

Source: ZTE
Title: Discussion on Repetition for Control Channel and Traffic Channel
Agenda item: 7.2.4.2
Document for: Discussion and Decision

1. Introduction

During RAN#60 meeting, “New WI: Low cost & enhanced coverage MTC UE for LTE” ([2]) was approved. One objective of this work item is to provide a relative LTE coverage improvement – corresponding to 15dB for FDD – for the UE category/type defined above and other UEs operating delay tolerant MTC applications with respect to their respective nominal coverage:

- Specify the following techniques (which shall be applicable for both FDD and TDD) to achieve this:
 - Simplification of PHICH and PCFICH functionality or alternative mechanism to PHICH and PCFICH functionality so that coverage limited UE is not constrained by PHICH and PCFICH physical channels
 - A mechanism(s) to support scalability of spectral efficiency impact for coverage improvement by identifying UE requiring additional coverage improvement and informing eNB the amount of coverage the UE requires.
 - Repetition/TTI bundling and extension to PSD boosting for applicable channels/signals identified during study phase.
 - A relaxed requirement for “probability of missed detection” for PRACH.
- When defining the detailed solutions for the above coverage enhancement techniques, relative spectral efficiency impact and cost/power consumption impact should be taken into account, and divergence of solutions between the new UE category/type and other UEs (mentioned above) should be minimized where possible.

Repetition is identified as the most effective and significant coverage enhancement technique for control channels and traffic channels during study phase. Repetition times needed for the control channel ((E)PDCCH/PUCCH) and traffic channels (PDSCH/PUSCH), timing relationship between control channel and traffic channel, and other related factors are discussed in this contribution.

2. Repetition Transmission for control channel(s) and traffic channel(s)

As discussed in TR.36.888 [1], time domain repetition is the most important coverage enhancement technique for almost all the physical channels. Some specification impact is expected for (E)PDCCH, PDSCH and PUSCH while minor specification impact is expected for PUCCH.

If (E)PDCCH is used for DL/UL traffic channel scheduling and PUCCH is used for uplink feedback, repetition transmission for control channel (PDCCH/PUCCH), repetition transmission for traffic channel (PDSCH/PUSCH), and timing relationship between control channel and traffic channel should be studied. For PUSCH, UL HARQ timeline and/or frequency hopping pattern combined with repetition may need to be further studied.

2.1 Repetition Transmission for Control Channel(s)

Considering 15dB coverage improvement target for FDD system, coverage target for PDCCH (format 1a, similarly for EPDCCH with similar number of REs) is about 14.6dB (up to 5dB coverage loss as evaluated in [5] for 1Rx low cost MTC UEs) while coverage target for PUCCH (format 1a) is 8.5dB. Repetition of (E)PDCCH/PUCCH across

multiple sub-frames may be required to achieve the coverage enhancement target. In order to reduce the repetition times, PSD boosting could be combined with repetition to compensate coverage loss caused by single receive RF chain

- Repetition times

The repetition times for control channel(s) may be a fixed or variable value. The benefit of fixed repetition times is from simple implementation, but the system efficiency may be degraded. For system to support multiple coverage enhancement levels, repetition times for control channel(s) may be set to a fixed value corresponding to the maximum coverage enhancement level, or to a particular coverage enhancement level.

Required repetition times for control channel(s) with different coverage enhancement levels (according to the evaluation results in [3], only repetition method applied) are shown in Table 1.

Table 1 Repetition times for control channels with different coverage enhancement levels

Coverage enhancement target	PDCCCH Coverage enhancement gap	Required repetition times for PDCCCH	PUCCH Coverage enhancement gap	Required repetition times for PUCCH
15dB	14.6dB	100	8.5dB	10
10dB	9.6dB	20	3.5dB	2
5dB	4.6dB	4	-	-

The benefit of variable repetition times is higher system efficiency, but the value should be determined before the transmission of control channel(s). The repetition times for (E)PDCCCH would be different for different DCI format and different aggregation level for the same coverage enhancement requirement. (E)PDCCCH may carry common control information and UE specific control information. The repetition times for common control information and for UE specific control information may need to be configured separately considering specific performance requirement. The repetition times for common control information could be determined according to the repetition times of PBCH. The repetition times for UE specific control information could be determined by coverage enhancement level of the specific UE, DCI format and the aggregation level of (E)PDCCCH.

Since UCI carried in PUCCH may only include Scheduling Request (SR) and HARQ-ACK, format 1a would be enough. The repetition times for PUCCH could be determined by coverage enhancement level.

Proposal 1: Repetition times for downlink control channel(s) is determined by the coverage enhancement level and the control channel type (e.g., information type carried in the control channel, DCI format, and aggregation level). Repetition times for PUCCH could be determined by coverage enhancement level.

- Sub-frame resources for one transmission cycle of (E)PDCCCH repetitions

One transmission cycle of (E)PDCCCH repetitions includes first transmission and the following repeating transmissions. There are several alternatives on how to choose the starting sub-frame.

ALT 1: Any sub-frame may be allowed as the starting sub-frame of first transmission for (E)PDCCCH repetition as shown in Figure 1. (E)PDCCCH transmission with repetition can be blindly detected. The shortage of this scheme is large storage requirement and high detection complexity, but the flexibility of UE scheduling could be ensured.

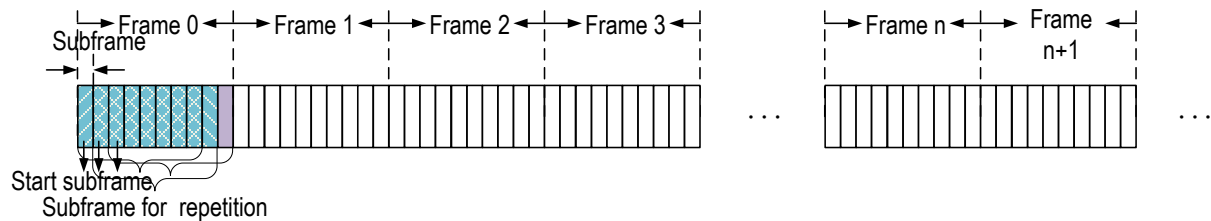


Figure 1 Starting sub-frame of first transmission for (E)PDCCH repetitions – ALT 1

ALT 2: The starting sub-frame of first transmission for (E)PDCCH repetitions may be restricted as shown in Figure 2. The benefit of restricting the starting sub-frame of first transmission for (E)PDCCH repetitions is lower storage cost and lower blind detection complexity compared to scheme in Figure 1.

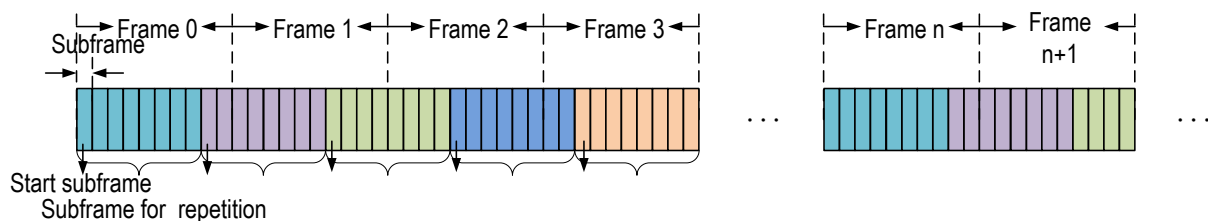


Figure 2 Starting sub-frame of first transmission for (E)PDCCH repetitions – ALT 2

ALT 3: Only one transmission cycle of (E)PDCCH repetitions can be scheduled in a predefined cycle as shown in Figure 3. This scheme can further reduce the impact to normal UEs. (Note: In figure 3, the radio frame number in a predefined cycle is one as an example. It could be larger than one.)

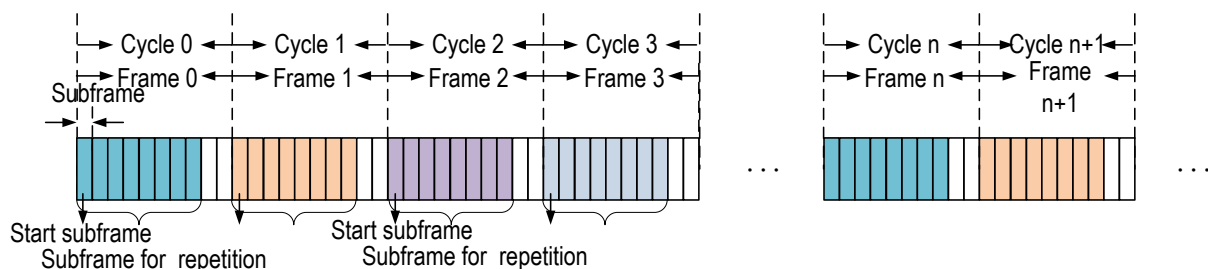


Figure 3 Starting sub-frame of first transmission for (E)PDCCH repetitions – ALT 3

Sub-frames for one transmission cycle for (E)PDCCH repetitions may also be determined by corresponding traffic channel since common information carried by the traffic channel has fixed location and period.

Proposal 2: It is beneficial to restrict the starting sub-frame of first transmission for (E)PDCCH repetitions.

- Downlink Control Information

DCI formats for low cost MTC UEs with poor coverage can be restricted to DCI Format 0, 1A or 1C.

As discussed in [1], Compact DCI format can be considered for coverage compensation. Fields such as “resource block assignment” and “HARQ process number” may be simplified. In order to support the repetition of traffic channels, some fields may be changed to indicate information of repetition times for traffic channels.

Proposal 3: DCI formats for low cost MTC UEs with poor coverage can be restricted to DCI Format 0, 1A or 1C. Fields in DCI may be simplified or adjusted for low cost MTC UEs with poor coverage.

2.2 Repetition Transmission for Traffic Channel

Considering 15dB coverage improvement target for FDD system, coverage target for PDSCH is about 14.3dB (up to 4dB coverage loss as evaluated in Annex A.2 for 1Rx low cost MTC UEs) while coverage target for PUSCH is 15dB. Repetition of PDSCH/PUSCH across multiple sub-frames may be required to achieve the coverage enhancement target. It is required to evaluate if current interference mitigation scheme is enough when the combination of repetitions and PSD boosting are applied.

- Repetition times

Repetition times for traffic channel may be fixed or variable. A fixed repetition times for traffic channel can be determined according to the maximum coverage enhancement requirement and the corresponding TBS. In order to improve the system efficiency, a fixed value of repetition times for traffic channels can be determined for each coverage enhancement level.

The required repetition times for PDSCH/PUSCH with different coverage enhancement levels (based on the evaluation results in [3], only repetition method applied) are shown in Table 2.

Table 2 Repetition times for traffic channels with different coverage enhancement levels

Coverage enhancement target	PDSCH Coverage enhancement gap	Required repetition times for PDSCH	PUSCH Coverage enhancement gap	Required repetition times for PUSCH
15dB	14.3dB	150	15 dB	100
10dB	9.3 dB	25	10 dB	20
5dB	4.3 dB	4	5 dB	4

The repetition times for traffic channel would be different for different packet size, different MCS and different resource allocation. The repetition times may be indicated by downlink control channel. The repetition times for traffic channel could be reduced if CRC size for small packets could be reduced.

Proposal 4: Repetition times for traffic channel would be variable according to the packet size and MCS level. Reduction of CRC size would be considered for small size packets.

- Cell-specific traffic transmission without control channel indication

Repetition of (E)PDCCH across multiple sub-frames will result in increased latency and overhead for data transmission. Cell-specific traffic (SIB, Paging, RAR, etc) transmission without (E)PDCCH indication may be considered in order to reduce the latency caused by repetitions of control channel. Blind transmission of common

control information for MTC UEs could be supported in order to save CSS resources and reduce the impact on common control information scheduling for normal UEs.

Proposal 5: Cell-specific traffic transmission without control channel indication may be considered.

2.3 Relationship between Control Channel and Traffic Channel

Timing relationship between control channel and traffic channel, and transmission latency should be considered when repetition for control channel and traffic channel are applied for MTC UEs.

- Timing relationship between PDSCH and (E)PDCCH

Considering different coverage enhancement gap, different physical layer resources and different information size carried by the corresponding channel, the repetition times for control channel and data channel would be different. There have three potential solutions for timing relationship between PDSCH and (E)PDCCH.

- Option 1: The starting sub-frame of first transmission for (E)PDCCH repetitions and the starting sub-frame of first transmission for PDSCH repetitions are the same as shown in Figure 3.

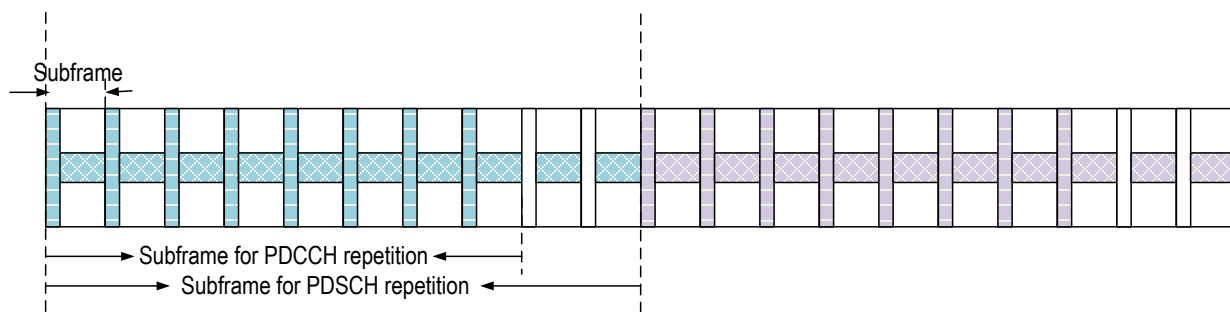


Figure 3 Timing relationship between PDSCH and (E)PDCCH – Option 1

This timing relationship option has relatively small transmission latency but with huge storage needs.

- Option 2: The starting sub-frame of first transmission for PDSCH repetitions is same as the end sub-frame of last transmission for (E)PDCCH repetitions as shown in Figure 4.

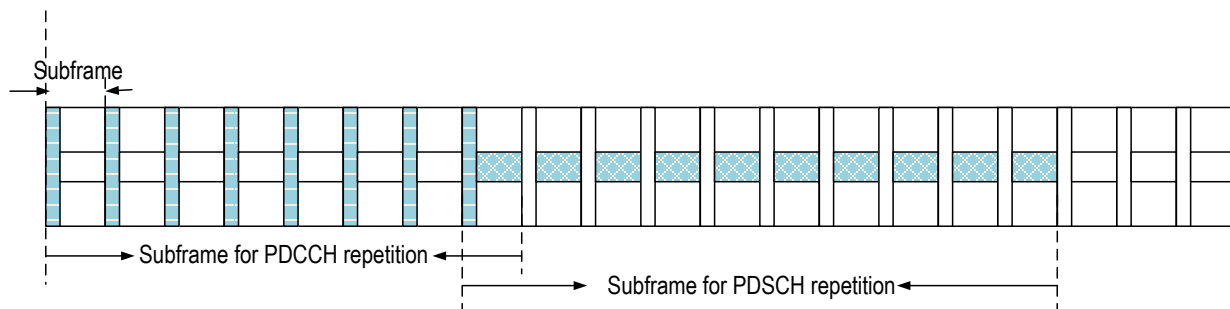


Figure 4 Timing relationship between PDSCH and (E)PDCCH – Option 2

This timing relationship option has moderate latency and relatively small storage overhead..

- Option 3: Interval of k sub-frames is expected between the start sub-frame of first transmission for PDSCH repetitions and the end sub-frame of last transmission for (E)PDCCH repetitions as shown in Figure 5.

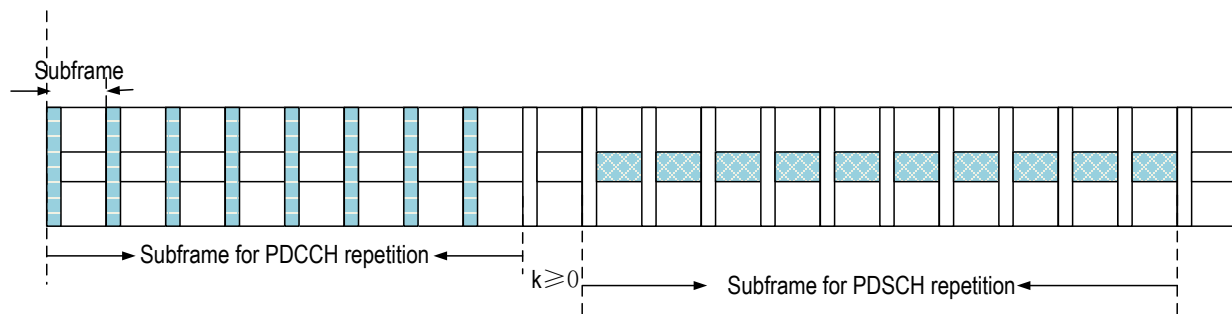


Figure 4 Timing relationship between PDSCH and (E)PDCCH – Option 3

This timing relationship option is more flexible but with longer latency and less storage overhead compared to Option 1

Proposal 6: The starting sub-frame of first transmission for PDSCH repetitions is same as the end sub-frame of last transmission for (E)PDCCH repetitions.

- Timing relationship between PUSCH and (E)PDCCH

Starting sub-frame of repetition transmission of PUSCH would be 4 sub-frames after the ending of (E)PDCCH repetition transmission in FDD system.

The timing of retransmission would be determined according to the corresponding simplification scheme for PHICH as discussed in [4].

- Analysis on transmission latency

Repetition transmission will cause longer latency. According to Annex A in [1], latency requirement for traffic model A, B and C is 10s, 3~5s and 1 hour respectively.

In uplink, traffic size of ~100 bytes is assumed for the three traffic models. The uplink latency may be determined by the available UL RBs for each UE. Based on the transmission latency calculated in Annex A.1, if 50 UL RBs could be allocated for an MTC UE and 16 bits are carried by one RB, one uplink transmission procedure is needed for ~100 bytes traffic and the latency would be 0.9s. 50 uplink transmission procedures are needed for ~100 bytes traffic and the latency would be $0.9 \times 50 = 45s$ if only one UL RB is allocated for an MTC UE.

In downlink, traffic size of 20bytes is assumed for traffic model A. If 6 DL RBs could be allocated for an MTC UE, two downlink transmission procedures are needed for ~20bytes traffic. The latency would be $0.64 \times 2 = 1.28s$ for timing relationship option 1 and would be $1.04 \times 2 = 2.08s$ for timing relationship option 2 and 3.

Proposal 7: Latency requirement should be considered when determining the repetition times for control channel and traffic channel.

Physical layer transmission latency has considerable impact on higher layer. For example, with current RLC timer settings, RLC AM PDU with latency longer than 200ms will never be successfully received. In C-plane, similar problem exists. Current maximum value for UE RRC request is 2s, any physical layer latency longer than 2s will

cause a problem for that procedure. With repetition being the most important coverage improvement techniques being standardized, it is important that corresponding higher layer aspects be adjusted.

3. Conclusions

Repetition times needed for the control channel ((E)PDCCH/PUCCH) and traffic channels(PDSCH/PUSCH), time relationship between control channel and traffic channel, and other repetition related standardization are discussed in this contribution. We propose the following:

Proposal 1: Repetition times for downlink control channel(s) is determined by the coverage enhancement level and the control channel type (e.g., information type carried in the control channel, DCI format, and aggregation level). Repetition times for PUCCH could be determined by coverage enhancement level.

Proposal 2: It is required to restrict the starting sub-frame of first transmission for (E)PDCCH repetitions.

Proposal 3: DCI formats for low cost MTC UEs with poor coverage can be restricted to DCI Format 0, 1A or 1C. Fields in DCI may be simplified or adjusted for low cost MTC UEs with poor coverage.

Proposal 4: Repetition times for traffic channel would be variable according to the packet size and MCS level. Reduction of CRC size would be considered for small size packets.

Proposal 5: Cell-specific traffic transmission without control channel indication may be considered.

Proposal 6: The starting sub-frame of first transmission for PDSCH repetitions is same as the end sub-frame of last transmission for (E)PDCCH repetitions.

Proposal 7: Latency requirement should be considered when determining the repetition times for control channel and traffic channel.

References

- [1] 3GPP TR 36.888 V12.0.0, "Study on provision of low-cost MTC UEs based on LTE, (Release 12)"
- [2] RP-130848, "New WI: Low cost & enhanced coverage MTC UE for LTE", Vodafone, RAN #60
- [3] R1-132110, "Diminishing returns and coverage improvement summary for TR36.888", ZTE, 3GPP RAN1 #73
- [4] R1-133061, "Simplification of PHICH and PCFICH functionalities for coverage improvement MTC UE", ZTE, 3GPP RAN1 #74
- [5] R1-120291, "TP for evaluation/analysis of single receive RF chain", ZTE, 3GPP RAN1 #68

Annex

A.1 Transmission latency

As evaluation in [3], for 15dB coverage enhancement requirement and single receive RF chain, 150 times PDSCH repetition for 152bit TBS, 100 times PUSCH repetition for 16bit TBS, 100 times PDCCH repetition for 8CCE and Format 0/1A PDCCH and 10 times PUCCH are considered. According to maximum 4 times retransmission (including first transmission) in physical layer, the transmission procedure is shown in Figure A.1-1.

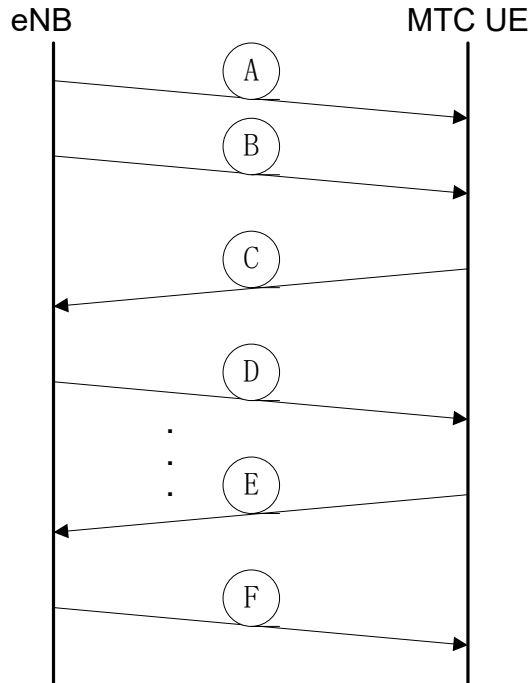


Figure A.1-1 Transmission procedure

Downlink transmission: A) repetition transmission of (E)PDCCH; B) repetition transmission of PDSCH; C) repetition transmission of PUCCH; D) repetition transmission of (E)PDCCH which carries the scheduling information of the PDSCH retransmission; ...; E) repetition transmission of PUCCH which carries the feedback information for PDSCH. (Note: Transmission interval between PDSCH and PUCCH is omitted.) For timing relationship option 1, PDCCH and PDSCH will start transmission at the same time, the transmission latency will be $(100+50+10) \text{ ms} \times 4 = 0.64\text{s}$;

For timing relationship option 2 and 3, PDSCH transmission will start after the PDCCH transmission, the transmission latency will be $(100+150+10)\text{ms} \times 4 = 1.04\text{s}$;

Uplink transmission: A) repetition transmission of (E)PDCCH; C) repetition transmission of PUSCH; D) repetition transmission of PDCCH instead of PHICH; ...; E) repetition transmission of PUSCH; F) repetition transmission of PDCCH which carries feedback information for PUSCH. (Note: Transmission interval between PUSCH and (E)PDCCH is omitted.) The transmission latency will be $100\text{ms} + (100+100)\text{ms} \times 4 = 0.9\text{s}$

A.2 Simulation assumption and simulation results for PDSCH performance with different antenna number

Table A.2-1

Parameters	Value
System bandwidth	10MHz
Frame structure	FDD
Carrier frequency	2.0 GHz
Antenna configuration	2x2/2x1, low correlation
Channel model	EPA

Dopplerspread	1Hz
MCS	0 (TBS=152)
Number of DL RBs	6
Transmission mode	TM2
Frequency tracking error	100Hz
Performance target	10% iBLER

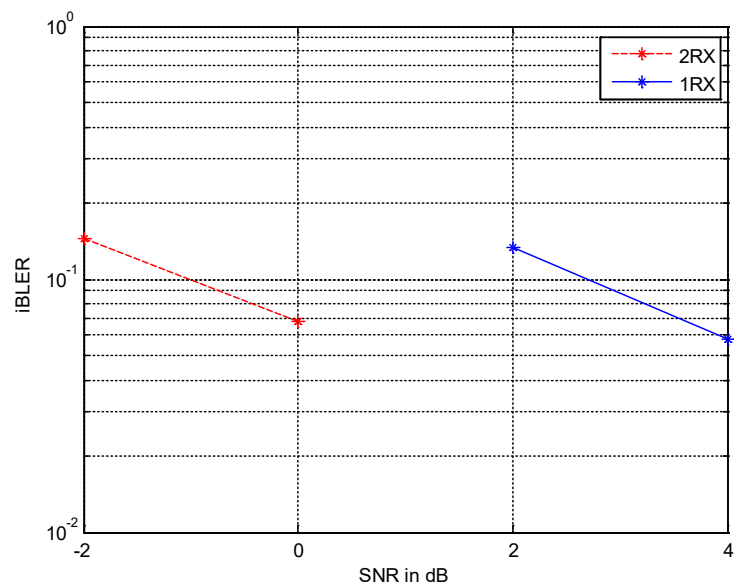


Figure A.2-2 PDSCH difference performance with 1RX/2 RX