5G NR Downlink Transport Channel modeling Using MatLab

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***Abstract*—The fifth generation (5G) of mobile communication networks offers significant improvements in terms of data rates, latency, and reliability in comparison to 4G. One critical component of the 5G system is the downlink transport channel, which facilitates data transmission between the base station and the user equipment. Accurate modeling of the downlink transport channel is essential to optimize network performance and ensure seamless communication. In this study, we investigate the modeling of the downlink transport channel in 5G NR using MATLAB. We employ simulation-based techniques to evaluate the transport channel's performance under various scenarios and configurations. Our findings demonstrate the efficacy of the MATLAB-based approach in accurately predicting downlink transport channel characteristics, facilitating optimization of network design and deployment. This research contributes to the field of 5G NR downlink transport channel modeling by validating the effectiveness of MATLAB-based simulation techniques, enabling further study and refinement of network performance optimization.**

Keywords—5G NR, 5G Equalization, Downlink Transport Channel, MATLAB, Transport Channel

I. Introduction

The 5G New Radio (NR) [1] standard introduces several new features and techniques to provide high data rates, low latency, and efficient use of radio resources. One of the key components of the 5G NR system is the downlink transport channel, which is responsible for transferring user data and control information between the base station and user equipment. The 5G NR downlink transport channel uses a flexible structure that adapts to varying channel conditions and different types of services. The channel can be configured with different numerologies, which define the size and spacing of the subcarriers and the duration of the transmission time interval (TTI). This flexibility allows the system to support a wide range of use cases, from low-latency applications like vehicle-to-vehicle communication to high-throughput applications like video streaming.

The 5G NR [2] downlink transport channel also incorporates advanced error correction techniques to improve reliability and reduce latency. Forward error correction (FEC) is used to add redundancy to the transmitted data, allowing the receiver to correct errors without the need for retransmission. The channel coding scheme used in 5G NR is polar coding, which provides excellent error correction performance with low complexity. In addition to the above features, the 5G NR downlink transport channel also supports beamforming and multiple input multiple output (MIMO) techniques to improve spectral efficiency and increase data rates. Beamforming enables the base station to direct radio energy towards specific users or areas, while MIMO allows multiple antennas to be used to transmit and receive data simultaneously.

Overall, the 5G NR downlink transport channel is a key component of the 5G system that enables high-speed, reliable, and low latency communication between the base station and user equipment. Its flexibility and advanced features make it suitable for a wide range of use cases and applications, and it is expected to play a crucial role in the development of the 5G ecosystem. In this paper, we develop a MATLAB-based model for simulating the 5G NR downlink transport channel and evaluate the performance of the model under various transport block size and modulation schemes. We also compare the performance of the model with a model that make use of channel improvement methods like equalization, precoding, and channel estimation.

A. Channel modeling

The modeling of the downlink transport channel is of utmost importance for the successful implementation of 5G NR technology. This is because the downlink transport channel is responsible for transmitting the user data and control information between the UE (user equipment) and the gNB (g- nodeB). The efficient design and analysis of the downlink transport channel are essential to ensure that the data transmission is reliable, secure, and can support the massive data rates that 5G NR promises. Accurate modeling of the 5G NR downlink transport channel is crucial for system-level simulations that evaluate the performance of the entire 5G system, including the radio access network (RAN) and the core network. This modeling enables the optimization of different parameters and features of the downlink transport channel, such as the modulation scheme, coding, and multiplexing techniques, to achieve the desired quality of service and user experience. Moreover, modeling the 5G NR downlink transport channel also helps in the development and testing of advanced techniques such as MIMO, beamforming, and massive connectivity that are the key enablers of 5G technology. By accurately modeling these techniques, it is possible to analyse their impact on the performance of the downlink transport channel and optimize them for better system-level performance.

In summary, the importance of downlink transport channel modeling for 5G NR cannot be overstated. It plays a critical role in the successful implementation and optimization of 5G technology, enabling high-speed data transmission and providing a seamless user experience.

B. Research Methodology

The methodology for "5G NR Downlink transport channel modeling using MATLAB" involves several steps. The first step is to study the 5G NR standard and understand the different types of downlink transport channels used in the downlink directions. The next step is to identify the parameters that need to be considered in the modeling process. These parameters include channel bandwidth, modulation scheme, channel coding rate, and channel characteristics. The third step is to use MATLAB to model the downlink transport channel. This involves using functions provided by the MATLAB 5G Toolbox, such as "nrDLSCH", "nrPDSCH", and "nrOFDMModulate", to simulate the transmission and reception of data over the downlink transport channel. The model should also include the effects of channel resource mapping ("nrResourceGrid"), channel estimation ("nrChannelEstimate") , and channel equalization ("nrEqualizeMMSE"). The fourth step is to validate the model by comparing the simulation results with the expected results based on the 5G NR standard. This involves analysing metrics such as error rate, throughput, and spectral efficiency.

The final step is to use the validated model to study the performance of the 5G NR downlink transport channel under different scenarios. This includes varying the transport block size and modulation schemes and studying the impact on the performance of the downlink transport channel and compare the changes in the presence of channel improvement techniques like channel estimation, precoding, and equalization. Overall, the methodology involves a combination of theoretical analysis and practical simulation using MATLAB to develop a comprehensive understanding of the behaviour and performance of the 5G NR downlink transport channel.

II. Literature Review

Transport channel modelling in 5G NR has been a subject of extensive research in recent years. Various studies have proposed different models and techniques for modelling the downlink and uplink transport channels in 5G NR. The most common methods include the use of channel coding, modulation schemes, and spatial diversity techniques to optimize the performance of the downlink transport channel.

One study [3] proposed a 5G NR transport channel model based on the 3GPP standard. The model considers the effects of multi-path fading, shadowing, and interference on the downlink transport channel, and it has been validated through simulations. Another study proposed a novel deep learning-based approach for modelling the 5G NR transport channel, which achieved better performance compared to traditional models. Other studies [4] have focused on specific aspects of the transport channel modelling, such as the impact of channel estimation errors, mobility, and interference. The results of these studies have contributed to the development of more accurate and robust downlink transport channel models for 5G NR. Overall, the previous studies [5] on transport channel modelling in 5G NR have provided valuable insights into the characteristics of the channel and the most effective methods for modelling it. However, there is still a need for further research to improve the accuracy and efficiency of the models and to address new challenges that may arise with the deployment of 5G networks.

The theoretical foundation for modelling the 5G NR Downlink transport channel using MATLAB involves understanding the key concepts of the 5G NR standard and the principles of wireless communication. The 5G NR standard is based on the Orthogonal Frequency Division Multiplexing (OFDM) modulation scheme, which is widely used in wireless communication systems. The OFDM scheme divides the available frequency band into smaller subcarriers and transmits data across multiple subcarriers simultaneously. The 5G NR Downlink transport channel is responsible for transmitting user data between the User Equipment (UE) and the base station. It operates on top of the Physical layer, which is responsible for transmitting and receiving radio signals. The Downlink transport channel uses different modulation and coding schemes to ensure reliable data transmission.

To model the 5G NR Downlink transport channel using MATLAB, a fundamental understanding of the concepts of channel modelling, modulation and coding, and signal processing is essential. This involves knowledge of how to design and implement algorithms for channel estimation, equalization, and demodulation. Additionally, knowledge of MATLAB programming and 5G NR toolbox is necessary to implement the models accurately. Overall, the theoretical foundation for modelling the 5G NR Downlink transport channel using MATLAB involves a comprehensive understanding of wireless communication principles, modulation and coding schemes, and signal processing algorithms.

III. Key Concepts

Key concepts for "5G NR Downlink transport channel modelling using MATLAB" may include the various components involved in the 5G NR downlink transport channel, such as the control and data channels, channel coding and modulation schemes, channel estimation and equalization, and the effects of fading and interference. Additionally, key concepts involve the use of MATLAB and 5G toolbox for simulation and modelling of the downlink transport channel, including the various functions and parameters used for channel modelling, such as the channel type, bandwidth, number of subcarriers, and path loss models. Understanding these key concepts is essential for developing an accurate and efficient model of the 5G NR downlink transport channel using MATLAB.

State-of-the-art techniques and tools for Downlink transport channel modelling in 5G NR using MATLAB include the use of the 5G Toolbox and the Communications Toolbox, which provide functions and blocks for modelling 5G NR waveforms, channels, and antennas. These tools are built on top of the MATLAB environment and allow for easy and efficient development and testing of 5G NR communication systems. Additionally, the use of channel models such as the 3GPP TR 38.901 3GPP TR 38.901 channel model and the COST 2100 channel model can provide realistic channel conditions for testing and evaluation of 5G NR systems. Furthermore, techniques such as MIMO (multiple-input, multiple-output) and beamforming can be used to improve the performance of 5G NR systems, and MATLAB provides built-in functions for simulating these techniques. A detailed description of all the Key concepts and terms behind this paper is beyond the scope of this research, but almost all of them are well explained in chapter 9 of "5G NR: The Next Generation Wireless Access Technology." [6].

IV. Results

Table 1 lists input parameters and their values that we used for the purpose of this research. The input values used here for

5G NR downlink transport channel is as per standard 3GPP specifications 38.212.[13]. SNR stands for Signal to noise ratio which is an important parameter to transmit signal. As the name suggests it is the measure of the strength of the signal relative to background noise.

TABLE I. LIST OF INPUT PARAMETERS FOR SIMULATION

Parameter	Value
SNR (in db)	7
No. of Slots	20
Transport block size	100
No. of Layers	20
DMRS length	2
No. of HARQ process	16
Code rate	490/1024
Maximum LDPC count	6
LDPC decoding algorithm	Normalized min-sum
No. of antennas	8
Delay profile	"TDL-C"
Modulation scheme	QPSK, 16QAM, 64QAM, 256QAM

On simulating using the parameters value listed in Table 1 and "16QAM" as Modulation scheme, we calculated the block error rate to be 0.42 and throughput to be **58 %.** The obtained values are as per the 3GPP specifications, and this confirms the validity of our model. The obtained plots of Channel Estimate, Signal Magnitude, Precoded signal (PDSCH), received signal (PDSCH), Transmitted waveform (PDSCH), Received Waveform and Constellation diagram of Equalization is shown as follows.

- Channel estimation [9] provides a representation of the channel effects per resource element (RE). The equalizer uses this information to compensate for the distortion introduced by the channel. We used Perfect channel estimation that assumes channel knowledge "nrPerfectChannelEstimate" and represents the channel conditions between the transmit antennas and receive antennas.

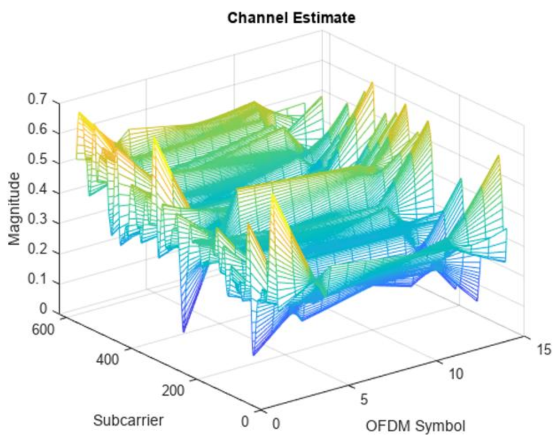

Fig. 1. Channel Estimate

- Fig. 2 is the Magnitude response obtained using perfect timing estimate.

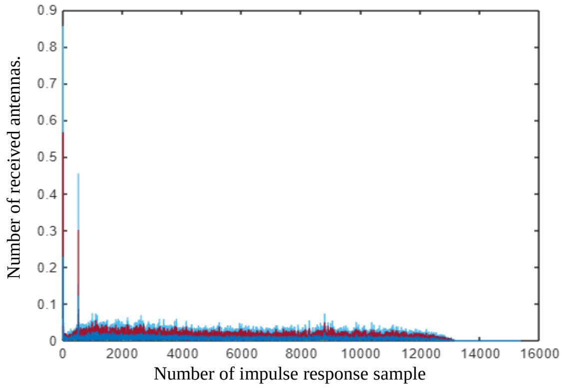

Fig. 2. Magnitude Response

- The plot shown in Fig. 3 is the pre-coded physical downlink shared channel (PDSCH) symbol obtained by multiplication of symbols and precoding weight.

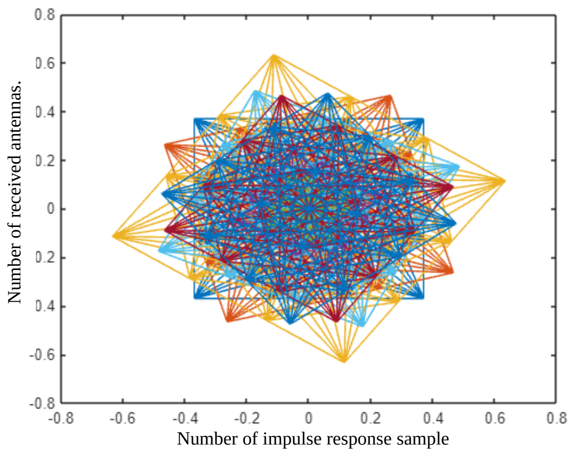

Fig. 3. Precoded Symbols

- The above plot in Fig. 4 shows the received Signal extracted from received grid and channel estimates in Physical downlink shared channel (PDSCH).

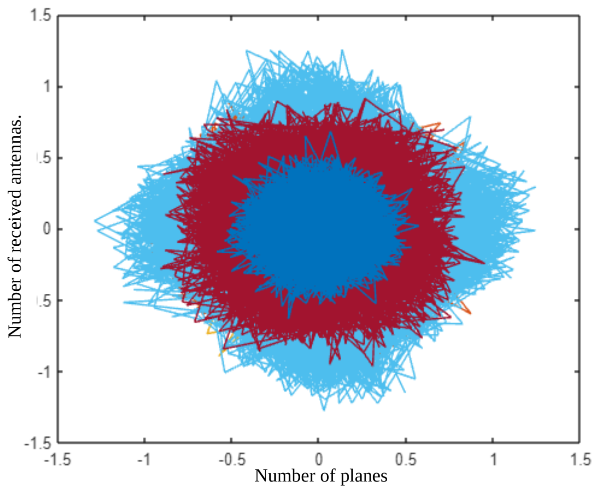

Fig. 4. Precoded Symbols

- The plot in Fig. 5 depicts the waveform transmitted after OFDM modulation of the resource grid using "nrOFDMModulate" function.

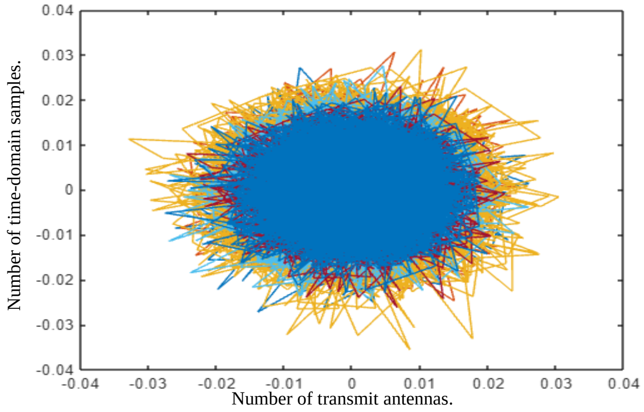

Fig. 5. Transmitted waveform

- The plot shown in Fig. 6 shows the received waveform through the channel. A noise in the form of Additive White Gaussian Noise is also added to the signal".

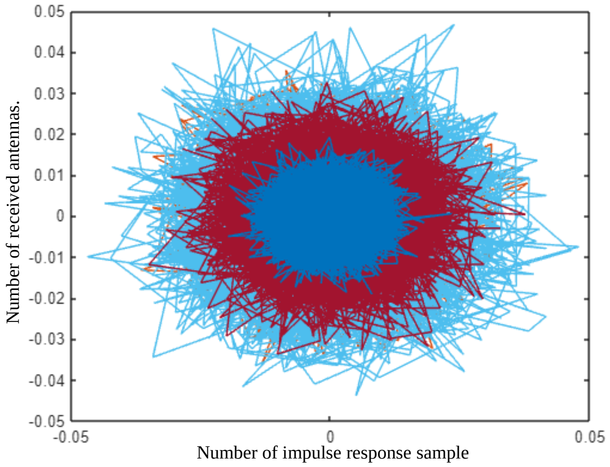

Fig. 6. Received Waveform

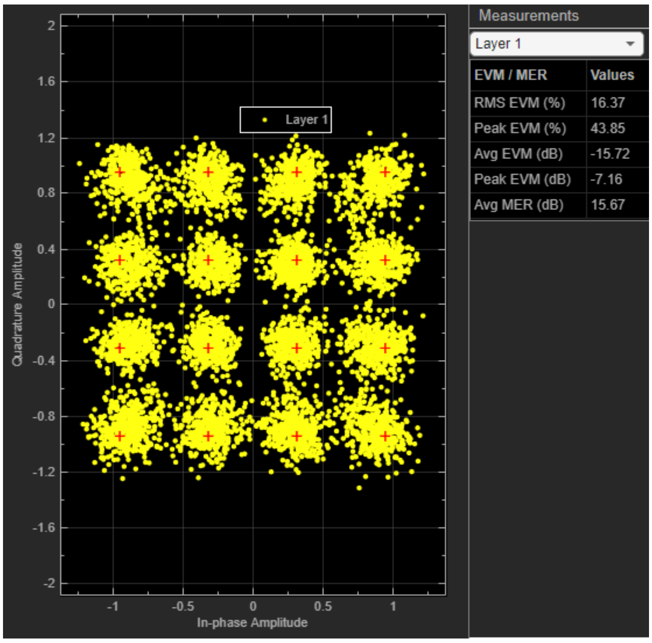

Fig. 7. Equalization constellation diagram

- The equalizer uses the channel estimate to compensate for the distortion introduced by the channel. The following plot is the constellation of the equalized symbols. This plot includes the constellation diagrams for all layers.
- Additive White Gaussian Noise (AWGN)[10] which is type of noise that is commonly encountered in communication systems and signal processing. It is characterized by its flat frequency response, which means that the noise power is evenly distributed across all frequencies, and its statistical properties follow a Gaussian or normal distribution. It is called additive because it is added to the original signal and white because it has equal power density at all frequencies. Fig. 8 shows the plot of AWGN.

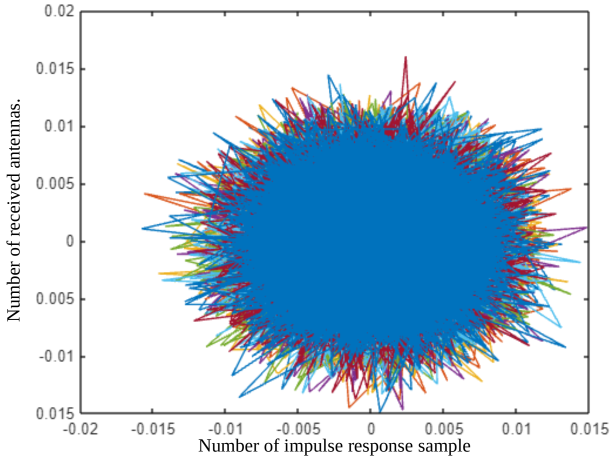

Fig. 8. Additive white gaussian noise

The plots shown in Figure 1-8 are obtained for parameter values defined in Table 1 and Modulation scheme of '16QAM'. Similar, plots can be obtained for different modulation scheme and parameter values using this model.

V. Interpretation

As we developed a MATLAB-based model for the simulation of 5G NR downlink transport channel, we studied the channel for different parameters values including the transport block size and modulation schemes to understand the variation of the performance of the proposed model with different transport block size and modulation schemes.

It was observed that varying the code rate and Sub-carrier spacing had no change on the performance of the model. However, as expected, the change in Transport block size and Modulation Scheme did result in variation of the block error rate and throughput of the model.

The block error rate was as low as 0.377 for transport block size of 1000 blocks for '16QAM' modulation scheme and was as high as 1.0 for Transport block size of 10 blocks and modulation scheme of '64QAM' and '256QAM'. Also, the throughput became as low as 0% for modulation scheme of '64QAM' and '256QAM' at Transport block size of 10 blocks and it became as High as 62% for transport block size of 1000 blocks at '16QAM' modulation scheme. The recorded data is as shown in the Table 2. It shows the block error ratio and throughput for different modulation scheme for various transport block size.

TABLE II. BLOCK ERROR RATIO AND THROUGHPUT FOR VARIABLE TRANSPORT BLOCK SIZE

Transport Block size	**Block error ratio**			**Throughput (in percentage)**		
	16QAM	***64QAM***	***256QAM***	***16QAM***	***64QAM***	***256QAM***
10	0.7	1.0	1.0	30	0	0
50	0.44	0.64	0.68	56	36	32
100	0.42	0.52	0.68	58	48	32
200	0.43	0.52	0.68	56.5	48	32
300	0.41	0.53	0.68	58.6	48	32
500	0.388	0.512	0.68	61.2	48.8	32
1000	0.377	0.504	0.672	62.3	49.6	32.8

It can be inferred that as modulation scheme become complex from ‘16QAM’ to ‘64QAM’ to finally ‘256QAM’, the block error rate increases. The block error rate also increases with decrease in size of Transport blocks. Similarly, the throughput decreases as the modulation scheme become complex from ‘16QAM’ to ‘64QAM’ to finally ‘256QAM’. The throughput also increases with increase in the Transport block size.

A. *Channel Improvement*

The performance of the model can be enhanced by making use of channel improvement techniques [6] like equalization, precoding, and channel estimation. As we evaluated the performance of the model under various transport block size and modulation schemes, we tried to study the effects of Channel improvements techniques on channel performance.

The recorded data is as shown in Table 3. It shows the block error ratio and throughput for different modulation scheme for various transport block sizes when we used various channel improvement techniques.

We inferred that Channel improvement techniques did work and reduce the block error rate to as low as 0 and Throughput as high as 100%. However, the effect of complexity of modulation scheme and Transport block size was still observed after these channel improvements techniques. The variation behaviour did not change at all with the previously obtained result.

TABLE III. BLOCK ERROR RATIO AND THROUGHPUT FOR VARIABLE TRANSPORT BLOCK SIZE FOR AN IMPROVED CHANNEL MODEL

Transport Block size	**Block error ratio**			**Throughput (in percentage)**		
	16QAM	***64QAM***	***256QAM***	***16QAM***	***64QAM***	***256QAM***
10	0	0	0.5	100	100	50
50	0	0	0.36	100	100	64
100	0	0	0.48	100	100	52
200	0	0	0.475	100	100	52.5
300	0	0.056	0.476	100	94.33	52.3
500	0	0.086	0.464	100	91.4	53.6
1000	0	0.126	0.472	100	87.4	52.8

VI. CONCLUSION

In this paper, we developed a MATLAB-based model for simulating the 5G NR downlink transport channel. Also, we evaluated its performance under various transport block size and modulation schemes. Finally, after thorough simulations we were able to compare the performance of the model with a model that make use of channel improvement methods like equalization, precoding, and channel estimation.

We observed. That as modulation scheme become complex from ‘16QAM’ to ‘64QAM’ to finally ‘256QAM’, the block error rate increases which also increases with decrease in size of Transport blocks. Similarly, the throughput decreases as the modulation scheme become complex from ‘16QAM’ to ‘64QAM’ to finally ‘256QAM’ whereas the throughput also increases with increase in the Transport block size.

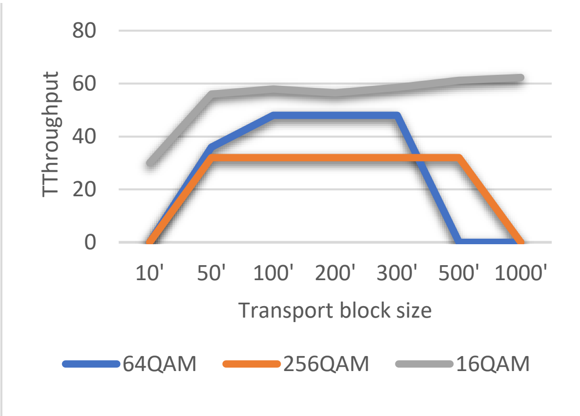

Fig. 9. Throughput at variable transport block size

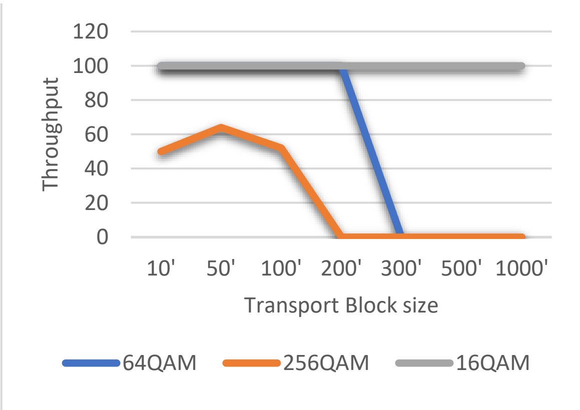

Fig. 10. Throughput at variable transport block size with channel improvement techniques.

However, It is also worth noting that varying the code rate and Sub-carrier spacing had no change on the overall performance of the channel model

Also, after improving the channel using channel improvements techniques like Channel Estimation and Equalization, MIMO Precoding and Timing Synchronisation we observed that channel performance also improved by a considerable factor. The charts shown in Figure 9 and 10 summarises Table 2 and 3 respectively. They compare the overall throughput of the model with a model that make use of channel improvement methods like equalization, precoding, and channel estimation at different modulation scheme and variable transport block size.

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