**3GPP TSG RAN WG1 Meeting #107-e R1-21xxxxx**

**e-Meeting, November 11th – 19th, 2021**

**Agenda Item: 8.9.1**

**Source: Moderator (Huawei)**

**Title: Feature lead summary #3 on 107-e-LTE-Rel17-NB-IoT-eMTC-01**

**Document for: Discussion and Decision**

# Introduction

The WID for Rel-17 enhancements for NB-IoT and LTE-MTC [1] includes an objective to support 16-QAM for unicast in UL and DL in NB-IoT.

* *Specify 16-QAM for unicast in UL and DL, including necessary changes to DL power allocation for NPDSCH and DL TBS. This is to be specified without a new NB-IoT UE category. For DL, increase in maximum TBS of e.g. 2x the Rel-16 maximum, and soft buffer size will be specified by modifying at least existing Category NB2. For UL, the maximum TBS is not increased. [NB-IoT] [RAN1, RAN4]*
	+ *Extend the NB-IoT channel quality reporting based on the framework of Rel-14—16, to support 16-QAM in DL. [NB-IoT] [RAN2, RAN1, RAN4]*

This documents provides the proposals and summary of discussions of the corresponding email discussion according to the inputs [2-10].

[107-e-LTE-Rel17-NB-IoT-eMTC-01] Email discussion on support of 16-QAM for unicast in UL and DL for NB-IoT – Yubo (Huawei)

* 1st check point: November 15
* Final check point: November 19

# Discussion

## Uplink power control

### Issue 1: uplink power control

From previous discussion, the following proposals are agreeable.

**Proposal 1: confirm the following working assumption.**

**For the new term** $∆\_{TF,c}$ **introduced for power control of NPUSCH,**

* Reuse the LTE definition simplified for NB-IoT: $∆\_{TF,c}\left(i\right)=10log\_{10}\left(\left(2^{BPRE∙K\_{s}}-1\right)\right)$ for $K\_{s}=1.25$ and $∆\_{TF,c}\left(i\right)=0$ for $K\_{s}=0$, where $K\_{s}$ is given by higher layer parameter *deltaMCS-Enabled*, and $BPRE=\frac{K}{N\_{RE}}$ where K is the code block size.
* FFS: whether the new term applies to QPSK when configured with 16QAM, if it does not, whether an additional term is introduced to avoid jump between QPSK and 16QAM

On the FFS part, based on the comments, it will be down-selected from the following options:

* Option 1: The term $∆\_{TF,c}\left(i\right)$ can also be applied to NPUSCH with QPSK, when 16-QAM is configured.
* Option 2: An offset to $∆\_{TF,c}\left(i\right)$ is configured from a set of {[1dB], [2dB], [4dB], [6dB]}, when 16-QAM is configured.

For information, the $∆\_{TF,c}\left(i\right)$calculated are summarized in the following table:

|  |  |  |  |
| --- | --- | --- | --- |
| Modulation | $$I\_{TBS}$$ |  | $$I\_{RU}$$ |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| QPSK | 13 | TBS | 224 | 488 | 744 | 1032 | 1256 | 1544 | 2024 | 2536 |
| $$∆\_{TF,c}\left(i\right)$$ | 4.546765 | 5.238875 | 5.374201 | 5.708471 | 5.481782 | 5.686359 | 5.542038 | 5.562083 |
| 16QAM | 14 | TBS | 256 | 552 | 840 | 1128 | 1416 | 1736 | 2280 |  |

And the power control values for both options are listed as below, assuming 5RUs, and that the default P0 is 0dB, and the power of 16QAM NPUSCH for option 1 and option 2 is the same.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| $$I\_{TBS}$$ | TBS | $∆\_{TF,c} $: option 1 | P0 setting for option 1 | $∆\_{TF,c} $: option 2 | Offset for option 2 | P0 setting for option 2 |
| 1 | 176 | -6.27282 | 0 | 0 | 0 | 6.5 |
| 3 | 256 | -4.42746 | 0 | 0 | 0 | 6.5 |
| 4 | 328 | -3.15198 | 0 | 0 | 0 | 6.5 |
| 5 | 424 | -1.76735 | 0 | 0 | 0 | 6.5 |
| 6 | 504 | -0.7883 | 0 | 0 | 0 | 6.5 |
| 7 | 584 | 0.083221 | 0 | 0 | 0 | 6.5 |
| 8 | 680 | 1.026534 | 0 | 0 | 0 | 6.5 |
| 9 | 776 | 1.887086 | 0 | 0 | 0 | 6.5 |
| 10 | 872 | 2.685284 | 0 | 0 | 0 | 6.5 |
| 11 | 1000 | 3.676093 | 0 | 0 | 0 | 6.5 |
| 12 | 1128 | 4.603156 | 0 | 0 | 0 | 6.5 |
| 13 | 1256 | 5.481782 | 0 | 0 | 0 | 6.5 |
| 14 | 1416 | 6.528084 | 0 | 6.528084 | -6.5 | 6.5 |
| 15 | 1544 | 7.332797 | 0 | 7.332797 | -6.5 | 6.5 |
| 16 | 1608 | 7.726365 | 0 | 7.726365 | -6.5 | 6.5 |
| 17 | 1800 | 8.878457 | 0 | 8.878457 | -6.5 | 6.5 |
| 18 | 1992 | 9.996363 | 0 | 9.996363 | -6.5 | 6.5 |
| 19 | 2152 | 10.90802 | 0 | 10.90802 | -6.5 | 6.5 |
| 20 | 2344 | 11.98355 | 0 | 11.98355 | -6.5 | 6.5 |
| 21 | 2536 | 13.04336 | 0 | 13.04336 | -6.5 | 6.5 |

**Proposal 2: it is down-selected from following options in this meeting:**

* **Option 1: The term** $∆\_{TF,c}\left(i\right)$ **can also be applied to NPUSCH with QPSK, when 16-QAM is configured.**
* **Option 2: An offset to** $∆\_{TF,c}\left(i\right)$ **is configured from a set of {[1dB], [2dB], [4dB], [6dB]}, when 16-QAM is configured.**

Please input your comments regarding following points in the table:

* Your comments to the proposals.
* Your proposal on the offset.

|  |  |
| --- | --- |
| Companies | Comments |
| Moderator | From the comments, there are concerns for option 1 as below:ZTE: If the term $∆\_{TF,c}\left(i\right)$ is used for QPSK, the legacy QPSK power for some entries would be decreased, which would effect the legacy QPSK performance.Ericsson: Option 1 results in side effects that should not be overlooked, and that is the reason why Option 2 is preferred.And the concerns over option 2 is:Nokia: In our understanding, when deltaMCS is enabled, the UL power should be adjusted according to the MCS level. If this is only done for 16QAM, then in our view this does not follow the underlying principle of this power control operation.Please proponents of each option address the above concerns. |
| Lenovo, MotoM | We share the similar view as Nokia, and if 16QAM is configured, UE will follow the new power control scheme (e.g., new term $∆\_{TF,c}\left(i\right)$adoped for QPSK and 16QAM). If we consider the side effect on before and after 16QAM configured, it can be up to eNB to configure a suitable P0 when 16QAM is configured. |
| Ericsson | Proposal 1: We are Ok.Proposal 2:We are standardizing 16-QAM, however Option 1 adds a new term for QPSK, the problem with it is that while it alleviates the “jump between QPSK and 16QAM” it also introduces as a side effect that the QPSK UL power control behavior will be different with and without 16-QAM configured. Any other work-around to fix this situation is yet another side effect.I think we should solve the “jump between QPSK and 16QAM” acting on what we have introduced for 16-QAM without touching QPSK. Thus, for Proposal 2 we support Option 2. |
| Nokia, NSB | Proposal 1: We support the proposalProposal 2: Since we have adopted the LTE power control operation mode $∆\_{TF,c}\left(i\right)$ for 16-QAM, we should be consistent with the underlying principle of this mode, which is to adjust UL transmission power based on MCS. We should not have two separate behaviors for this mode based on whether 16-QAM or QPSK is used. It’s true that QPSK UL power control will be different depending on whether deltaMCS is enabled, but it’s meant to be based on how this operation mode was designed. If the gNB does not wish to allow power to change with MCS, it can disable deltaMCS which is consistent with current LTE operation. There is no need to increase UE Tx power when 16-QAM is used. |

## Channel quality reporting

### Issue 2: CQI table

The following has been achieved:

Agreement

* The table is taken as working assumption.

|  |  |  |  |
| --- | --- | --- | --- |
| Reported value | NPDCCH repetition level | NPDSCH transport block error probability not exceeding 0.1 | SNR |
| Modulation | Code rate x 1024 | Repetition | Efficiency |
| noMeasurement | No measurement reporting | Out of range |  |
| candidateRep-A | 1 | QPSK (TBS index 4) | 221 | 1 | 0.4316 | -0.6 dB ([2]) |
| candidateRep-B | 2 | QPSK (TBS index 2) | 280 | 1 | 0.2737 | -3.6 |
| candidateRep-C | 4 | QPSK (TBS index 0) | 81 | 1 | 0.1579 | -6.6 |
| candidateRep-D | 8 | QPSK (TBS index 0) | 81 | 2 | 0.0789 | -9.6 |
| candidateRep-E | 16 | QPSK (TBS index 0) | 81 | 4 | 0.0395 | -12.6 |
| Working assumptioncandidateRep-F | 32 | QPSK (TBS index 0) | 81 | 8 | 0.0198 | -15.6 |
| candidateRep-G | 1 | QPSK (TBS index 6) | 336.8 | 1 | 0.6579 | 1.0 dB ([3]) |
| candidateRep-H | 1 | QPSK (TBS index 8) | 453.6 | 1 | 0.8860 | 2.6 dB ([3]) |
| candidateRep-I | 1 | QPSK (TBS index 10) | 579.4 | 1 | 1.1316 | 4.1 dB ([3]) |
| candidateRep-J | 1 | QPSK (TBS index 12) | 759 | 1 | 1.4825 | 6.3 dB ([3]) |
| candidateRep-K | 1 | 16QAM (TBS index 14) | 487.3 | 1 | 1.9035 | 8.9 dB ([3]) |
| candidateRep-L | 1 | 16QAM (TBS index 16) | 541.2 | 1 | 2.1140 | 9.7 dB ([3]) |
| candidateRep-M | 1 | 16QAM (TBS index 18) | 658 | 1 | 2.5702 | 11.7 dB ([3]) |
| candidateRep-N | 1 | 16QAM (TBS index 20) | 783.7 | 1 | 3.0614 | 13.0 dB ([3]) |
| candidateRep-O | 1 | 16QAM (TBS index 21) | 837.6 | 1 | 3.2719 | 14.1 dB ([3]) |

Note: The (TBS index X) and SNR are just for information, based on standalone deployment. They will be removed once it’s agreed.

On the CQI derivation, there’s the following in TS 36.213:

For a BL/CE UE, based on an unrestricted observation interval in time and frequency, the UE shall derive for each CQI value the highest CQI index between 1 and 10 in Table 7.2.3-3 which satisfies the following condition, or CQI index 0 if CQI index 1 does not satisfy the condition:

- A single PDSCH transport block with a combination of modulation scheme and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks termed the CSI reference resource, could be received with a transport block error probability not exceeding 0.1.

And for NB-IoT measurement report, there’s the following TS 36.133:

The DL channel quality provides the serving eNB with information about the minimum NPDCCH repetition level to satisfy the hypothetical NPDCCH block error rate of 1% with the parameters specified in Table 6.6.2.6-1.

Then, it would be straightforward to combine the above for channel quality reporting of 16QAM:

The DL channel quality provides the serving eNB with information about the minimum entry satisfying the folllowing condition,

- NPDCCH repetition level to satisfy the hypothetical NPDCCH block error rate of 1% with the parameters specified in Table 6.6.2.6-1, and

- A single PDSCH transport block with a combination of modulation scheme and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks termed the CSI reference resource, could be received with a transport block error probability not exceeding 0.1.

As this is verbose, and the majority view is to capture it in RAN4, maybe the above can be included in the LS to RAN4 as an information.

On the concern on different deployment, as there’s the sentence “A single PDSCH transport block with a combination of modulation scheme and transport block size corresponding to the CQI index” as in legacy, the eNB and UE can derive the corresponding TBS for different deployments based on available REs, which is known to both eNB and UE.

With the above explanation, please give your comments on confirming the above working assumption:

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo, MotoM | We are fine to confirm the working assumption.Regarding the LS to RAN4. It seems we don’t want to introduce the CSI reference resource for NBIoT, so the text should be refined.A single NPDSCH transport block with a combination of modulation scheme and transport block size corresponding to the CQI index, and occupying a group of downlink physical resource blocks ~~termed the CSI reference resource~~, could be received with a transport block error probability not exceeding 0.1. |
| Ericsson | About including in the LS to RAN4 a combination of channel quality definitions (it seems not necessary and prone to create confusion). In our opinion, it seems enough with the channel quality definition we agreed in RAN1#104-bis-e for 16-QAM related entries and the legacy definition for QPSK related entries.About the CQI Table, I was under the impression that an alignment at the moment of performing the “code rates to ITBS indices” was being pursued, especially because the “Modulation” column displays “(TBS index …)”. But during yesterday’s session it was clarified that in the case of the proposed CQI Table only the “Code Rates” would be provided, and it will be up to each vendor implementation to perform (i.e., in a proprietary manner) the mapping of “code rates to I\_TBS indices”. We can be fine with that approach, but to avoid further misunderstanding perhaps the CQI table can be presented in a cleaned formed (i.e., removing any “(TBS index …)” and the SNR column).

|  |  |  |
| --- | --- | --- |
| Reported value | NPDCCH repetition level | NPDSCH transport blockerror probability not exceeding 0.1 |
| Modulation | Code rate x 1024 | Repetition | Efficiency |
| noMeasurement | No measurement reporting | Out of range |
| candidateRep-A | 1 | QPSK  | 221 | 1 | 0.4316 |
| candidateRep-B | 2 | QPSK  | 280 | 1 | 0.2737 |
| candidateRep-C | 4 | QPSK  | 81 | 1 | 0.1579 |
| candidateRep-D | 8 | QPSK  | 81 | 2 | 0.0789 |
| candidateRep-E | 16 | QPSK  | 81 | 4 | 0.0395 |
| Working assumptioncandidateRep-F | 32 | QPSK  | 81 | 8 | 0.0198 |
| candidateRep-G | 1 | QPSK | 336.8 | 1 | 0.6579 |
| candidateRep-H | 1 | QPSK | 453.6 | 1 | 0.8860 |
| candidateRep-I | 1 | QPSK | 579.4 | 1 | 1.1316 |
| candidateRep-J | 1 | QPSK | 759 | 1 | 1.4825 |
| candidateRep-K | 1 | 16QAM | 487.3 | 1 | 1.9035 |
| candidateRep-L | 1 | 16QAM | 541.2 | 1 | 2.1140 |
| candidateRep-M | 1 | 16QAM | 658 | 1 | 2.5702 |
| candidateRep-N | 1 | 16QAM | 783.7 | 1 | 3.0614 |
| candidateRep-O | 1 | 16QAM | 837.6 | 1 | 3.2719 |

About the WA on “candidateRep-F”, we prefer to keep the CQI table as it is without any further modification.  |
| Nokia, NSB | We support confirming the working assumption including the candidateRep-F value. We agree with Ericsson on the proposed table update above (removal of TBS index and SNR column).We are fine to capture the definition as proposed by the FL. We would like to keep the CSI reference resource in the NPDSCH definition and leave it to RAN4 to define this.  |

### Issue 3: Switching of CQI table

As commented by several companies, the switching between the legacy table and the CQI table should be discussed.

**Proposal 3: When 16QAM is configured, the new CQI table is used. FFS on use of legacy measurement reporting down-selected from following options:**

* + **Option 1: UE indicates the use of legacy or new CQI table via MAC CE.**
	+ **Option 2: eNB indicates the use of legacy or new CQI table via MAC CE.**
	+ **Option 3: eNB configures the use of legacy or new CQI table via RRC configuration**
	+ **Option 4: if Rmax<=16, the new CQI table is used, otherwise, the legacy CQI table is used.**

For Qualcomm’s preference and option 5 proposed by Ericsson, my understanding is that it has been captured in the main bullet of the above proposal. The 4 options are FFS whether a further step is needed based on the main bullet. Therefore, the option 5 seems not needed. Please check whether this makes sense.

Please input your comments regarding the above options.

|  |  |
| --- | --- |
| Companies | Comments |
| Huawei, HiSilicon | We prefer option 1. For option 2 and option 3, the report is controlled by eNB, which will lead to the result that the CQI reporting will lack accuracy and does not reflect the channel condition level according to the UE real-time measurement. Thus, the switching of CQI table should be determined by the UE. |
| MTK | Our first preference is **Option 1**, second preference is **Option 2**. Although network can take legacy report in Msg3 as initial reference for selection of new or old CQI table, the indicated CQI table may be mismatched due to the channel are varying. For example, UEs may report NPDCCH repletion 16/32 in Msg3 and accordingly the network should indicate the use of new CQI table, but the UE measured Channel quality may become too worse after an uncertain period so that UE need to report 64 repetition, this will cause CQI table changing. Option 1 can completely accommodate this case. |
| ZTE, Sanechips | Option1 is preferred.From option1 to option4, it is observed that the flexibility for reporting is decreasing. * For option1, UE can flexibly choose any entry to report according the channel condition. Moreover, Mac CE report is faster than RRC configuration.
* For option2, eNB decide which table will be used for UE CQI reporting. Compared with option1, eNB is not as sensitive to channel condition as UE and switching between legacy table and new table is also not as flexible as option1.
* For option3, as mentioned, RRC configuration would have larger delay than Mac CE report.
* For option4, it is a kind of eNB implementation of option3 and option4 can be viewed as an specific example of option3.
 |
| Ericsson v020 | As we said we prefer Option 4, and as a second preference we are open to discuss MAC CE-based solutions (although that will create another impact in the “MAC CE impacts” list).To Qualcomm, by “variant of Option 3”, do you mean that if 16QAM in DL is configured in msg4, then the UE should use the 16QAM CQI table, otherwise the UE will use the legacy table, so no additional signal explicitly indicates to switch the table in connected mode? |
| Qualcomm | @Ericsson: Yes. This is the same approach that was followed in LTE in the past (the CQI and MCS table are configured together). Additionally, when we discussed the feature list for 16-QAM, Qualcomm wanted to make the CSI report optional in a separate FG from 16-QAM, but companies commented (summary [here](https://www.3gpp.org/ftp/tsg_ran/WG1_RL1/TSGR1_106b-e/Docs/R1-2109715.zip)) that the enhanced CSI report was necessary to schedule 16-QAM.  |
| Moderator | The discussion of each option is reserved for further reference. And the situation is as following:* + Option 1: UE indicates the use of legacy or new CQI table via MAC CE.
		- Huawei, HiSilicon, MTK (1st), ZTE, Sanechips,
	+ Option 2: eNB indicates the use of legacy or new CQI table via MAC CE.
		- Ericsson (2nd), Lenovo, Moto (2nd), MTK(2nd)
	+ Option 3: eNB configures the use of legacy or new CQI table via RRC configuration
		- Lenovo, Moto (2nd), Nokia, NSB
	+ Option 4: if Rmax<=16, the new CQI table is used, otherwise, the legacy CQI table is used.
		- Ericsson (1st), Lenovo, Moto (1st),
	+ The legacy CQI table is not needed.
		- QC

Please continue discussion to address the concerns presented by companies. |
| Lenovo, MotoM | CQI table switching is not a critical issue for UE reporting, so we think it is better to be controlled by eNB. Regarding the option4, we think there is no new signaling needed. We are OK with option 2 and 3 as listed by moderator above. |
| Ericsson | To the Moderator: I do not think Qualcomm meant that “the legacy CQI table is not needed”. Based on the comments we exchanged, they confirmed they meant the following: Option 5: if 16QAM in DL is configured in msg4, then the UE should use the 16QAM CQI table, otherwise the UE will use the legacy table.About the MAC CE based solutions, thinking more about them it seems that RSRP/SINR knowledge at the UE side is needed. Hence taking into account that aspect Option 1 seems more suitable.In summary, we still prefer Option 4, and as a second choice we would be Ok with Option 1 or Option 5: if 16QAM in DL is configured in msg4, then the UE should use the 16QAM CQI table, otherwise the UE will use the legacy table. |
| Nokia, NSB | We are fine with Option 2,3,5 where Option 5 is given by Ericsson above. |

### Issue 4: The capturing of CQI table in spec

Based on the comments, the following seems to be agreeable:

**Proposal 4: The new CQI table is captured in TS 36.133, send LS to RAN2/RAN4 of the agreements on channel quality reporting.**

Please input your comments regarding the above options.

|  |  |
| --- | --- |
| Companies | Comments |
| Lenovo, MotoM | OK |
| Ericsson | Ok, and we suggest including in the LS the proposal 3 that Nokia has in [4], which suggests that the CSI reference resource to be used for 16-QAM CQI measurement can be up to RAN4. |
| Nokia, NSB | OK and also agree with Ericsson to add that CSI reference resource to be used for 16-QAM CQI measurement can be up to RAN4. |

# Summary

# References

1. RP-211340, “WID revision: Additional enhancements for NB-IoT and LTE-MTC”, Huawei, HiSilicon, RAN#92e, E-meeting, June 2021.
2. R1-2110857 Support of 16QAM for unicast in UL and DL in NB-IoT Huawei, HiSilicon
3. R1-2111070 Discussion on 16QAM for NB-IoT ZTE, Sanechips
4. R1-2111133 Support of 16-QAM for NB-IoT Nokia, Nokia Shanghai Bell
5. R1-2111449 Support of 16-QAM for NB-IoT Qualcomm Incorporated
6. R1-2112001 Support 16QAM for NBIoT Lenovo, Motorola Mobility
7. R1-2112300 Discussion on CQI table and NPUSCH power control parameter for 16QAM MediaTek Inc.
8. R1-2112361 Support of 16-QAM for unicast in UL and DL in NB-IoT Ericsson
9. R1-2111939 Further considerations on Rel-17 NB-IoT and eMTC enhancements Huawei, HiSilicon
10. R1-2112363 On the support of 16-QAM for unicast in UL and DL in TDD NB-IoT Ericsson

# Appendix A

## A.1 The coding rate and efficiency

Assuming 2 NRS ports in standalone deployment, then the coding rate and efficiency for QPSK and 16QAM MCS are summarized in the following table, assuming repetition number is one

|  |  |  |
| --- | --- | --- |
| Modulation | I\_TBS | I\_sf |
| 0 | 1 | 2 | 3 |
| TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency |
| BPSK | 0 | 16 | 107.7894737 | 0.105263158 | 32 | 107.7894737 | 0.105263158 | 56 | 125.754386 | 0.122807018 | 88 | 148.2105263 | 0.144736842 |
| QPSK | 1 | 24 | 80.84210526 | 0.157894737 | 56 | 94.31578947 | 0.184210526 | 88 | 98.80701754 | 0.192982456 | 144 | 121.2631579 | 0.236842105 |
| BPSK | 2 | 32 | 215.5789474 | 0.210526316 | 72 | 242.5263158 | 0.236842105 | 144 | 323.3684211 | 0.315789474 | 176 | 296.4210526 | 0.289473684 |
| QPSK | 3 | 40 | 134.7368421 | 0.263157895 | 104 | 175.1578947 | 0.342105263 | 176 | 197.6140351 | 0.385964912 | 208 | 175.1578947 | 0.342105263 |
| QPSK | 4 | 56 | 188.6315789 | 0.368421053 | 120 | 202.1052632 | 0.394736842 | 208 | 233.5438596 | 0.456140351 | 256 | 215.5789474 | 0.421052632 |
| QPSK | 5 | 72 | 242.5263158 | 0.473684211 | 144 | 242.5263158 | 0.473684211 | 224 | 251.5087719 | 0.49122807 | 328 | 276.2105263 | 0.539473684 |
| QPSK | 6 | 88 | 296.4210526 | 0.578947368 | 176 | 296.4210526 | 0.578947368 | 256 | 287.4385965 | 0.561403509 | 392 | 330.1052632 | 0.644736842 |
| QPSK | 7 | 104 | 350.3157895 | 0.684210526 | 224 | 377.2631579 | 0.736842105 | 328 | 368.2807018 | 0.719298246 | 472 | 397.4736842 | 0.776315789 |
| QPSK | 8 | 120 | 404.2105263 | 0.789473684 | 256 | 431.1578947 | 0.842105263 | 392 | 440.1403509 | 0.859649123 | 536 | 451.3684211 | 0.881578947 |
| QPSK | 9 | 136 | 458.1052632 | 0.894736842 | 296 | 498.5263158 | 0.973684211 | 456 | 512 | 1 | 616 | 518.7368421 | 1.013157895 |
| QPSK | 10 | 144 | 485.0526316 | 0.947368421 | 328 | 552.4210526 | 1.078947368 | 504 | 565.8947368 | 1.105263158 | 680 | 572.6315789 | 1.118421053 |
| QPSK | 11 | 176 | 592.8421053 | 1.157894737 | 376 | 633.2631579 | 1.236842105 | 584 | 655.7192982 | 1.280701754 | 776 | 653.4736842 | 1.276315789 |
| QPSK | 12 | 208 | 700.6315789 | 1.368421053 | 440 | 741.0526316 | 1.447368421 | 680 | 763.5087719 | 1.49122807 | 904 | 761.2631579 | 1.486842105 |
| QPSK | 13 | 224 | 754.5263158 | 1.473684211 | 488 | 821.8947368 | 1.605263158 | 744 | 835.3684211 | 1.631578947 | 1032 | 869.0526316 | 1.697368421 |
| 16QAM | 14 | 256 | 431.1578947 | 1.684210526 | 552 | 464.8421053 | 1.815789474 | 840 | 471.5789474 | 1.842105263 | 1128 | 474.9473684 | 1.855263158 |
| 16QAM | 15 | 280 | 471.5789474 | 1.842105263 | 600 | 505.2631579 | 1.973684211 | 904 | 507.5087719 | 1.98245614 | 1224 | 515.3684211 | 2.013157895 |
| 16QAM | 16 | 296 | 498.5263158 | 1.947368421 | 632 | 532.2105263 | 2.078947368 | 968 | 543.4385965 | 2.122807018 | 1288 | 542.3157895 | 2.118421053 |
| 16QAM | 17 | 336 | 565.8947368 | 2.210526316 | 696 | 586.1052632 | 2.289473684 | 1064 | 597.3333333 | 2.333333333 | 1416 | 596.2105263 | 2.328947368 |
| 16QAM | 18 | 376 | 633.2631579 | 2.473684211 | 776 | 653.4736842 | 2.552631579 | 1160 | 651.2280702 | 2.543859649 | 1544 | 650.1052632 | 2.539473684 |
| 16QAM | 19 | 408 | 687.1578947 | 2.684210526 | 840 | 707.3684211 | 2.763157895 | 1288 | 723.0877193 | 2.824561404 | 1736 | 730.9473684 | 2.855263158 |
| 16QAM | 20 | 440 | 741.0526316 | 2.894736842 | 904 | 761.2631579 | 2.973684211 | 1384 | 776.9824561 | 3.035087719 | 1864 | 784.8421053 | 3.065789474 |
| 16QAM | 21 | 488 | 821.8947368 | 3.210526316 | 1000 | 842.1052632 | 3.289473684 | 1480 | 830.877193 | 3.245614035 | 1992 | 838.7368421 | 3.276315789 |

|  |  |  |
| --- | --- | --- |
| Modulation | I\_TBS | I\_sf |
| 4 | 5 | 6 | 7 |
| TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency | TBS | Coding rate (X 1024) | Efficiency |
| BPSK | 0 | 120 | 161.6842105 | 0.157894737 | 152 | 170.6666667 | 0.166666667 | 208 | 175.1578947 | 0.171052632 | 256 | 172.4631579 | 0.168421053 |
| QPSK | 1 | 176 | 118.5684211 | 0.231578947 | 208 | 116.7719298 | 0.228070175 | 256 | 107.7894737 | 0.210526316 | 344 | 115.8736842 | 0.226315789 |
| BPSK | 2 | 208 | 280.2526316 | 0.273684211 | 256 | 287.4385965 | 0.280701754 | 328 | 276.2105263 | 0.269736842 | 424 | 285.6421053 | 0.278947368 |
| QPSK | 3 | 256 | 172.4631579 | 0.336842105 | 328 | 184.1403509 | 0.359649123 | 440 | 185.2631579 | 0.361842105 | 568 | 191.3263158 | 0.373684211 |
| QPSK | 4 | 328 | 220.9684211 | 0.431578947 | 408 | 229.0526316 | 0.447368421 | 552 | 232.4210526 | 0.453947368 | 680 | 229.0526316 | 0.447368421 |
| QPSK | 5 | 424 | 285.6421053 | 0.557894737 | 504 | 282.9473684 | 0.552631579 | 680 | 286.3157895 | 0.559210526 | 872 | 293.7263158 | 0.573684211 |
| QPSK | 6 | 504 | 339.5368421 | 0.663157895 | 600 | 336.8421053 | 0.657894737 | 808 | 340.2105263 | 0.664473684 | 1032 | 347.6210526 | 0.678947368 |
| QPSK | 7 | 584 | 393.4315789 | 0.768421053 | 680 | 381.754386 | 0.745614035 | 968 | 407.5789474 | 0.796052632 | 1224 | 412.2947368 | 0.805263158 |
| QPSK | 8 | 680 | 458.1052632 | 0.894736842 | 808 | 453.6140351 | 0.885964912 | 1096 | 461.4736842 | 0.901315789 | 1352 | 455.4105263 | 0.889473684 |
| QPSK | 9 | 776 | 522.7789474 | 1.021052632 | 936 | 525.4736842 | 1.026315789 | 1256 | 528.8421053 | 1.032894737 | 1544 | 520.0842105 | 1.015789474 |
| QPSK | 10 | 872 | 587.4526316 | 1.147368421 | 1032 | 579.3684211 | 1.131578947 | 1384 | 582.7368421 | 1.138157895 | 1736 | 584.7578947 | 1.142105263 |
| QPSK | 11 | 1000 | 673.6842105 | 1.315789474 | 1192 | 669.1929825 | 1.307017544 | 1608 | 677.0526316 | 1.322368421 | 2024 | 681.7684211 | 1.331578947 |
| QPSK | 12 | 1128 | 759.9157895 | 1.484210526 | 1352 | 759.0175439 | 1.48245614 | 1800 | 757.8947368 | 1.480263158 | 2280 | 768 | 1.5 |
| QPSK | 13 | 1256 | 846.1473684 | 1.652631579 | 1544 | 866.8070175 | 1.692982456 | 2024 | 852.2105263 | 1.664473684 | 2536 | 854.2315789 | 1.668421053 |
| 16QAM | 14 | 1416 | 476.9684211 | 1.863157895 | 1736 | 487.2982456 | 1.903508772 | 2280 | 480 | 1.875 | 2856 | 481.0105263 | 1.878947368 |
| 16QAM | 15 | 1544 | 520.0842105 | 2.031578947 | 1800 | 505.2631579 | 1.973684211 | 2472 | 520.4210526 | 2.032894737 | 3112 | 524.1263158 | 2.047368421 |
| 16QAM | 16 | 1608 | 541.6421053 | 2.115789474 | 1928 | 541.1929825 | 2.114035088 | 2600 | 547.3684211 | 2.138157895 | 3240 | 545.6842105 | 2.131578947 |
| 16QAM | 17 | 1800 | 606.3157895 | 2.368421053 | 2152 | 604.0701754 | 2.359649123 | 2856 | 601.2631579 | 2.348684211 | 3624 | 610.3578947 | 2.384210526 |
| 16QAM | 18 | 1992 | 670.9894737 | 2.621052632 | 2344 | 657.9649123 | 2.570175439 | 3112 | 655.1578947 | 2.559210526 | 4008 | 675.0315789 | 2.636842105 |
| 16QAM | 19 | 2152 | 724.8842105 | 2.831578947 | 2600 | 729.8245614 | 2.850877193 | 3496 | 736 | 2.875 | 4264 | 718.1473684 | 2.805263158 |
| 16QAM | 20 | 2344 | 789.5578947 | 3.084210526 | 2792 | 783.7192982 | 3.061403509 | 3752 | 789.8947368 | 3.085526316 | 4584 | 772.0421053 | 3.015789474 |
| 16QAM | 21 | 2472 | 832.6736842 | 3.252631579 | 2984 | 837.6140351 | 3.271929825 | 4008 | 843.7894737 | 3.296052632 | 4968 | 836.7157895 | 3.268421053 |