**3GPP TSG RAN WG1 #102-e R1-** **200xxxx**

**e-Meeting, August 17th – 28th, 2020**

**Agenda item:** 8.8.2.2

**Source:** Qualcomm Incorporated

**Title:** FL summary of PUCCH coverage enhancement

**Document for:** Discussion/Decision

# Introduction

In this document, a summary of companies’ view on potential techniques for PUCCH coverage enhancement is provided.

# Summary of submitted proposals

There were in total 20 contributions submitted to this meeting under 8.8.2.2. The proposed techniques for PUCCH coverage enhancement are categorized and summarized in the following Table.

The list of supporting companies is an initial list based on FL’s understanding of companies’ position expressed in their contributions. Companies are welcome to add your name in the list to support a scheme or modify the list if the position is changed.

Table 0: Summary of PUCCH coverage enhancement techniques and supporting companies

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| --- | --- |
| **Proposed PUCCH coverage enhancement techniques** | **Supporting companies** |
| Sequence based DMRS-less PUCCH | ZTE/Sanechips, Huawei/HiSi, NEC, Intel, CMCC, QC, Interdigital, Sharp, EURECOM (11) |
| PUSCH repetition Type-B like PUCCH repetition | Nokia/NSB, VIVO, Huawei/HiSi, Panasonic, WILUS, Samsung (8) |
| (Explicit or implicit) Dynamic PUCCH repetition factor indication | OPPO, ZTE/Sanechips, CATT, Ericsson, QC, Samsung (7) |
| Sequence based PF 0/1 with Pi/2 BPSK | IITH, CeWiT, IITM, Reliance Jio, Tejas Networks (5) |
| Pre-DFT data-RS multiplexing for PF2 with Pi/2 BPSK | IITH, CeWiT, IITM, Reliance Jio, Tejas Networks (5) |
| DMRS bundling for PUCCH | Intel, CATT, VIVO, NEC, Panasonic (5) |
| Compact UCI | OPPO, QC, Nokia/NSB (low priority), Sony (5) |
| Freq hopping enhancement for PUCCH | Intel, NEC, Panasonic, Wilus (4) |
| Short/mini-slot PUCCH repetition | DCM, Panasonic, Sharp, QC (4) |
| Power control enhancement for PUCCH | Huawei/HiSi, Sony, Samsung (4) |
| Increase maximum # allowed repetitions for PUCCH | OPPO, Intel, CATT, Samsung (4) |
| PUCCH Transmit diversity scheme | Intel, CATT, Sony (3) |
| DMRS overhead reduction | OPPO, Intel (2) |
| UE Antenna configuration enhancement for FR2 | Sony (1) |
| Higher DMRS density | Intel (1) |
| A-CSI on PUCCH | Ericsson (1) |
| Symbol-level PUCCH repetition | Panasonic (1) |
| Relay (including sidelink relay) | Sony (1) |
| Reflective arrays | Sony (1) |

# Discussion

The next phase is to have technical discussions on each proposed technique. Companies are welcome to express feedback and comments to discuss the pros. and cons. for each technique in the following tables. For those schemes that already been evaluated with link level simulations (LLS), companies are welcome to report the observed gain in the following tables.

## Sequence based DMRS-less PUCCH

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 1: Comments on the “Sequence based DMRS-less PUCCH”

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo | FFS |  | 1, Unclear performance gain.  2, A new PUCCH format may bring about noneligible spec effort. | As proposed by several companies, the motivation of sequence based PUCCH is to enhance UCI with 3-11 bits. However, the sequence based detection can also be performed based on current PUCCH format 3, the modulated symbols can be considered, as well as the DMRS symbol, can be considered as a long sequence, ML sequence detection can be performed at gNB by implementation. Therefore, the enhanced scheme should be compared with current PUCCH format 3 with the ML sequence detector in LLS. |
| Samsung |  |  |  | Need to first conclude on a set of LLS assumptions, on a set of specific sequences and on 1-2 specific schemes (e.g. “short” or “long” sequences). Comparisons should consider enhancements to Rel-16 PUCCH formats (e.g. improved channel estimation) and also consider bursty interference (e.g. 1-2 lost symbols) and not only AWGN+fading. Some of the solutions grouped under this category might be quite different, details are needed to understand them and potentially evaluate them. |
| ZTE | About 3dB gain for 11 bits UCI | 1. Clear performance improvement without causing more time/frequency resources. 2. More multiplexing capacity. If we use a same sequence pool with up to 2^11 sequences for 3~11 bits. 1~X UEs could be multiplexed in the same time/frequency resources. X could be theoretically up to 2^8 if all UEs are with 3 bits UCI. 3. Lower processing latency at gNB side. Given no channel estimation is needed, gNB can check different hypotheses in parallel. |  |  |
| IITH, CeWiT, IITM, Reliance Jio, Tejas Networks |  |  |  | Support the proposal with sequence-based transmission when the payload < X bits and for > X bits we support pre-DFT-based transmission. |
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## PUSCH repetition Type-B like PUCCH repetition

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 2: Comments on the “PUSCH repetition Type-B like PUCCH repetition”

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company name | | LLS gain observed over Rel-15 baseline | | Pros. of the proposed scheme | | Cons. of the proposed scheme | | Other comments | |
| vivo | | Depending on the additional resources can be utilized. | | The UL resources in S slot can be utilized together with the resources in U slots. | |  | |  | |
| Samsung | |  | | Similar pros as for PUSCH. Reduced latency as more available symbols can be used. Enhanced resource allocation. Additional flexibility for gNB scheduling. | |  | | High priority | |
| ZTE | |  | |  | |  | | Open to discuss | |
| IITH, CeWiT, IITM, Reliance Jio, Tejas Networks | |  | | |  | |  | | Support the proposal | |
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## (Explicit or implicit) Dynamic PUCCH repetition factor indication

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 3: Comments on the “(Explicit or implicit) Dynamic PUCCH repetition factor indication”

|  |  |  |  |  |  |  |  |  |  |
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| Company name | | LLS gain observed over Rel-15 baseline | | Pros. of the proposed scheme | | Cons. of the proposed scheme | | Other comments | |
| vivo | | None | |  | | For the explicit scheme, additional bit field would be introduced in DCI, which may degrade the performance of PDCCH.  For the implicit scheme, does it mean dynamically determine the number of PUCCH repetitions? In our opinion, in current spec, UE can select different PUCCH resource set according to UCI bits, and different repetition numbers can be configured to different PUCCH resource set. Therefore, current PUCCH resource set selection rule is quite flexible to support determine the number PUCCH repetition number implicitly. | |  | |
| Samsung | |  | | Can adapt to UCI payload and total number of available REs/symbols for repetitions. An RRC-only indication needs to account for a “worst case” scenario and is too wasteful. | |  | | Details of the signaling can be left for later discussions, after 2.2 progresses. | |
| ZTE | |  | | 1. Resource efficient. To ensure the reliability of PUCCH, gNB has to semi-statically a conservative repetition factor in Rel-15. A more appropriate repetition factor can be indicated by dynamic repetition which would be more resource efficient. 2. Enable more flexibility for gNB to avoid collision of PUSCH. In Rel-15, when PUCCH repetition overlaps with PUSCH, PUSCH would be dropped. This would impacts system efficiency a lot. | |  | |  | |
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## Sequence based PF 0/1 with Pi/2 BPSK

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 4: Comments on the “Sequence based PF 0/1 with Pi/2 BPSK”

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| --- | --- | --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | | Other comments | |
| vivo | FFS |  |  | | Based on RAN4 MPR requirement, the MPR for PUCCH format 0/1 is 0 for inner RB allocation. Therefore, low PAPR transmission can be realized by proper gNB configuration. Therefore, the additional gain brought by pi/2 BPSK for PF0/1 is doubtful. | |
| Samsung |  | Can improve coverage | | Requires changes to UE implementations. | | Neutral |
| ZTE |  |  | |  | | Fine to discuss but we don’t see much motivation on enhancement of PF0/1 |
| IITH, CeWiT, IITM, Reliance Jio, Tejas Networks |  | Improves Coverage. Can align the transmission characteristics when PUSCH and its DMRS use pi/2 BPSK. |  | | High priority. | |
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## Pre-DFT data-RS multiplexing for PF2 with Pi/2 BPSK

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 5: Comments on the “Pre-DFT data-RS multiplexing for PF2 with Pi/2 BPSK”

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | | Other comments | |
| vivo |  |  |  | | We prefer PUCCH based on long PUCCH format, and enhancements based on PF2 should be deprioritized. | |
| Samsung |  |  | |  | | Deprioritize |
| ZTE |  |  | |  | | Same as about. We don’t see much motivation on enhancement of PF2 |
| IITH, CeWiT, IITM, Reliance Jio, Tejas Networks |  | Significantly improves coverage. There is a significant disconnect between transmit power characteristics of low PAPR waveforms being considered and the PUCCH formats of CP-OFDM. This gap must be bridged. Pre-DFT can send arbitrary payloads just like CP-OFDM. |  | | High priority | |
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## DMRS bundling for PUCCH

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 6: Comments on the “DMRS bundling for PUCCH”

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| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo | Around 1dB | Channel estimation accuracy can be improved. And this scheme is easy to be implemented. |  |  |
| Samsung |  | Improved channel estimation | Possible restrictions and not readily available | OK to study |
| ZTE |  |  |  | OK to study |
| IITH, CeWiT, IITM, Reliance Jio, Tejas Networks |  |  |  | Support the proposal |
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## Compact UCI

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 7: Comments on the “Compact UCI”

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| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo | FFS | Lower coding rate can provide better coverage | DL coverage may be degraded due to some UCI information, e.g. CSI, is dropped. While DL coverage is far better than UL coverage, the DL performance loss is acceptable. |  |
| Samsung |  |  |  | Deprioritize |
| ZTE |  |  |  | Not sure how to compact the UCI. Maybe proponents can clarify more and we are fine to further study if it doesn’t impact the system efficiency too much. |
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## Freq hopping enhancement for PUCCH

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 8: Comments on the “Freq hopping enhancement for PUCCH”

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| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo | Around 1dB | Easy to be implemented, and spec impact is limited. |  |  |
| Samsung |  |  | No benefit as with 4 gNB Rx antennas and 1 FH, all diversity benefits are obtained. | Deprioritize |
| IITH, CeWiT, IITM, Reliance Jio, Tejas Networks |  |  |  | No support |
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## Short/mini-slot PUCCH repetition

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 9: Comments on the “Short/mini-slot PUCCH repetition”

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| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo |  |  |  | We think this topic can be covered by type-B PUCCH repetition in section 3.2 |
| Samsung |  |  | No need for coverage enhancements. It is currently considered in URLLC. | Deprioritize |
| ZTE |  |  |  | No clear motivation to enhance short PUCCH format. |
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## Power control enhancement for PUCCH

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 10: Comments on the “Power control enhancement for PUCCH”

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| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo |  |  |  | The solution seems not clear? |
| Samsung |  | BLER targets are individually controlled per UCI type in LTE and when multiplexed in PUSCH. But not possible for PUCCH and Tx power needs to always be based on the “worst case” (lowest target BLER). |  | Prioritize - important to provide same capability for individual UCI type target BLER on PUCCH as for PUSCH. |
| IITH, CeWiT, IITM, Reliance Jio, Tejas Networks |  | Power boosting capability of a waveform must be reflected in the power control calculations. Easily provides coverage gains. |  | High priority. |
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## Increase maximum # allowed repetitions for PUCCH

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 11: Comments on the “Increase maximum # allowed repetitions for PUCCH”

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| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo |  |  |  | In current PUCCH repetition mechanism, the PUCCH repetition is postponed if collision with DL or cancelled by SFI, therefore maximum 8 repetitions seems enough. |
| Samsung |  | Straightforward extension of existing solution with minimal specification impact. Provides additional flexibility to gNB to guarantee coverage. Also useful in extreme coverage cases. | Additional latency. | Prioritize. Also determine maximum UCI payload to support for repetitions. |
| ZTE |  |  |  | OK to study |
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## PUCCH Transmit diversity scheme

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 12: Comments on the “PUCCH Transmit diversity scheme”

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| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo |  |  | For SORTD, as that introduced in LTE, double resources would be used for two antenna ports.  For frequency domain precoding cycling, it may lead to higher PAPR for PUCCH with DFT-S-OFDM waveform, i.e. PF3 and PF4. | The transmission diversity scheme relies on UE Tx antenna design, the coverage enhancement solutions is preferred not to rely on antenna configuration. |
| Samsung |  | Can be beneficial if no FH to improve channel estimation while achieving all diversity gains. |  |  |
| ZTE |  |  |  | Ok to study |
| IITH, CeWiT, IITM, Reliance Jio, Tejas Networks |  | At low SNR it is important to focus on improving channel estimations using single layer transmissions than training the channels using multiple DMRS. |  | No support. |
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## DMRS overhead reduction

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 13: Comments on the “DMRS overhead reduction”

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| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo | FFS |  |  | When DMRS bundling is introduced, DMRS less PUCCH can also considered. |
| Samsung |  | Unclear | Potential increase in receiver complexity | DMRS overhead reduction solutions, including “DMRS-less” solutions, should be discussed together and compared. |
| ZTE |  |  |  | Not sure what’s the difference/relationship between DMRS bundling and DMRS overhead reduction here. |
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## UE Antenna configuration enhancement for FR2

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 14: Comments on the “UE Antenna configuration enhancement for FR2”

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| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| Samsung |  |  |  | Deprioritize, might be discussed in MIMO WI. |
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## Higher DMRS density

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 15: Comments on the “Higher DMRS density”

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| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo |  | Better channel estimation accuracy. | Higher coding rate | The balance between channel estimation accuracy and coding rate should be carefully studied. |
| Samsung |  | Improved performance | Additional gNB receiver complexity | OK to study. Format(s) can be clarified. |
| ZTE |  |  |  | Ok to study whether there is performance gain. |
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## A-CSI on PUCCH

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 16: Comments on the “A-CSI on PUCCH”

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| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo |  |  |  | It seems that URLLC is also discussing the same topic, it can be discussed in URLLC WI. |
| Samsung |  | Unclear | No difference to P/SP CSI reporting on PUCCH or CSI reporting on PUSCH in terms of coverage – not a coverage enhancement issue | Deprioritize |
| ZTE |  |  |  | Should be discussed in Rel-17 URLLC. |
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## Symbol-level PUCCH repetition

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 17: Comments on the “Symbol-level PUCCH repetition”

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| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo |  |  |  | We think symbol level PUCCH repetition have similar performance as (mini-)slot based repetition. |
| Samsung |  | Can utilize all available resources | May require significant complexity increase | OK to study if time allows |
| ZTE |  |  |  | Can be discussed together with 3.2. |
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## Relay (including sidelink relay)

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 18: Comments on the “Relay (including sidelink relay)”

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| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
| vivo |  |  |  | Do not consider in this SI. |
| Samsung |  |  |  | Deprioritize, might be discussed in Sidelink. |
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## Reflective arrays

Companies are welcomed to provide views in the following table to identify the pros. and cons. of this scheme.

Table 19: Comments on the “Reflective arrays”

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| --- | --- | --- | --- | --- |
| Company name | LLS gain observed over Rel-15 baseline | Pros. of the proposed scheme | Cons. of the proposed scheme | Other comments |
|  |  |  |  | Do not consider in this SI. |
| Samsung |  |  |  | Deprioritize, might be discussed in MIMO WI. |
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# References

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| --- | --- | --- |
| **Tdoc #** | **Title** | **Source** |
| [R1-2005273](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2005273.zip) | Discussion on the potential coverage enhancement solutions for PUCCH | Huawei, HiSilicon |
| [R1-2005300](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2005300.zip) | Discussion on potential approaches and solutions for NR PUCCH coverage enhancement | Nokia, Nokia Shanghai Bell |
| [R1-2005396](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2005396.zip) | Discussion on Solutions for PUCCH coverage enhancement | vivo |
| [R1-2005428](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2005428.zip) | Discussion on potential techniques for PUCCH coverage enhancements | ZTE |
| [R1-2005585](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2005585.zip) | On PUCCH coverage enhancement techniques | Sony |
| [R1-2005725](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2005725.zip) | Discussion on potential techniques for PUCCH coverage enhancement | CATT |
| [R1-2005759](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2005759.zip) | Discussion on PUCCH coverage enhancement | NEC |
| [R1-2005890](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2005890.zip) | Discussion on potential techniques for PUCCH coverage enhancement | Intel Corporation |
| [R1-2006048](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006048.zip) | Consideration on PUCCH coverage enhancement | OPPO |
| [R1-2006163](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006163.zip) | PUCCH coverage enhancement | Samsung |
| [R1-2006227](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006227.zip) | Discussion on the PUCCH coverage enhancement | CMCC |
| [R1-2006246](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006246.zip) | PUCCH coverage enhancement | InterDigital, Inc. |
| [R1-2006349](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006349.zip) | Discussion on PUCCH coverage enhancements | Panasonic Corporation |
| [R1-2006457](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006457.zip) | PUCCH coverage enhancements | IITH, CeWiT, IITM, Reliance Jio, Tejas Networks |
| [R1-2006580](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006580.zip) | PUCCH coverage enhancement | Sharp |
| [R1-2006614](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006614.zip) | PUCCH coverage enhancement | Ericsson |
| [R1-2006742](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006742.zip) | Potential techniques for PUCCH coverage enhancements | NTT DOCOMO, INC. |
| [R1-2006821](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006821.zip) | Potential coverage enhancement techniques for PUCCH | Qualcomm Incorporated |
| [R1-2006880](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006880.zip) | Limitations of NR short block-length codes for PUCCH coverage enhancement | EURECOM/Sophia Antipolis |
| [R1-2006893](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_102-e/Docs/R1-2006893.zip) | Discussion on potential techniques for PUCCH coverage enhancement | WILUS Inc. |