF-IC is feasible, up to 20-30dB | less/no RF-IC |
| **Part 3**: Digital baseband processing, e.g., high pass filter, and/or spatial signalling processing | high pass filter can avoid DC interference,  spatial signalling processing can avoid Tx/Rx signal interference.  Up to 80dB cancellation. | |

Contribution [10] shared values on total cancellation capability (**132dB**) for BS. The capability also includes three parts:

* Passive suppression, e.g., antenna placement technology 47dB and antenna physical separation 30dB, 47dB+30dB=77dB
* Analog cancellation, e.g., extra cancellation circuit 45dB
* Digital cancellation, e.g., cancellation circuit based on channel estimation 10dB

Contribution [12] shared values on total cancellation capability (**147-167dB**) for single tone CW. The capability also includes three parts:

* Path loss for an isolation distance of 20 meters: 57 dB
* RF interference cancellation : 10-30 dB
* Digital cancellation, high-pass filtering: e.g., >80 dB

Contribution [19] also provided values: 1) spatial domain, e.g., physical shielding through Tx/Rx antenna isolation or cross-polarization between Tx and Rx antennas which can provide about 40dB interference suppression. 2) about 50dB interference suppression can be provided by the interference cancelation in analog domain.

Based on the above, it seems CW interference cancellation capability include at least three parts:

* **Part 1:** Spatial domain, e.g., antenna isolation, additional circulator or directional coupler
* **Part 2:** Analog domain, e.g., RF-IC suppression, BB filtering, BB/IF self-interference cancellation
* **Part 3:** Digital domain e.g., high pass filter, digital BB interference cancellation

In order to capture CW interference suppression capability, companies are invited to provide CW interference suppression values for different domains, if any. Therefore, the following two questions are considered.

**FL1/FL3 High Priority Question 2.1.3.4-1a: For CW interference suppression capability at D2R receiver, companies are invited to fill out the following tables.**

**Note: CMCC’s values are filled in as an example, please check and update, if any**

**Table 2.1.3.4-2: CW interference suppression capability at D2R receiver for A2 (SI)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Company** | **Part 1**  **Spatial domain** | **Part 2**  **Analog domain** | **Part 3**  **Digital domain** | **Other part or note, if any** | **Total capability** |
| **CMCC** | Less Spatial separation, 10-30dB | RF-IC is feasible, up to 20-30dB | Up to 80dB cancellation. |  | 110-140dB |
| **Huawei, HiSilicon** | - | 10-30 dB by RF-IC | Up to 80 dB cancellation. | 40-60 dB, by circulator or directional coupler | 130-150 dB |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |

**Table 2.1.3.4-3: CW interference suppression capability at D2R receiver for A1/B (CLI)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Company** | **Part 1**  **Spatial domain** | **Part 2**  **Analog domain** | **Part 3**  **Digital domain** | **Other part,**  **if any** | **Total capability** |
| **CMCC** | 10m, large spatial separation, 60dB | less/no RF-IC | Up to 80dB cancellation. |  | 140dB |
| **Huawei, HiSilicon** | 10-20 m, large spatial separation, 50-60 dB | No RF-IC or  10-30 dB by RF-IC | Up to 80 dB cancellation |  | 130-150 dB |
|  |  |  |  |  |  |

The plan for CW interference suppression capability study is to capture CW cancellation capability value/range to the TR based on the feedback in table 2.1.3.4-2 and table 2.1.3.4-3. FL would like to collect companies’ suggestions or comments for the above tables and plan.

**FL1/FL3 High Priority Question 2.1.3.4-2a: Suggestions or comments on table 2.1.3.4-2 and table 2.1.3.4-3.**

|  |  |
| --- | --- |
| **Company** | **Comments** |
| **TCL** | For the value of spatial domain, it is up to whether physical separation is used, and we think the range of spatial domain can be [10-60dB]. |
| Ericsson | We think the companies should first agree on a common set of assumptions and based on that report the values for CW interference cancellation capability. It would be premature to directly agree on the values without any consensus on the assumptions. Also, we think that there should be separate tables for D1T1 and D2T2, and for single-tone and multi-tone cases |

### Relative complexity of CW generation [Open]

Contribution [8], [9], [12], [14], [16], [18], [21], [33], [34] compared relative complexity of CW generation for single-tone unmodulated sinusoid waveform and two unmodulated single-tones.

The views are summarized as follows:

* **The** **complexity difference of** **CW generation is marginal:** 
  + [8][12][14][16][18][33]
* **Multiple unmodulated single-tone increases the complexity**
  + [9] in particular, D1T1-B
  + [12] Complicated PA implementation
  + [33] needs to construct the multiple single-tone unmodulated sinusoid waveforms simultaneously
  + [34] high complexity/power consumption

In addition, contribution [35] propose to study the transmitter for single-tone waveform for CW for backscattering, include Non-OFDM-based transmitter and OFDM-based transmitter. While contribution [17] prefers to study in-band baseband generation of carrier wave reusing OFDM transmitter

Based on the above, at least the observations mentioned by the majority can be captured. Therefore, the following proposal is considered.

**FL1/FL3 High Priority Proposed Observation 2.1.4-1a: For relative complexity of CW generation**

* **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones increases the relative complexity of CW generation, but the difference is marginal.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| TCL | Y | Ok |
| OPPO | No | We suggest removing “but the difference is marginal”. There may be different implementations which lead to different levels of additional complexity. |
| MTK | Comment | OK for the suggestion from Oppo |
| LGE |  | Similar view as OPPO. |
| NTT Docomo | N | We suggest modification as  **For relative complexity of CW generation, at least the following observations is captured.**  **The different between single-tone unmodulated sinusoid waveform and two unmodulated single-tones is marginal.** |
| xiaomi | Y |  |
| Huawei, HiSilicon | Comments | While we agree that the CW generation complexity between the waveforms is marginal, one issue to be considered is the PAPR of the generated CW, which impacts the implementation of the power amplifier in the CW transmitter.  In our understanding, more tones in the multi-tone CW waveform lead to higher PAPR, which may cause power back-off especially for the case of reusing existing hardware of e.g. BS or intermediate UE to transmit the external CW. |
| Panasonic | Y |  |
| Ericsson |  | The proposal is too vague. We suggest to elaborate it. |
| Futurewei | Y |  |
| vivo | Y | Agree that the difference is marginal.  Besides, impacts of PAPR of two-tone CW is also marginal, in our understanding, if compared with OFDM transmitter with even higher PAPR which have been widely used. |
| Qualcomm |  | It is to compare with single-tone without FH. |

### Other characteristics for waveform [Open]

* **Power consumption and complexity at device side**

Contribution [16] observed that compared to single tone CW, there is no additional power consumption and complexity at AIoT device side by adopting multiple single-tone CW. While contribution [19] thinks that the complexity of the A-IoT device would increase exponentially with the number of single tone carrier wave reception with the wideband matching network and RF bandpass filter for each subband.

Based on the above, the views for power consumption and complexity at device side are different. At this stage, FL would like to check companies’ views on whether the power consumption and complexity at device side should be one of the characteristics of CW waveforms study.

**FL1/FL3 Low Priority Proposal 2.1.5-1a: Whether the power consumption and complexity at A-IoT device side should be one of the characteristics of unmodulated single-tone and multiple unmodulated single-tone CW waveforms for backscattering.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| xiaomi | comment | We think the difference of the power consumption and complexity might be minor between unmodulated single-tone CW and multiple unmodulated single-tone CW. |
| Huawei, HiSilicon | comment | We prefer to study the existing and already identified aspects first before considering any additional ones. |
| Ericsson | N | Devices may be unaware of the number of tones of CW. They modulate their data with whatever the single-tone or multi-tone CW with the same backscattering behavior, i.e., switching between impedances of different RF loads. The number of tones of the CW has no impact on devices in terms of power consumption and complexity. |

## Multi-tone waveform

In the last RAN1 meeting, it was agreed to study multiple unmodulated single-tone waveform. In addition, two unmodulated single-tones was agreed as a starting point, other number of tones and gap between tones are FFS.

|  |
| --- |
| Agreement  For CW waveform for D2R backscattering, multiple unmodulated single-tone is studied compared to single-tone in R19 SI.   * Two unmodulated single-tones as a starting point   + FFS: Other number of tones   + FFS: how large gap is needed between tones |

### Number of tones for multi-tone CW waveform [Open]

Contribution [9], [10], [12], [13], [14], [16], [18], [20], [21], [23], [26], [27], [34] shared views on number of tones. The views for different number of tones are summarized in the table below.

**Table 2.2.1-1 views/preference on number of tones**

|  |  |  |
| --- | --- | --- |
| **Options** | **Contributions** | **views** |
| 2 tones | [9], [10], [12], [13], [14], [16], [20], [21], [23], [26], [34] | * Multiple single tones require larger NR channel bandwidth/resources than a single tone[9][12][16] * Limited frequency diversity gain[12] [16] * Increased complexity of CW interference suppression[12][13][14] [16] * Increased PAPAR[12] * For simplicity and generalizability[20] * Increased number of tones has higher possibility of overlapping issue[26] |
| 3 tones | [10]: <=3 | * Three single-tone as CW waveform will achieve higher frequency diversity and occupy larger bandwidth[10] |
| 4 tones | [23]: 2 and up to 4 | * multi-tone based waveform is advantageous for mitigating the frequency fading and diversity gains[23] |

In addition to the above, contribution [18] thinks that multiple single tone carrier waves should be deprioritized in Rel-19 study, and contribution [26] propose that single-tone waveform should be assumed as the baseline for CW for D2R backscattering for R19 A-IoT. Contribution [35]observed that N>2 unmodulated single-tones can improve the D2R reception performance in case of large frequency-selective channel, but the available bandwidth of D2R backscattering is decreased by 1/(N-1).

Based on the above, it seems the majority prefer to study two unmodulated single-tones only. FL suggests the following proposal.

**FL1 High Priority Proposal 2.2.1-1a: For multiple unmodulated single-tone, other number of tones (i.e. >2) is not studied.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Y/N** | | **Comments** |
| Apple | N | | Need further study before drawing the conclusion, including system BW, D2R transmission BW needs to be discussed first. In case there are many CW nodes within a cell/reader, and each CW transmit only single tone, by device will backscattering all nearby CW node transmission, effectively forming multi-tone transmission. In this case, 2 is very limited. |
| OPPO | Yes | |  |
| MTK | Y | |  |
| LGE | Y | |  |
| CEWiT | Need a clarification | | It is not yet clear whether the tones are confined within a transmission bandwidth, or the tones are defined per transmission bandwidth. When tones are defined within transmission bandwidth and when tones are defined per transmission bandwidth, the maximum number of tones may differ in each case. Need a clarification on how to map multiple single tones to transmission bandwidth. |
| xiaomi | Y | | For more than two unmodulated single-tone, although the frequency diversity gain can be obtained, but the spectrum utilization is decreased and system complexity is increased, so for trade-off, the two tone is sufficient. |
| Huawei, HiSilicon | Yes | | Based on our analysis, increasing the number of tones would not cause the frequency diversity gain to increase proportionally, since the frequency gap between adjacent tones becomes smaller than the coherence bandwidth. Moreover, the spectral utilization becomes poorer and the interference cancellation becomes more complex.  Hence, tones higher than 2 should not be considered in the study. |
| Panasonic | N | | It is not clear whether the two tones are restricted for the device or reader. Even with a single or two tones per device, the reader may use higher numbers of tones to communicate with several devices. |
| Ericsson | N | | We are fine that 2-tone CW can be studied first. It is premature to preclude other numbers larger than 2. Proponents can bring results if obvious gains are observed. |
| FL2/FL3 | Based on the replies, the following proposal is considered.  **FL2/FL3 High Priority Proposal 2.2.1-1b: For multiple unmodulated single-tone transmitted by one CW node, other number of tones (i.e. >2) is deprioritized.**   * **Note: other number of tones (i.e. >2) is studied only when obvious gains are provided.** | | |
| Futurewei |  | FL2 suggestion is Ok; for FR1 NR in-band operation below 1 GHz, there is limited NR channel bandwidth to support more than 2 unmodulated single tones in order to accommodate multiple frequency gaps needed. | |
| vivo |  | Agree with FL2 proposal. | |
| Qualcomm |  | ok | |

### Gap between tones for multi-tone CW waveform [Open]

Contribution [8], [12], [16], [20], [23], [24], [25], [30], [34], [37], [38] discussed or mentioned the gap between tones. The views are as follows:

* **Views for gap determination factors**
  + Larger than the coherence bandwidth (related to delay spread, to achieve frequency diversity gain): [9][12][16][19][20][34][38]
  + Frequency shift and BW of main sidelobe [10][16]



**Figure 2.2.2-1 Frequency gap between two tones for two tone CW [16]**

* + Multiple of NR subcarrier spacing [25]
  + Harmonics impacts [12][10]
  + SFO impacts[10]
* **Detailed values for gap**
  + 1.65MHz: [8][30]
  + ~ 5MHz: [9][20]
  + 6.7MHz: [19]
  + 3 PRBs, 6PRBs and full bandwidth: [23]
  + 90KHz [24] (in their simulation)

Based on the above, it seems the gap values are quite divergent. However, most companies observed some factors for gap determination, e.g., the gap between tones should be larger than coherence bandwidth, which is related to the delay spread. Therefore, the following proposal can be considered.

**FL1 High Priority Proposal 2.2.2-1a: To determine the gap size of two unmodulated single-tones, at least the following aspects need to be jointly considered for further study:**

* **Coherence bandwidth**
* **D2R transmission BW**
* **frequency shift and BW of main sidelobe**
* **harmonics impacts**

|  |  |  |  |
| --- | --- | --- | --- |
| **Company** | **Y/N** | | **Comments** |
| OPPO | Comments | | In licensed spectrum how to determine the gap size should be fully up to gNB. We suggest to replace “To determine” with “On”  **~~To determine~~ On the gap size of two unmodulated single-tones, at least the following aspects need to be jointly considered for further study:** |
| LGE | Y | |  |
| NTT Docomo |  | | We think D2R system bandwidth also needs to be considered. |
| CEWiT |  | | Agree with NTT Docomo’s suggestion. |
| xiaomi | Y | |  |
| Huawei, HiSilicon | Yes | | We are fine with the proposal. |
| Ericsson | Y | |  |
| FL2/FL3 | The following can be considered.  **FL2/FL3 High Priority Proposal 2.2.2-1b: On the gap size of two unmodulated single-tones, at least the following aspects need to be jointly considered for further study:**   * **Coherence bandwidth** * **D2R transmission and system BW** * **frequency shift and BW of main sidelobe** * **harmonics impacts** | | |
| Futurewei |  | A question for clarification regarding the third bullet: what is BW of sidelobe? | |
| vivo |  | Agree with FL2 proposal. | |

## Variants for waveforms

### Single-tone waveform with frequency hopping [Open]

Contribution [8], [15], [16], [17], [21], [27], [35], [37] discussed single-tone waveform with frequency hopping, and part of these contributions ([8], [15], [17], [21], [27], [35]) observed that frequency hopping with an offset can improve the performance for single-tone waveform in fading channel. Contribution [21] analyzed characteristics (i.e. characteristics discussed in section 2.1) for single-tone waveform with frequency hopping

However, contribution [8] further observed that for backscattering based on 2-hop single-tone signal, to exploit the benefits of frequency diversity, repetition on bit-level or packet-level is required. Contribution [16] also observed the condition that TB level repetition is needed to achieve frequency diversity. the views from contribution[8][16] can be illustrated by the following figures.

|  |
| --- |
|  |
| 1. **Figure from contribution [8]** |
|  |
| 1. **Figure from contribution [16]** |

**Figure 2.3.1-1: repetition on bit-level/TB-level to achieve frequency diversity**

Based on the above, if single-tone waveform with frequency hopping needs to be studied, sevral **aspects** should considered based on the contributions, e.g., whether/how to achieve diversity gain (combine bit/TB repetition). Therefore, the following proposal is considered.

**FL1/FL3 High Medium Proposal 2.3.1-1a: Single-tone unmodulated sinusoid waveform with frequency hopping is studied by jointly considering the following aspects:**

* **Whether/how to achieve diversity gain (e.g., combine with bit/TB repetition)**
* **Gap between two hops**
* **Number of hops.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| NTT Docomo | Y | Agree tow study single-tone with frequency hopping. |
| xiaomi | comment | We propose to deprioritize the discussion for frequency hopping. |
| Huawei, HiSilicon | No | We do not see the need to involve frequency hopping for unmodulated single-tone, which can be viewed as implementation optimization since the frequency of CW is transparent to the device. |
| Ericsson | Y |  |
| vivo |  | We understood CW frequency hopping put additional constraints to achieve frequency diversity gain. But it seems no harm to further study and summarize these constraints. |

### Other views for waveforms [Open]

For multi-tone waveform, contribution [27], [35], [37] discussed the case that multi-tone waveforms from different node. Contribution [35] indicated that the two-tone CW from different nodes could have less self-interference than that of same node, but they need to be synchronized between two tones.

Contribution [34] proposed that multiple modulated single-tone and multiple unmodulated contiguous-tone are not supported as the candidate of CW. For this issue, FL’s understanding is that no discussion is needed as there is no contribution discussed these waveforms.

For the above, the following proposal is considered.

**FL1/FL3 Low Priority Question 2.3.2-1a: Whether the case of two single-tones transmitted from two different CW nodes should be studied. If yes, what characteristics need to be considered.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| xiaomi | N | The system level interference and the complexity are dramatically increased. |
| Huawei, HiSilicon | No | While it is very much possible that a device could receive CW from different CW nodes, the frequency of the CW is transparent to the device and hence would simply transmit the D2R based on the received CW. |
| Ericsson | N | This is a multi-static mode. It depends on topology of CW nodes. Some devices in the overlapping area of two CW nodes may receive the combined signal as a two-tone CW. We are concerned that devices close to one CW node and far from other CW node only backscatter a single-tone CW. It requires a reader to distinguish between the two kinds of devices. |
|  |  |  |
|  |  |  |

# CW transmission

## Cases without large frequency shift

For the case that D2R backscattering is transmitted in the same carrier as CW for D2R backscattering, Six CW transmission cases were agreed in the last meeting RAN1#116.

|  |
| --- |
| Agreement  For the case that D2R backscattering is transmitted in the same carrier as CW for D2R backscattering, and for topology 1, the following cases for CW transmission are studied.   * Case 1-1: CW is transmitted from inside the topology, transmitted in DL spectrum * Case 1-2: CW is transmitted from inside the topology, transmitted in UL spectrum * Case 1-4: CW is transmitted from outside the topology, transmitted in UL spectrum   Agreement  For the case that D2R backscattering is transmitted in the same carrier as CW for D2R backscattering, and for topology 2, the following cases for CW transmission are studied.   * Case 2-2: CW is transmitted from inside the topology (i.e., intermediate UE), transmitted in UL spectrum * Case 2-3: CW is transmitted from outside the topology, transmitted in DL spectrum * Case 2-4: CW is transmitted from outside the topology, transmitted in UL spectrum |

The agreed cases in RAN1#116 can be illustrated by the following figure.

|  |  |  |  |
| --- | --- | --- | --- |
| Case 1-1 | Case 1-2 | Case 1-4 |  |
|  |  |  |  |

**Figure 3.1-1 CW transmission for topo 1**

|  |  |  |  |
| --- | --- | --- | --- |
| Case 2-2 | Case 2-3 | Case 2-4 |  |
|  |  |  |  |

**Figure 3.1-2 CW transmission for topo 2**

Contribution [8], [9], [10], [12], [13], [14], [16], [17], [18], [19], [20], [21], [22], [23], [24], [25], [26], [28], [29], [30], [31], [33], [34], [37], [38], [39] continue shared views for those CW transmission cases.

### CW transmission cases for topo 1 [Open]

Views from contributions for the topology 1 CW cases are summarized below.

**Table 3.1.1-1 views for CW transmission cases for topology 1**

|  |  |  |
| --- | --- | --- |
| **CW Transmission case** | **Advantages** | **Disadvantages** |
| Case 1-1: inside/DL | * CW transmission by BS in DL spectrum is in-line with existing spectrum regulations.[12] * Low power D2R backscattered transmissions would not interfere with other R2D transmissions in the DL spectrum.[12] * Higher CW power[20] | * FDD gNB needs to support full-duplex capability (for A2) [8][16][10][12][14] [22][29] [30] [37] * Additional hardware is required at gNB to receive D2R transmissions in DL spectrum. [8] [16][38][12] [21] [33] * D2R in DL spectrum, which may conflict the regulatory restraints[10][13] [14][26] [29][33] [38] * Spatial isolation is only possible for ‘A1’. [12] * Dense deployment of gNBs, less cost-efficient [8] |
| Case 1-2: inside/UL | * No changes required at BS to receive D2R transmissions in UL spectrum. [12][16] * No regulation limitation for gNB to transmit CW in UL band. [19][23] | * FDD gNB needs to support full-duplex capability(for ‘A2’) [8] [13] [14][16] [22] [29] [33][37] * Additional hardware is required at gNB to transmit CW in UL spectrum. [8] [13] [12] [33] [21] * CW transmission by BS in UL spectrum is not allowed as per existing spectrum regulations. [12] [38] [14][17] [26] [29] [33] * Spatial isolation is only possible for ‘A1’. [12] * Dense deployment of gNBs, less cost-efficient [8] |
| Case 1-4: outside/UL | * In-line with existing spectrum regulations. [8] [12] [14] [26][33] [37] [38] * No changes required at BS to receive D2R transmissions in UL spectrum. [12] [14][16][33] * Full duplex capability is not required[16][33] [24] [30] * Spatial isolation is possible, reducing the received interference power. [12] |  |

For regulation issue, contribution [12] indicated that regulatory issues like this pertain to the interference to other RATs, such consistence evaluations are expected to be handled by RAN4, while contribution [15] thinks that it is necessary to first check the global regulatory aspects.

In the above table, the views for regulation are divergent, e.g., contribution [19] [23] point out that no regulation limitation for gNB to transmit CW in UL band. While contribution [12] [38] [14][17] [26] [29] [33] understand that CW transmission by BS in UL spectrum is not allowed as per existing spectrum regulations. Contribution [17] proposes to study whether reduced gNB transmit power (e.g., maximum 23/26 dBm as UE) could satisfy the regulation.

During the offline discussion in last RAN1 meeting, company's views are also very divergent for regulation. Some views mentioned that spectrum regulation is out of 3GPP work scope.

Based on the situation for regulation, FL’s suggestion is that, RAN1 only identify whether the spectrum used for CW/D2R transmission is in-line with the usage of current spectrum, and RAN1 does not discuss whether the case is allowed by the regulation or not.

Based on the table and the above, the following proposals are considered for topology 1.

**FL1/FL3 High Proposed Observation 3.1.1-1a: For CW transmission case 1-1**

* **Advantages of case 1-1:**
  + **CW transmission by BS in DL spectrum is in-line with the existing spectrum usage**
  + **Low power D2R backscattered transmissions would not interfere with other R2D transmissions in the DL spectrum**
  + **Higher CW power**
* **Disadvantages of case 1-1:**
  + **For ‘A2’, FDD gNB needs to support full-duplex capability for CW transmission and D2R reception**
  + **Additional hardware is required at gNB to receive D2R transmissions in DL spectrum**
  + **D2R in DL spectrum is not in-line with the existing spectrum usage**
  + **Spatial isolation is only possible for ‘A1’**
  + **Dense deployment of gNBs, less cost-efficient**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| TCL | Y | Okay with this proposal. |
| OPPO | Comments | We disagree with “Low power D2R backscattered transmissions would not interfere with other R2D transmissions in the DL spectrum”, due to the large SFO of AIOT devices and near-far effect there may be interference to R2D reception. |
| NTT Docomo | Y |  |
| CEWiT | Y | Suggestion, device capability needs to be considered for e.g. whether device supports large frequency shift or not to study the case 1-1. |
| Huawei, HiSilicon | Comments | We are fine with the advantages, but have a few comments on the disadvantages.  For the 1st bullet, since the focus of these cases is to select the spectrum on which the CW is to be transmitted, the requirement for the BS to support full duplex for A2 is true immaterial of whether we use the DL or UL spectrum. It also depends on the deployment scenario considered. Hence it does not make sense to use this as a disadvantage.  For the 2nd bullet, most components in the RF chain of the BS can support reception from both the DL and UL spectrum, apart from a few filters, and it would not warrant being labelled as a disadvantage.  For the 3rd bullet, while existing regulations do not cover such a scenario, it is our understanding that the D2R backscattered transmissions would be of a much lower, and hence would not cause interference to the other transmissions in the DL spectrum.  For the 5th bullet, it is not clear why a dense deployment of BSs would be required, since the CW in the DL spectrum can be transmitted at a higher power, and would actually increase the coverage and reduce the number of CW nodes required. |
| Ericsson |  | Perhaps it would be good to further clarify the following advantage:   * + **Low power D2R backscattered transmissions would not interfere with other R2D transmissions in the DL spectrum**   Regarding the disadvantages, could FL confirm the first subbullet does not apply to A1? If so, a price is that A1 has to offer double number of BS compared with A2.  For the last sub-bullet, we suggest to make it clear that the dense deployment of gNB is compared with Case 1-4 and add that A1 requires double number of gNBs of that of A2. |
| vivo |  | For ‘Low power D2R backscattered transmissions would not interfere with other R2D transmissions in the DL spectrum’, it seems belong to inter/intra-AIoT system co-existence, and prefer to let RAN4 to make the observations. |
| Qualcomm |  | ‘higher CW power’ means to compare with CW in UL?  Not sure whether/how to capture the spectrum usage aspect.  Prefer to replace ‘gNB’ by BS to align with the SID terminology.  Also, what does ‘**Dense deployment of gNBs, less cost-efficient**’ mean? |

**FL1/FL3 High Proposed Observation 3.1.1-2a: For CW transmission case 1-2**

* **Advantages of case 1-2:**
  + **No changes required at BS to receive D2R transmissions in UL spectrum**
* **Disadvantages of case 1-2:**
  + **For ‘A2’, FDD gNB needs to support full-duplex capability for CW transmission and D2R reception.**
  + **Additional hardware is required at gNB to transmit CW in UL spectrum**
  + **CW transmission by BS in UL spectrum is not in-line with the existing spectrum usage**
  + **Spatial isolation is only possible for ‘A1’**
  + **Dense deployment of gNBs, less cost-efficient**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| OPPO | Yes |  |
| NTT Docomo | Y |  |
| CEWiT | Yes |  |
| Xiaomi | Y |  |
| Huawei, HiSilicon | Comments | For the disadvantages, we have the same comments for the 1st and last bullet as Proposal 3.1.1-1a. |
| Ericsson | N | We don’t agree with “No changes required at BS to receive D2R transmissions in UL spectrum”.  There needs to be changes to the existing BS software to handle Ambient IoT. Whether changes are required at the BS RF depends on several factors (e.g., D2R waveform, D2R frame structure, etc.), and not just the spectrum. |
| Qualcomm |  | Not sure whether/how to capture the spectrum usage aspect.  Prefer to replace ‘gNB’ by BS to align with the SID terminology.  Also, what does ‘**Dense deployment of gNBs, less cost-efficient**’ mean? |

**FL1/FL3 High Proposed Observation 3.1.1-3a: For CW transmission case 1-4**

* **Advantages of case 1-4:**
  + **In-line with the existing spectrum usage**
  + **No changes required at BS to receive D2R transmissions in UL spectrum**
  + **Full duplex capability is not required for CW transmission and D2R reception**
  + **Spatial isolation is possible, reducing the received interference power**
* **Disadvantages of case 1-4:**
  + **No obvious disadvantage is observed**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| TCL | Y | Okay with this proposal. |
| OPPO | Yes |  |
| NTT Docomo | Y |  |
| CEWiT |  | Proper coordination needs to be maintained between the CWN and the BS, to ensure that the carrier wave should be transmitted in the UL spectrum for the case 1-4, therefore additional signaling exchange required between CWN and reader. |
| xiaomi | Y |  |
| Huawei, HiSilicon | Yes | We agree with the proposal. |
| Ericsson | N | We don’t agree with “No changes required at BS to receive D2R transmissions in UL spectrum”.  There needs to be changes to the existing BS software to handle Ambient IoT. Whether changes are required at the BS RF depends on several factors (e.g., D2R waveform, D2R frame structure, etc.), and not just the spectrum. |
| Futurewei | Y |  |
| vivo |  | One disadvantage for case 1-4 should be ‘lower CW Tx power’. |
| Qualcomm |  | Need to consider the cost and complexity of outside CW.  The outside CW requires additional node, which needs coordination with the reader.  The CW estimation is also more complicated than self-CW. |

### CW transmission cases for topo 2 [Open]

Views from contributions for the topology 2 cases are summarized below.

**Table 3.1.2-1 views for CW transmission cases for topology 2**

|  |  |  |
| --- | --- | --- |
| **CW Transmission case** | **Advantages** | **Disadvantages** |
| Case 2-2: inside/UL | * CW transmission by intermediate UE in UL spectrum is in-line with existing spectrum regulations.[12] [14][33] * D2R transmissions by device in UL spectrum is in-line with existing spectrum regulations.[12] [14] [33] | * Intermediate UE needs to support full duplex(for A2) [8] [14][16][13][23][22] [29] [30] [33][38] * Additional hardware is required at UE to receive D2R in UL spectrum. [8] [13] [16] [33] [34] [38] [14] [21] [26][37] [38] * Spatial isolation is only possible for ‘A1’. [12] |
| Case 2-3: outside/DL | * UE does not need to support higher capability, e.g., reception in DL, Full duplex capability [8] [14][16] [21] [24] [33] * Spatial isolation is possible, reducing the received interference power.[12] | * A-IoT Tx in DL band, spectrum restraints [33][10][13][14] [26] [29] |
| Case 2-4: outside/UL | * D2R in UL spectrum is in-line with existing spectrum regulations. [12][33] [26] [29] * Spatial isolation is possible, reducing the received interference power. [12] * Full duplex capability is not required[33] [16] [24] | * Additional hardware is required at UE to receive D2R in UL spectrum. [16][33] [34] [21] [37][38] |

In addition to the above, contribution [8] observed that supporting both Case 1-4 and Case 2-3 may require devices to differentiate the two topologies. Contribution [12] observed that for case 2-3, the complexity of the intermediate UE is increased since it would be required to support reception on the DL spectrum and UL spectrum (to support the CW being transmitted from inside the topology). Contribution [8][14] mentioned that intermediate UE needs to support full duplex, if an intermediate UE simultaneously receives D2R in an UL band and transmits to gNB for Uu interface in the same UL band. For this views, FL suggests to focus on the full duplex capability for intra A-IoT transmission first, e.g., CW transmission and D2R reception.

For regulation, same suggestion as section 3.1.1. Based on the above, the following proposals are considered.

**FL1/FL3 High Proposed Observation 3.1.2-1a: For CW transmission case 2-2**

* **Advantages of case 2-2:**
  + **CW transmission by intermediate UE in UL spectrum is in-line with the existing spectrum usage**
  + **D2R transmissions by device in UL spectrum is in-line with the existing spectrum usage**
* **Disadvantages of case 2-2:**
  + **For ‘A2’, intermediate UE needs to support full duplex for CW transmission and D2R reception**
  + **Additional hardware is required at UE to receive D2R in UL spectrum**
  + **Spatial isolation is only possible for ‘A1’**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| TCL | Y | Okay |
| OPPO | Yes |  |
| NTT Docomo | Y |  |
| CEWiT | Yes |  |
| Huawei, HiSilicon | Comments | For the disadvantages, for the 1st bullet, the requirement for full duplex depends on the deployment scenario, irrespective of the spectrum used. Hence it does not make sense to use this as a disadvantage. |
| Ericsson | Y |  |
| Futurewei | Y |  |
| vivo | comments | For ‘ **Spatial isolation is only possible for ‘A1’** in disadvantages, our view is that the spatial isolation may be possible even for A2, since the CW transmitter and D2R receiver may use different antennas, although the spatial isolation is lower compared with ‘A1’ which is bi-static. |
| Qualcomm |  | Not sure whether/how to capture the spectrum usage aspect. |

**FL1/FL3 High Proposed Observation 3.1.2-2a: For CW transmission case 2-3**

* **Advantages of case 2-3:**
  + **UE does not need to support higher capability, e.g., reception in DL, full duplex capability for CW transmission and D2R reception**
  + **Spatial isolation is possible, reducing the received interference power**
* **Disadvantages of case 2-3:**
  + **A-IoT Tx in DL band is not in-line with the existing spectrum usage**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| OPPO | Yes |  |
| NTT Docomo | Y |  |
| CEWiT | Yes |  |
| xiaomi | Y | For this case, one advantage is that no changes required at UE to receive D2R transmissions in DL spectrum. So we add the following blue part:   * **Advantages of case 2-3:**   + **UE does not need to support higher capability, e.g., reception in DL, full duplex capability for CW transmission and D2R reception**   + **Spatial isolation is possible, reducing the received interference power**   + **no changes required at UE to receive D2R transmissions in DL spectrum** |
| Huawei, HiSilicon | Comments | For case 2-3 alone, it is true that the intermediate UE can receive in the DL spectrum, but in order to support the case when the device is inside the topology, it would anyway have to support receiving in the UL spectrum.  In our view, this would place an additional burden on the UE to support both, and to reduce complexity, only receiving on the UL spectrum is preferred. |
| Ericsson | Y |  |
| Futurewei | Y |  |
| vivo | Y |  |
| Qualcomm |  | Need to consider the cost and complexity of outside CW.  The outside CW requires additional node, which needs coordination with the reader.  The CW estimation is also more complicated than self-CW. |

**FL1/FL3 High Proposed Observation 3.1.2-3a: For CW transmission case 2-4**

* **Advantages of case 2-4:**
  + **Full duplex capability is not required for CW transmission and D2R reception**
  + **D2R in UL spectrum is in-line with the existing spectrum usage**
  + **Spatial isolation is possible, reducing the received interference power**
* **Disadvantages of case 2-4:**
  + **Additional hardware is required at UE to receive D2R in UL spectrum**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| TCL | Y | Okay |
| OPPO | Yes |  |
| NTT Docomo | Y |  |
| Huawei, HiSilicon | Comments | The intermediate UE would have to support receiving in the UL spectrum since the only option for this UE to support the inside topology case is to transmit in the UL spectrum, resulting in it having to support reception of the D2R transmission in the UL spectrum. |
| CEWiT | Yes |  |
| Ericsson | Y |  |
| Futurewei | Y |  |
| vivo | Y |  |
| Qualcomm |  | Need to consider the cost and complexity of outside CW.  The outside CW requires additional node, which needs coordination with the reader.  The CW estimation is also more complicated than self-CW. |

### Down selection for CW cases [Closed]

Several contribution continue share views for down selection for CW cases without large frequency shift, the views are summarized as follows.

**Table 3.1.3-1 preference for CW transmission cases**

|  |  |  |
| --- | --- | --- |
|  | **Deprioritize** | **Prioritize** |
| Case 1-1 | [13] ,[18], [39] | [12], [24] |
| Case 1-2 | [9], [10], [13] , [28] | [15] ,[18] ,[19], [21] , [24] , [30] |
| Case 1-4 |  | [12], [13], [15] ,[18] ,[19] , [21] , [25] , [26], [29] , [30] , [31], [37] |
| Case 2-2 | [34] | [15], [18], [19], [24], [25], [30], [31] , [37] |
| Case 2-3 | [10] , [13], [18] , [28], [31], [34] , [39] | [21] |
| Case 2-4 |  | [14], [15] ,[18] ,[19] , [21] , [25] , [26], [29] , [30], [31] , [37] |

Down-selection of CW transmission cases was discussed in the previous meeting, but no consensus was reached.

FL observed that all the CW transmission cases have been inputted into the simulation section and RAN4, whether to down-select CW cases for evaluation or coexistence studies should be discussed in simulation section(9.4.1.1) or RAN4. Otherwise, additional LS may needed to inform such a modification to RAN4. This may affect RAN4’s work plan and progress.

The CW discussions in this section are focused on the interference type and the pros/cons, the observed workload is not that heavy. In order to avoid further redundant discussion and save time, down-selection discussion is not suggested. Whether the CW cases are suitable for deployment can be discussed in later phase.

Therefore, FL suggests to close the discussion of this issue.

**FL:** No further down-selection of CW transmission cases is pursued in A.I 9.4.2.4 in SI phase.

## Cases with large frequency shift [Postponed]

In the last RAN1 meeting,CW transmission cases with large frequency shift was discussed, the proposal in the last RAN1 meeting [6] is as follows.

|  |
| --- |
| **FL7 Medium Priority Proposal 2.2-3a:**  For the case that D2R backscattering is transmitted in the different band as CW for D2R backscattering, and for topology 1, at least the following case for CW transmission is studied.   * Case 1-1a: CW is transmitted from inside the topology, transmitted in DL spectrum   For the case that D2R backscattering is transmitted in the different band as CW for D2R backscattering, and for topology 2, at least the following case for CW transmission is studied.   * Case 2-2a: CW is transmitted from inside the topology (i.e., intermediate UE), transmitted in UL spectrum   Note: This study can be captured in the TR only when the support of frequency shifter is confirmed in 9.4.1.2. |

According to the feedback last meeting, many companies prefer to defer the study, until 9.4.1.2 confirm its capability for backscattering device, the discussion is postponed.

In this meeting, several contributions( [8], [18], [14], [15], [21], [23], [24], [25], [28], [30], [33], [34], [37]) continue discussed CW transmission with frequency shift capability (e.g., CW transmitted in DL band, and D2R transmitted in UL band). Contribution [8] indicated that a drawback common for the cases without a large frequency shift between CW transmission and backscattered transmission is the direct interference from CW node to gNB.

The proposed CW transmission cases with large frequency shift are summarize below.

**Table 3.2-3 Priority views for CW cases with large frequency shift**

|  |  |  |  |
| --- | --- | --- | --- |
| **Cases for topo1** | **Supporters** | **Cases for topo2** | **Supporters** |
| Inside CW in DL, D2R in UL | [8][15][24][30][33][34][37] | Inside CW in DL, D2R in UL | [33] |
| Inside CW in UL, D2R in DL | [24] [33] | Inside CW in UL, D2R in DL | [21] [24] [33] [34] [37] |
| Outside CW in DL, D2R in UL | [33] [34] | Outside CW in DL, D2R in UL | [15] [30] [33] |
| Outside CW in UL, D2R in DL | [33] | Outside CW in UL, D2R in DL | [33] [34] |

Contribution [33] shared detailed analysis for the above cases. In addition to the above, serval contributions [26][28] shared negative views for CW cases with large frequency shift.

Contribution [18] proposes to deprioritize D2R backscattering is transmitted in the different carrier as CW for D2R backscattering, until 9.4.1.2 confirms the support of large frequency shift for device type 1. This contribution also observed that the power consumption is at least in order of 100 µW, if the tag support frequency shift from DL spectrum to UL spectrum.

RAN 1 agreed the following agreement to check the feasibility of large frequency shift, and no consensus for now.

|  |
| --- |
| Agreement  Further study the feasibility of large frequency shift (large FS, i.e. between DL/UL spectrum of an FDD band) for device 2a considering at least following aspects.   * Power consumption characteristics * Frequency shift range and granularity * Image suppression or SSB backscatter for large FS * IF carrier frequency accuracy * Harmonics suppression   Note: the necessity (including applicable potential scenarios) of large FS can still be discussed in other agendas of the SI |

Therefore, until 9.4.1.2 confirm its capability for backscattering device, the discussion is postponed.

**FL:** Until 9.4.1.2 confirm its capability for backscattering device, the discussion on CW cases with large frequency shift is postponed.

## CW interference at base station [Open]

Several contributions discussed CW interference at base station.

Contribution [23] analyzed gNB-gNB CLI, intra-cell CW-gNB interference, etc., for CW transmission cases. Contribution [21] also analyzed CW interference at base station, e.g., NR gNB UL reception may suffer interference from CW for case1-2/1-4. Contribution [34] prefers to study interference handling at Uu UL reception.

Contribution[19] propose to study interference between NR UL signal and R2D/D2R A-IoT transmissions in UL spectrum. Contribution [20] also propose to study potential interference types at base station for topology 1 and topology 2, e.g., for topo1, The NR UL signal and the IoT signal are received at the same time by gNB if one device and one gNB are considered.

Contribution [24] thinks that for the interference at the BS, interference handling might be up to the BS implementation. While contribution [26] propose to study CW interference to UL reception at BS and potential solutions to eliminate interference between CW/D2R and NR signal. Contribution [17] propose to study in-band transmission of carrier wave and the required frequency guard band to reduce the interference between carrier wave and UE UL data. Contribution[15] thinks that for CW interference in legacy NR system, study TDM and FDM between the legacy NR and AIoT systems are studied as a starting point. Contribution [37] proposed that in topology 2, the CW interference handing method at NR base station includes guard band between CW and gNB, a CW power control by gNB et.al.

Contribution [16] pointed out that for interference types other than CW interference, e.g., NR transmission aggressor and AIoT victim or AIoT aggressor, AIoT victim, belongs to co-existence study, can be left to RAN4 co-existence evaluation. Further comparison and down-selection of the CW transmission cases can be considered after observations from RAN4 co-existence evaluation are ready.

Similar to contribution [16], contribution [35] also thinks that RAN1/4 will both discuss the co-existence scenarios. The coexistence evaluation study, e.g., co-channel coexistence/adjacent channel coexistence, may be studied in RAN4. The interference handling schemes if needed may be studied in RAN1 later. RAN1 can study the intra-AIoT interferences and discuss interference handling schemes if needed.

**FL observation：**It can be seen in the above, the views on CW interference at base station are divergent. As far as FL knows, RAN4 is now discussing interference cases and evaluating interference level at gNB side. Therefore, there is no need to discuss these parts in RAN1 at current stage, unless RAN4 ask RAN1 to involve.

**FL1/FL3 Medium Priority Question 3.3-1a: Whether the following conclusion can be agreed, if no, please share views on what aspects should be studied in RAN1 for CW interference at base station in this meeting.**

* **The study on CW interference at base station is postponed, until RAN4 ask RAN1 to involve.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| OPPO | No | CW interference to UL RX @BS and DL RX @UE should be studied in RAN1:  These two interferences are caused by resource collision between A-IoT and NR (e.g., in neighboring cell), and the strength of the interference is related to the TX power and deployment of CW, thus they are more RAN1 related issues and corresponding procedures to avoid the collision and reduce the interference should be studied. |
| CEWiT | Yes with comment | 1. Agree with Oppo’s suggestion on removing the note.   “**Beam or directional transmission if the CW supports**”, can be added in the aspects which can be controlled, in the FL’s proposal. |
| xiaomi | comment | CW interference still needs to be studied in RAN1, including the potential solutions. Because CW interference will impact the decision of which spectrum is used to transmit the CW. |
| Huawei, HiSilicon | Yes | We are supportive of having RAN4 handle the CW interference on the BS first.  We would also like to clarify that in the SID, we are tasked to study the characteristics of the CW waveform, and this study would include assessing the interference handling at the NR basestation ONLY to determine the best characteristics of the CW. For this purpose, we do not need to have a detailed CW interference analysis at the BS, and this would be handled by RAN4 under the coexistence study. |
| Ericsson | N | From FL’s summary above, it seems there is no consensus on what the CW interference at BS is, e.g., CW node-gNB interference in Typology 2, interference to legacy NR. There are other types of interference companies have concerns on.  We prefer to list the combination of aggressor and victim first. |
|  |  |  |
|  |  |  |

# CW characteristics which need control [Open]

The issue on whether CW node can be controlled was discussed in RAN#103, the following agreements was achieved in RAN#103.

|  |
| --- |
| **RAN#103 agreement:**   * Regarding the objective in the SID: *Study necessary characteristics of carrier-wave waveform for a carrier wave provided externally to the Ambient IoT device, including for interference handling at Ambient IoT UL receiver, and at NR basestation.*   + This objective allows studying CW waveform characteristics which would need control of the CW node(s), e.g. waveform characteristics that impact interference such as when CW is transmitted or not transmitted, power, bandwidth, spectrum, etc. * No SID revision is necessary |

According to the agreements and the discussion in RANP [7], the SI can consider “characteristics which would need control” and does not introduce the study of how to do that control.

In last RAN1 meeting, CW characteristics which need control was discussed, the latest proposal is as follows.

|  |
| --- |
| **FL6/FL7 Medium Priority Question 2.4-2c:** From RAN1 perspective, at least the following CW characteristics would need study:   * Timing (e.g., when CW is transmitted or not transmitted, Time resources) * Transmission Power * Frequency resources * Spectrum * Frequency hopping patterns * Beam or directional transmission if the CW supports it.   FFS what kind of control is needed or suggested  Note: How to do that control (including signaling design) is not studied in R19 SI phase. |

In this meeting, [8], [10], [12], [13], [14], [15], [16], [17], [18], [19], [21], [22], [23], [24], [24], [26], [29], [31], [33], [35], [36], [38], [39], [40] continue discussed this issue. For the characteristics that would need control, the views from contributions are summarized below

**Table 4-1: CW characteristics would need control**

|  |  |
| --- | --- |
| **CW characteristics would need control** | **Contributions** |
| Timing (e.g., when CW is transmitted or not transmitted, Time resources) | [10] [12] [13] [15][17] [22] [24][25] [26][29] [31][33] [35][36][38][39][40] |
| Transmission Power | [10] [12] [13] [17] [22] [24] [25] [26] [29] [31] [33] [35] [38] [39] |
| Frequency resources | [10] [13] [15] [17] [22] [25] [26] [29] [31] [33] [35] [38] [39] [40] |
| Spectrum | [10] [25] [31] |
| Frequency hopping patterns | [10] [15] [25] [31] |
| Beam or directional transmission if the CW supports it. | [31] |

In addition to the above, contribution [8] thinks that whether the control of a CW node which is a UE by a reader (which is a gNB), would incur any signaling or data is unclear. contribution [24] propose to study mechanism to control CW timing and power. While contribution [12] pointed out that RAN1 is tasked with studying the characteristics that would need control of the CW node, the exact procedures or methods of how the CW node controls these characteristics, such as signaling details, are beyond the scope of the study.

Contribution [14] suggests RAN1 to study and clarify how an intermediate UE performs CW transmission. Contribution [15] [21] thinks that when CW is inside topology, study necessary CW control, details can be up to WI. Contribution [17] prefers to study the network-controlled carrier wave node for ‘A1/B’. Contribution [16] proposed that not support UE to be the CW node without R2D transmission or D2R reception with AIoT device. Contribution [19] thinks that CW control is facilitating to the interference cancelation.

Some contribution discussed what kind of control is needed or suggested. Contribution[12] propose to consider dynamic CW on-off and semi-static CW on-off for time domain characteristics control, and consider interference and CW transmitter capability for CW power control. Contribution [15] thinks that time duration and period of CW should be considered for time domain characteristics control, and center frequencies, gap, frequency hopping pattern should be considered for frequency domain control. Contribution [19] thinks that carrier-wave should be transmitted after the R2D signal to allow the A-IoT device processing the R2D signals. Contribution [36] prefers that the CW node should support burst mode and persist mode to fulfill various needs. Contribution [31] proposes to study CW bandwidths adaptation. Contribution [18] prefers to study CW node selection and transmission

Contribution [22] thinks that the reader or network should be able to control the reference signal that is sent on the carrier wave. FL understanding is that, there is no any agreements on CW can carry reference signals.

Based on the above and the RAN agreements, at least the characteristics mentioned by the majority can be considered. Other views can be discussed later, if needed.

**FL1/FL3 High Priority Proposal 4-1a: From RAN1 perspective, at least the following CW characteristics would need control:**

* **Timing (e.g., when CW is transmitted or not transmitted, Time resources)**
* **Transmission Power**
* **Frequency resources**
* **FFS other CW characteristics**
* **FFS what kind of control is needed**

**Note: How to control (including signaling design) is not studied in R19 SI phase.**

|  |  |  |
| --- | --- | --- |
| **Company** | **Y/N** | **Comments** |
| TCL | Y | Agree. Modulated CW may be used for interference suppression, thus, we think CW waveform with modulation may be as one optional item or included in “other CW characteristic”. |
| OPPO | Yes with comments | We think the general solution to control these characteristics of CW can also be discussed during the SI phase, so we propose to remove the note. |
| LGE | Y | Simila view as OPPO. |
| NTT Docomo | Y |  |
| xiaomi | Y | RAN1 shall also study which spectrum (e.g., UL or DL) is used to transmit CW, so we make the following update:  **FL1 High Priority Proposal 4-1a: From RAN1 perspective, at least the following CW characteristics would need control:**   * **Timing (e.g., when CW is transmitted or not transmitted, Time resources)** * **Transmission Power** * **Frequency resources** * **Spectrum of CW transmission** * **FFS other CW characteristics** * **FFS what kind of control is needed**   **Note: How to control (including signaling design) is not studied in R19 SI phase.** |
| Huawei, HiSilicon | Comments | We agree with studying the timing and power related aspects of the CW needing control, but determining the frequency resources would be irrelevant to the device since the frequency of the CW is transparent to it.  Regarding what kind of control is needed, we do not see the need to specify this since for cases where the CW is outside the topology, the node itself is not specified and can be controlled in a proprietary manner. When inside the topology, for T1, since the CW transmitted is co-located with the BS, it can also be controlled over a proprietary interface. For T2, the UE can be controlled by regulations and certifications, both of which are outside the scope of this study. |
| Ericsson |  | What is the difference between the last two bullets? |

# Others

## CW interference at NR UE side [Closed]

Some contribution discussed CW interference at NR UE side.

Contribution [24] analyzed interference cases at the NR UE side, and provided handling options for these interferences. Contribution [21] analyzed interference to NR UE for different CW transmission cases. Contribution [23] propose to study UE-device CLI, and contribution [26] prefer to study potential solutions to eliminate the interference/half-duplex issue, e.g. TDM between CW/backscattered wave and UE’s DL/UL. Contribution [11] thinks that sufficient guard band should be used for AIoT transmissions to avoid any interference caused by the AIoT signals to legacy NR UEs.

Contribution [16] pointed out that for interference types other than CW interference, e.g., NR transmission aggressor and AIoT victim or AIoT aggressor, AIoT victim, belongs to co-existence study, can be left to RAN4 co-existence evaluation. Further comparison and down-selection of the CW transmission cases can be considered after observations from RAN4 co-existence evaluation are ready.

Contribution [35] thinks that RAN1/4 will both discuss the co-existence scenarios. The coexistence evaluation study, e.g., co-channel coexistence/adjacent channel coexistence, may be studied in RAN4. The interference handling schemes if needed may be studied in RAN1 later. RAN1 can study the intra-AIoT interferences and discuss interference handling schemes if needed.

According to the SID scope, CW interference at NR UE side is a kind of co-existence issue, and RAN4 is now studying co-existence including evaluation and interference scenarios. Therefore, FL thinks that there is no need to discuss these parts in RAN1, unless RAN4 ask RAN1 to involve.

**FL:** No discussion for CW interference at NR UE side in this meeting.

## NR interference to A-IoT system [Closed]

Some contribution discussed NR interference to A-IoT system.

Contribution [23] observed NR interference source for different CW transmission cases, e.g., for case 1-1, interference to A-IoT system mainly comes from NR DL transmission because both R2D and D2R transmission of A-IoT system are in DL spectrum. Contribution [24] also observed interference cases for CW transmission cases, e.g., for cases 1-1/1-2/1-4, ambient IoT gNB receives backscattering signal may suffer from NR co-channel DL interference. Contribution [10] also analyzed NR interference to A-IoT system in different CW cases.

Contribution [18] opposed that for topology 2, to enable efficient inference mitigation and cancellation, procedure for TDM schedule intermediate UE’s Uu link transmission and CW/R2D transmission and D2R receiving should be studied.

Contribution [24] proposed to study interference between the NR system and AIOT system, this contribution also analyzed interference cases for NR interference to A-IoT system, e.g., the NR UE transmits the NR signal on the uplink spectrum, and the NR UE receives the AIOT signal on the uplink spectrum simultaneously. Contribution [24] also proposed some options to handle interference.

Contribution [32] discussed interference from NR for deployment scenarios considered in RAN4, and observed that for D1T1 option 1-1, a small guard between NR and AIoT in frequency domain could be enough to protect AIoT signal from the potential interference of NR signal. For D1T1 option 1-2, a small guard between NR and AIoT in frequency domain could be enough to protect AIoT signal from the potential interference of NR DL signal. In scenario D1T1 option 1-2 with R2D/D2R on FDD UL, a large guard between AIoT and NR in frequency domain is necessary. In scenario D1T1 option 2, FDM or TDM between NR and AIoT is needed.

Contribution [16] pointed out that for interference types other than CW interference, e.g., NR transmission aggressor and AIoT victim or AIoT aggressor, AIoT victim, belongs to co-existence study, can be left to RAN4 co-existence evaluation. Further comparison and down-selection of the CW transmission cases can be considered after observations from RAN4 co-existence evaluation are ready.

Contribution [35] thinks that RAN1/4 will both discuss the co-existence scenarios. The coexistence evaluation study, e.g., co-channel coexistence/adjacent channel coexistence, may be studied in RAN4. The interference handling schemes if needed may be studied in RAN1 later. RAN1 can study the intra-AIoT interferences and discuss interference handling schemes if needed.

Similar to that of section 5.2, NR interference to A-IoT system is a kind of co-existence issue, according to the SID scope, RAN4 is now studying co-existence including evaluation and interference scenarios. Therefore, FL thinks that there is no need to discuss these parts in RAN1, unless RAN4 ask RAN1 to involve.

**FL:** No discussion for NR interference to A-IoT system in this meeting.

## Energy harvest [Closed]

In RAN#103, the following agreement was reached

|  |
| --- |
| **RAN#103 agreement:**   * 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 |

In this meeting, very few contributions share views for energy harvesting.

**Table 5.3-1 Views for energy harvesting**

|  |  |
| --- | --- |
| **Views** | **Details** |
| **No further study/low priority** | Contribution [9] indicates that RAN1 should not further discuss technical design of energy harvesting signal/waveform for Device 1, Device 2a, and Device 2b.  Contribution [23] proposed that design of signal/waveform for CW for energy harvesting is discussed as low priority in RAN1. |
| **CW for backscattering can be used for EH** | Contribution [23]: It is preferred that the CW can also be used for energy harvesting from the cost and deployment complexity aspect.  Contribution [33]: Multi-tone waveform is better for energy harvesting |
| **UE behaviors** | Contribution [23]: Study the UE behaviour when the device is in a state of energy harvesting. |
| **Resource allocation for EH CW** | Contribution [35]: CW for EH and R2D are in the same carrier frequency for device 1/2a/2b, No new waveform is needed for CW for energy harvesting, Study the resource allocation of CW for EH |

**FL:** Based on the above, energy harvesting will not be discussed in this meeting.

## Miscellaneous [Closed]

Contribution [11] thinks that RAN1 to identify the aspects and metrics that should drive the selection of the carrier-wave signal type and study the impact that a certain waveform selection has on the main L1 aspects considered in this SI.

**FL:** the aspects and metrics are discussed in section 2.1.

Contribution [12] [26] thinks that the unmodulated single-tone waveform is regarded as the baseline for the external carrier-wave. Contribution [19] propose that multiple single tone carrier waves should be deprioritized in Rel-19 study.

**FL:** in this meeting, RAN1 will discuss pros and cons for different waveforms, this point can be discussed later.

Contribution[23] thinks that the specific values of bandwidth and power for CW for backscattering need to be considered for D2R backscattering evaluation.

**FL:** this can be discussed in 9.4.1.1.

Contribution [40] thinks that interference should be included in evaluation assumptions for LLS

**FL:** this is already discussed in 9.4.1.1 or RAN4.

Contribution [18] thinks that the CW is in the center of transmission bandwidth of D2R channel, and within D2R system bandwidth, multiple transmission channel can be supported. Different CW node can be scheduled to transmit the single tone CW of one channel. Contribution [18] also thinks that for multi-tone CW, the CW is in evenly distributed within the transmission bandwidth of D2R channel.

Contribution [38] pointed out that RAN1 to clarify mapping between multiple single tones and transmission bandwidth. Number of tones should consider the mapping between multiple single tones and transmission bandwidth.

Contribution[36] suggested to establish a straightforward and clear communication method between the read and CW node with a harmonized scheme in all 6 cases for ambient IoT scenarios, which also involves signaling about the switching of single-tone and multi-tone waveform.

Contribution [17] thinks that the topology is transparent to the A-IoT devices, and the A-IoT devices support the backscatter communication in both topologies.

Contribution [23] thinks that spectrum used for CW, backscatter and R2D transmission should be considered together. Contribution [23] proposed that CW, backscatter and R2D transmission in same spectrum (e.g. case 1-2 (a)) to reduce A-IoT device complexity, interference to NR UE.

Contribution [39] thinks that RAN1 to study whether and how an A-IoT device reports its capability on frequency shifting to base station.

Contribution [22] suggests RAN1 to study both ambient and dedicated external carrier waves.

Contribution [27] studied time delay for forwarding, timing adjustment, collision handling between R1 and R2 and so on for different deployment cases listed in 9.4.1.1(e.g., D1T1-A1, D1T1-A2)

Contribution [30] proposes to study what CW characteristics (used by CW nodes in the system) would need to be known by type 2b devices in order to mimic the backscatter signals, to harmonize the three devices.

Contribution [35] study the impact of CW2D and D2D interference in FDD-DL at R2D receiver. whether/how to consider the interference of the FDMed D2R at D2R receiver if supported.

**FL:** For the above, as these issues mentioned by very few companies, they will not be discussed with high priority at least in this meeting.

# Proposals for online

## Monday (FLS#1 R1-2405438)

**Proposed Observation 2.1.1-1b: For D2R reception performance,**

* **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones provide higher frequency diversity gain in fading channel, depending on the gap between the two tones.**
  + **≥3dB gain can be observed for the case that the gap between tones is comparable to the coherence bandwidth (for 10% BLER or 1%BLER).**

|  |
| --- |
| Version after online discussion |
| **Proposed Observation 2.1.1-1b**  **For D2R reception performance,**   * **Compared to single-tone unmodulated sinusoid waveform without frequency hopping, two unmodulated single-tones provide higher frequency diversity gain in fading channel, depending on the gap between the two tones.** |

**Proposed Observation 2.1.2-1b: For D2R spectrum utilization,**

* **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones will consume two times the bandwidth of baseband signal.**

|  |
| --- |
| No discussion online for proposed observation 2.1.2-1b |

**Proposed Observation 2.1.3.3-1a: For interference suppression for different CW waveforms at D2R receiver,**

* **Compared to single-tone unmodulated sinusoid waveform, two unmodulated single-tones will lead to higher complexity for interference suppression,** 
  + **More challenging to reconstruct the CW waveform for two unmodulated single-tones**
  + **Additional complexity on RFIC, highpass/bandpass filters**

|  |
| --- |
| Version after online discussion |
| **Proposed Observation 2.1.3.3-1a:**  **For interference suppression complexity for different CW waveforms at D2R receiver,**   * **Compared to single-tone unmodulated sinusoid waveform without frequency hopping, two unmodulated single-tones:**   + **Is more complex to reconstruct the CW waveform for two unmodulated single-tones**   + **Requires additional complexity on RF interference cancellation and/or [highpass]/bandpass filters** |

**Proposed Observation 2.1.3.1-1b: For CW interference type at D2R receiver,**

* **For scenarios “B” and ‘A1’, the CW interference type at D2R receiver is cross-link interference.**
* **For scenarios “A2”, the CW interference type at D2R receiver is self-interference.**

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| No discussion online for proposed observation 2.1.3.1-1b |

**Proposal 2.2.1-1b: For multiple unmodulated single-tone transmitted by one CW node, other number of tones (i.e. >2) is deprioritized.**

* **Note: other number of tones (i.e. >2) is studied only when obvious gains are provided.**

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| No discussion online for proposed observation 2.2.1-1b |

**Proposal 2.2.2-1b: On the gap size of two unmodulated single-tones, at least the following aspects need to be jointly considered for further study:**

* **Coherence bandwidth**
* **D2R transmission and system BW**
* **frequency shift and BW of main sidelobe**
* **harmonics impacts**

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| No discussion online for proposed observation 2.2.2-1b |

# Proposals for offline

## Wednesday

|  |  |  |
| --- | --- | --- |
| **CW waveform** | **Single-tone unmodulated sinusoid waveform without frequency hopping** | **Multi single-tone unmodulated sinusoid waveform** |
| **Reception performance** |  |  |
| **Spectrum utilization** |  |  |
| **CW interference suppression** |  |  |
| **Complexity of CW generation** |  |  |
| **Other aspect (if any)** |  |  |
|  |  |  |

# Reference

|  |  |  |  |
| --- | --- | --- | --- |
|  | [RP-240826](https://www.3gpp.org/FTP/tsg_ran/TSG_RAN/TSGR_103/Docs/RP-240826.zip) | Revised SID: Study on solutions for Ambient IoT (Internet of Things) in NR, RAN#103, Maastricht, Netherlands. | RAN WGs SID (Revised SID) |
|  | [RP-223396](https://www.3gpp.org/FTP/tsg_ran/TSG_RAN/TSGR_98e/Docs/RP-223396.zip) | Study on Ambient IoT (Internet of Things) in RAN | RAN SID |
|  | [TR 38.848](https://www.3gpp.org/ftp/Specs/archive/38_series/38.848/38848-i00.zip) | Study on Ambient IoT (Internet of Things) in RAN | RAN TR |
|  | [S1-220118](https://www.3gpp.org/FTP/tsg_sa/WG1_Serv/TSGS1_97e_EM_Feb2022/Docs/S1-220118.zip) | Study on Energy Harvesting enabled Communication Services in 5GS. | SA1 SID |
|  | [TR 22.840](https://www.3gpp.org/ftp/Specs/archive/22_series/22.840/22840-j00.zip) | Study on Ambient power-enabled Internet of Things | SA1 TR |
|  | [R1-2403767](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_116b/Docs/R1-2403767.zip) | Final FL summary on CW waveform characteristics for A-IoT, RAN1#116b, April 15th – 19th, 2024. | Moderator (Spreadtrum) |
|  | [RP-240854](https://www.3gpp.org/FTP/tsg_ran/TSG_RAN/TSGR_103/Docs/RP-240854.zip) | Moderator's summary on R19 Ambient IoT, RAN#103, Maastricht, Netherlands. | Moderator (Huawei) |
|  | [R1-2403845](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2403845.zip) | Waveform characteristics of carrier wave provided externally to the Ambient IoT device | Ericsson |
|  | [R1-2403863](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2403863.zip) | Discussion on External Carrier Waveform Characteristics for Rel-19 Ambient IoT devices | FUTUREWEI |
|  | [R1-2403883](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2403883.zip) | Discussion on waveform characteristics of external carrier-wave for Ambient IoT | TCL |
|  | [R1-2403891](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2403891.zip) | Waveform characteristics of carrier-wave provided externally to the Ambient IoT device | Nokia |
|  | [R1-2403957](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2403957.zip) | On external carrier wave for backscattering based Ambient IoT device | Huawei, HiSilicon |
|  | [R1-2403968](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2403968.zip) | Discussions on waveform characteristics of carrier-wave for A-IoT | Intel Corporation |
|  | [R1-2404031](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404031.zip) | Discussion on waveform characteristics of external carrier-wave for Ambient IoT | Spreadtrum Communications |
|  | [R1-2404120](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404120.zip) | Considerations for Waveform characteristics of carrier-wave | Samsung |
|  | [R1-2404182](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404182.zip) | Discussion on CW waveform and interference handling at AIoT UL receiver | vivo |
|  | [R1-2404221](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404221.zip) | Discussion on external carrier wave for Ambient IoT | Lenovo |
|  | [R1-2404289](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404289.zip) | On carrier waveform and interference handling for AIoT | Apple |
|  | [R1-2404406](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404406.zip) | Discussion on the waveform characteristics of carrier-wave for the Ambient IoT device | CATT |
|  | [R1-2404432](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404432.zip) | Discussion on waveform characteristics of carrier-wave provided externally to the Ambient IoT device | China Telecom |
|  | [R1-2404461](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404461.zip) | Discussion on waveform characteristics of carrier-wave provided externally to the Ambient IoT device | CMCC |
|  | [R1-2404505](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404505.zip) | External carrier wave for Ambient IoT | Sony |
|  | [R1-2404559](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404559.zip) | Discussion on carrier wave for Ambient IoT | ZTE, Sanechips |
|  | [R1-2404623](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404623.zip) | Discussion on waveform characteristics of carrier-wave | Xiaomi |
|  | [R1-2404778](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404778.zip) | Waveform characteristics of carrier-wave provided externally to the A-IoT device | ETRI |
|  | [R1-2404873](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404873.zip) | Discussion on Waveform characteristics of carrier-wave provided externally to the A-IoT device | OPPO |
|  | [R1-2404893](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404893.zip) | Considerations on carrier-wave transmission for Ambient IoT | LG Electronics |
|  | [R1-2404902](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404902.zip) | Discussion on waveform characteristics of carrier-wave for Ambient IoT device | Panasonic |
|  | [R1-2404938](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404938.zip) | Considerations for carrier-wave aspects | Semtech Neuchatel SA |
|  | [R1-2404960](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404960.zip) | Discussion on carrier-wave for Ambient IoT | InterDigital, Inc. |
|  | [R1-2404965](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2404965.zip) | Discussion on waveform characteristics of externally provided carrier-wave | Sharp |
|  | [R1-2405006](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405006.zip) | Analyses on interference between AIoT and NR | Fujitsu |
|  | [R1-2405047](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405047.zip) | Study on waveform characteristics of carrier-wave for Ambient IoT | NTT DOCOMO, INC. |
|  | [R1-2405081](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405081.zip) | Waveform characteristics of carrier-wave provided externally to the Ambient IoT device | MediaTek Inc. |
|  | [R1-2405160](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405160.zip) | Waveform characteristics of carrier-wave provided externally to the Ambient IoT device | Qualcomm Incorporated |
|  | [R1-2405185](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405185.zip) | Discussion on waveform characteristics of carrier-wave provided externally to the Ambient IoT device | China Unicom |
|  | [R1-2405219](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405219.zip) | Discussion on waveform characteristics of carrier-wave for Ambient IoT | Comba |
|  | [R1-2405245](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405245.zip) | Discussion on Waveform characteristics of carrier-wave provided externally to the Ambient IoT device | CEWiT |
|  | [R1-2405275](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405275.zip) | Discussion on waveform characteristics of carrier-wave provided externally to the Ambient IoT device | Google |
|  | [R1-2405301](https://www.3gpp.org/ftp/TSG_RAN/WG1_RL1/TSGR1_117/Docs/R1-2405301.zip) | Discussion on Carrier wave related aspects for AIoT | IIT Kanpur, Indian Institute of Tech (M) |

# Appendix

## Contact info for 9.4.2.4

Based on feedback in RAN1#116. Please feel free to update it, if any.

|  |  |  |
| --- | --- | --- |
| **Company** | **Point(s) of contact** | **Email address(es)** |
| NTT Docomo | Weiqi Sun | sunwq@docomolabs-beijing.com.cn |
| FUTUREWEI | Brian Classon | brian@classonconsulting.com |
| China Telecom | Yi Gu | guy6@chinatelecom.cn |
| xiaomi | Yajun Zhu  Fu ting  Wensu Zhao | [zhuyajun@xiaomi.com](mailto:zhuyajun@xiaomi.com)  futing[@xiaomi.com](mailto:Zhuyajun@xiaomi.com)  zhaowensu@xiaomi.com |
| OPPO | Teng Ma | [mateng1@oppo.com](mailto:mateng1@oppo.com) |
| CEWiT | Deepak PM  Vishakha Singh | [deepakpm@cewit.org.in](mailto:deepakpm@cewit.org.in)  vish@cewit.org.in |
| TCL | Rongling Jian | [rongling.jian@tcl.com](mailto:rongling.jian@tcl.com) |
| Samsung | Hyemin Choe | hams.choe@samsung.com |
| Nokia/NSB | Ganesh Venkatraman | Ganesh.venkatraman@nokia.com |
| Spreadtrum | Mimi Chen | mimi.chen@unisoc.com |
| CATT | Fang-Chen Cheng  Ren Da | [fcc@catt.cn](mailto:fcc@catt.cn)  renda@catt.cn |
| SONY | Martin Beale | martin.beale@sony.com |

## [SID](https://www.3gpp.org/FTP/tsg_ran/TSG_RAN/TSGR_103/Docs/RP-240826.zip)(Revised in RAN#103)

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| 4 Objective 4.1 Objective of SI or Core part WI or Testing part WI  This study targets a further assessment at RAN WG-level of Ambient IoT, a new 3GPP IoT technology, suitable for deployment in a 3GPP system, which relies on ultra-low complexity devices with ultra-low power consumption for the very-low end IoT applications. The study shall provide clear differentiation, i.e. addressing use cases and scenarios that *cannot* otherwise be fulfilled based on existing 3GPP LPWA IoT technology e.g. NB-IoT including with reduced peak Tx power.  General Scope  The definitions provided in TR 38.848 are taken into this SI, and the following are the exclusive general scope:   1. The overall objective shall be to study a harmonized air interface design with minimized differences (where necessary) for Ambient IoT to enable the following devices: 2. ~1 *µ*W peak power consumption, has energy storage, initial sampling frequency offset (SFO) up to 10*X* ppm, neither DL nor UL amplification in the device. **The device’s UL transmission is backscattered on a carrier wave provided externally.** 3. ≤ a few hundred *µ*W peak power consumption1, has energy storage, initial sampling frequency offset (SFO) up to 10*X* ppm, DL and/or UL amplification in the device. The device’s UL transmission may be generated internally by the device, or **be backscattered** **on a carrier wave provided externally**.  * *X* is to be decided in WGs. * Coverage design target: Maximum distance of 10-50 m with device indoors as per TR 38.848: “*…a range that WGs can sub-select within*”. * For Topologies 1 & 2 (UE as intermediate node under NW control) per TR 38.848, with no RRC states, no mobility (i.e. at least no cell selection/re-selection -like function), no HARQ, no ARQ.   NOTE 1: It is to be understood that “≤ a few hundred *µ*W” means WGs are not tasked with setting a particular value, and that it will be for WG discussions to determine if a presented design with corresponding power consumption satisfies the “≤ a few hundred *µ*W” requirement.   1. Deployment Scenarios with the following characteristics, referenced to the tables in Clause 4.2.2 of TR 38.848:  * Deployment scenario 1 with Topology 1   + Basestation and coexistence characteristics: Micro-cell, co-site * Deployment scenario 2 with Topology 2 and UE as intermediate node, under network control   + Basestation and coexistence characteristics: Macro-cell, co-site   + The location of intermediate node is indoor  1. **FR1 licensed spectrum in FDD.** 2. **Spectrum deployment in-band to NR, in guard-band to LTE/NR, in standalone band(s).** 3. Traffic types DO-DTT, DT, with focus on rUC1 (indoor inventory) and rUC4 (indoor command).  * From RAN#104, the study will assess whether the harmonized air interface design (per bullet ‘A’ above) can address the DO-A (Device-originated autonomous) use case, only to identify which part(s) of the harmonized air interface design (per bullet ‘A’ above) is/are not sufficient for the DO-A use case.   Transmission from Ambient IoT device (including backscattering when used) can occur at least in UL spectrum.  The following objectives are set, within the General Scope:   1. Evaluation assumptions 2. Conclude at least the following aspects of design targets left to WGs in Clause 5 (RAN design targets) of TR 38.848 [RAN1].    * Clause 5.3: Applicable maximum distance target values(s)    * Clause 5.6: Refine the definition of latency suitable for use in RAN WGs    * Clause 5.8: 2D distribution of devices 3. Define necessary further evaluation assumptions of deployment scenarios for coverage and coexistence evaluations [RAN1, RAN4] 4. Identify basic blocks/components of possible Ambient IoT device architectures, taking into account state of the art implementations of low-power low-complexity devices which meet the RAN design target for power consumption and complexity. [RAN1] 5. Define link budget calculation for coverage, **including whether/how to model carrier wave from node(s) inside or outside the connectivity topology.**   NOTE: Assessment performance of the design targets is within the study of feasibility and necessity of proposals in the following objectives, e.g. by inspection of reference implementations in the field, simulations, analytically.  NOTE: strive to minimize evaluation cases in RAN1.   1. Study necessary and feasible solutions for Ambient IoT as prescribed in the General Scope, including decisions on which functions, procedures, etc. are needed and not needed, and ensuring at least the required functionalities in Section 6.2 of TR 38.848.   Study of positioning in Rel-19 is RAN3-led, limited to functionalities which would have no, or minimal, specification impact (note: this does not imply any decision relating to WI creation).  Study the feasibility and required functionalities for proximity determination, which is the determination of whether BS or intermediate UE and ambient IoT device are near each other or not (coordination with SA3 is required for privacy aspects).   * RAN1-led:   For the Ambient IoT DL and UL:   * + Frame structure, synchronization and timing, random access   + Numerologies, bandwidths, and multiple access   + Waveforms and modulations   + Channel coding   + Downlink channel/signal aspects   + Uplink channel/signal aspects   + Scheduling and timing relationships   + **Study necessary characteristics of carrier-wave waveform for a carrier wave provided externally to the Ambient IoT device, including for interference handling at Ambient IoT UL receiver, and at NR basestation.**   For Topology 2, no difference in physical layer design from Topology 1.   * RAN2-led:   + Study and decide which functions are needed for an Ambient IoT compact protocol stack and lightweight signalling procedure to enable DO-DTT and DT data transmission, and study those functions.   For example:   * + - Paging     - Random access     - Data transmission, including necessary radio resource control aspects, respecting the limitation in the General Scope     - Interactions with upper layers   For functionalities not listed above, they are studied only if found essential.   * RAN3-led:   + Identify necessary impacts on signaling and procedures for CN-RAN interface, to enable:     - Paging     - Device context management     - Data transport   + Identify RAN architecture aspects, including whether support for split architecture is necessary.   + Identify potential solutions for locating an Ambient IoT device with no specification impact, e.g. reusing existing user location report, or minimal specification impact to convey location information to core network. * RAN4-led:   + Coexistence study of Ambient IoT and NR/LTE.   + RF requirements study for Ambient IoT:     - Ambient IoT BS transmission and reception     - Ambient IoT Device, as per the General Scope, transmission and reception     - Intermediate node (UE), as per the General Scope, transmission and reception   RAN2 and RAN3 are expected to identify RAN-CN functional split in coordination with SA2.  Note: This study shall target for an IoT segment well below the existing 3GPP IoT technologies, e.g. NB-IoT, eMTC, RedCap, etc. The study shall not aim to replace existing 3GPP LPWA technologies. |

## Previous agreements

RAN1#116

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| Agreement  For R19 A-IoT study item, at least single-tone unmodulated sinusoid waveform is a candidate waveform for carrier wave for D2R backscattering.  Agreement  For R19 A-IoT study item, multi-tone waveforms for carrier wave for D2R backscattering can be studied.  Agreement  For the case that D2R backscattering is transmitted in the same carrier as CW for D2R backscattering, and for topology 1, the following cases for CW transmission are studied.   * Case 1-1: CW is transmitted from inside the topology, transmitted in DL spectrum. * Case 1-2: CW is transmitted from inside the topology, transmitted in UL spectrum. * Case 1-4: CW is transmitted from outside the topology, transmitted in UL spectrum.   Agreement  For the case that D2R backscattering is transmitted in the same carrier as CW for D2R backscattering, and for topology 2, the following cases for CW transmission are studied.   * Case 2-2: CW is transmitted from inside the topology (i.e., intermediate UE), transmitted in UL spectrum. * Case 2-3: CW is transmitted from outside the topology, transmitted in DL spectrum. * Case 2-4: CW is transmitted from outside the topology, transmitted in UL spectrum. |

RAN#103

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| **RAN#103 agreement:**   * Regarding the objective in the SID: *Study necessary characteristics of carrier-wave waveform for a carrier wave provided externally to the Ambient IoT device, including for interference handling at Ambient IoT UL receiver, and at NR basestation.*   + This objective allows studying CW waveform characteristics which would need control of the CW node(s), e.g. waveform characteristics that impact interference such as when CW is transmitted or not transmitted, power, bandwidth, spectrum, etc. * No SID revision is necessary   **RAN#103 agreement:**   * 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   **RAN#103 agreement:**   * RAN design targets for user experienced data rate, maximum message size, and moving speed of device: those can be used as assumptions in coverage evaluations, i.e. the coverage evaluations are done under the conditions that meet those targets. * Evaluations of RAN design targets for latency and connection/device density are allowed by the Rel-19 SID and observations on those evaluations can be captured in the TR38.769 * Note: this is as per the SID: “*NOTE: Assessment performance of the design targets is within the study of feasibility and necessity of proposals in the following objectives, e.g. by inspection of reference implementations in the field, simulations, analytically*.” |

RAN1#116bis

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| Agreement  For CW waveform for D2R backscattering, multiple unmodulated single-tone is studied compared to single-tone in R19 SI.   * Two unmodulated single-tones as a starting point   + FFS: Other number of tones   + FFS: how large gap is needed between tones   Agreement  For CW waveform for D2R backscattering, contiguous multi-tone OFDM signal is not studied in R19 SI.  Agreement  Study at least the following characteristics of unmodulated single-tone and multiple unmodulated single-tone CW waveforms for backscattering:   * For D2R   + Reception performance   + Spectrum utilization of backscattered signal corresponding to the CW waveforms * CW interference suppression at D2R receiver   + Including complexity and CW cancellation capability value/range (if any)   + For scenarios ’A1’, ’A2’ and ’B’ * Relative complexity of CW generation |

## Agreements in RAN1#117

To be added.