Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

Comparative Analysis of Design Tool Prediction for 4T4R and 64T64R Massive MIMO in 5G Stadium Environment

Tausif Ismail Patel[1], Syed Moazzam Pasha[2]
and Saad Mohammed Farrukh[3]

***Abstract*—Accurate radio network planning is essential for the successful deployment of fifth-generation (5G) New Radio (NR) networks, particularly in high-density stadium environments where thousands of users simultaneously access bandwidth-intensive services. During the network planning phase, radio frequency (RF) planning tools are widely employed to predict key performance indicators (KPIs), including coverage, Reference Signal Received Power (RSRP), and Signal-to-Interference-plus-Noise Ratio (SINR), enabling engineers to evaluate different deployment strategies before implementation. However, accurately predicting the performance of advanced Massive MIMO systems remains challenging because conventional planning tools primarily rely on propagation models and simplified antenna representations, while the dynamic characteristics of Massive MIMO, such as digital beamforming, adaptive beam steering, Multi-User MIMO (MU-MIMO), and scheduler-dependent spatial multiplexing, are only partially represented.**

This paper presents a comparative analysis of the design-stage KPI predictions for conventional 4T4R MIMO and 64T64R Massive MIMO in a 5G NR stadium environment using a commercial RF planning tool. The study is limited to the KPIs generated during the planning phase and does not include field measurements or post-deployment performance evaluation. The predicted RSRP, SINR, coverage, and interference characteristics are analyzed to examine how conventional planning models represent different antenna configurations. The results indicate that while the 64T64R Massive MIMO configuration provides stronger predicted coverage through higher antenna gain, the predicted SINR may be comparable to, or in some scenarios lower than, that of the conventional 4T4R configuration. These observations suggest that design-stage SINR predictions should be interpreted with an understanding of the inherent limitations of conventional planning models when evaluating advanced Massive MIMO technologies. The study highlights the need for more realistic Massive MIMO modeling techniques to improve prediction accuracy and support more reliable design decisions for high-capacity 5G NR deployments.

***Index Terms*—5G New Radio (NR), Massive MIMO, 4T4R MIMO, 64T64R Massive MIMO, RF Planning, Radio Network Planning, Signal-to-Interference-plus-Noise Ratio (SINR), Reference Signal Received Power (RSRP), Beamforming, Stadium Networks.**

I. INTRODUCTION

Fifth-generation (5G) New Radio (NR) has transformed mobile communications by enabling enhanced mobile broadband (eMBB), ultra-reliable low-latency communications (URLLC), and massive machine-type communications (mMTC). To meet the increasing demand for higher data rates, lower latency, and improved network capacity, 5G networks employ advanced radio technologies such as Multiple-Input Multiple-Output (MIMO), beamforming, flexible spectrum utilization, and network densification. As network complexity continues to increase, accurate radio network planning has become a critical step in ensuring that coverage, capacity, and quality-of-service requirements are achieved before commercial deployment.

High-density stadiums represent one of the most demanding deployment scenarios for 5G NR networks due to the large concentration of users simultaneously accessing bandwidth-intensive applications such as live video streaming, social media, cloud services, and real-time multimedia sharing. These environments require radio networks to provide high capacity while effectively managing interference, maintaining adequate signal quality, and ensuring a consistent user experience. Consequently, advanced antenna technologies have become essential for supporting the traffic demands of modern stadium deployments.

Conventional 4T4R MIMO has been widely deployed to improve network coverage and capacity through multiple transmit and receive antenna paths. More recently, 64T64R Massive MIMO has emerged as a key technology for enhancing spectral efficiency and increasing network capacity by employing large antenna arrays, digital beamforming, and Multi-User Multiple-Input Multiple-Output (MU-MIMO). However, during the network planning stage, RF planning tools primarily estimate performance using propagation models, antenna radiation patterns, and static interference calculations. While these models provide reliable coverage predictions, they may not fully capture the dynamic behavior of Massive MIMO technologies, including adaptive beamforming, user-specific beam steering, channel state information (CSI)-based precoding, and scheduler-dependent spatial multiplexing. As a result, the predicted Key Performance Indicators (KPIs), particularly Signal-to-Interference-plus-Noise Ratio (SINR), may differ from the performance achieved in operational networks.

This paper presents a comparative analysis of design-stage KPI predictions for conventional 4T4R MIMO and 64T64R Massive MIMO in a 5G NR stadium environment using a commercial RF planning tool. The study is limited to the analysis of predicted KPIs generated during the planning phase and does not include field measurements or post-deployment validation. The predicted performance of both antenna configurations is evaluated using key planning metrics, including Reference Signal Received Power (RSRP), Signal-to-Interference-plus-Noise Ratio (SINR), coverage, and interference. The objective is to examine how conventional

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

planning tools represent different antenna technologies and to discuss the implications of these predictions for planning high-capacity 5G NR stadium deployments.

II. Background and Related Work

The evolution of fifth-generation (5G) New Radio (NR) has introduced advanced antenna technologies and signal processing techniques to improve network coverage, capacity, and spectral efficiency. Conventional Multiple-Input Multiple-Output (MIMO) systems have been widely deployed to enhance wireless communication performance through spatial diversity and multiplexing. More recently, Massive MIMO has emerged as a key enabling technology for high-capacity 5G deployments by employing large-scale antenna arrays, digital beamforming, and Multi-User MIMO (MU-MIMO). During the network planning stage, radio frequency (RF) planning tools are commonly used to estimate key performance indicators (KPIs), including Reference Signal Received Power (RSRP), Signal-to-Interference-plus-Noise Ratio (SINR), coverage, and interference. Understanding the theoretical principles governing these KPIs is essential for interpreting the design-stage predictions generated by RF planning tools.

A. Link Budget

The link budget is a fundamental component of radio network planning that estimates the received signal strength between the transmitter and receiver. It accounts for the transmitted power, antenna gains, propagation losses, and additional system losses encountered during signal transmission. Accurate link budget analysis enables network planners to predict coverage, determine cell boundaries, and evaluate the feasibility of different deployment scenarios before network implementation.

The received signal power can be expressed as

$$P_r = P_t + G_t + G_r - PL - L_{misc} \quad (1)$$

where P_r is the received power, P_t is the transmit power, G_t and G_r represent the transmitter and receiver antenna gains, PL denotes the propagation loss, and L_{misc} represents miscellaneous system losses. The predicted RSRP generated by RF planning tools is primarily derived from link budget calculations combined with the selected propagation model.

B. Array Gain and Beamforming

Massive MIMO improves radio performance by employing a large number of antenna elements to concentrate transmitted energy toward intended users through digital beamforming. Compared with conventional MIMO systems, larger antenna arrays provide higher array gain, improve signal quality, and increase spectral efficiency by directing energy more efficiently while reducing unnecessary interference.

The theoretical array gain can be approximated as

$$G_{Array} = 10 \log_{10} \left(\frac{N}{N_{ref}} \right) \quad (2)$$

where N represents the number of antenna elements and N_{ref} is the reference antenna configuration. Although RF planning tools generally account for antenna gain through radiation patterns, they may not fully represent the adaptive beamforming behavior that occurs during live network operation.

C. Shannon Capacity

The theoretical maximum data rate of a wireless communication channel is governed by the Shannon-Hartley theorem, which establishes the relationship between channel bandwidth, signal quality, and achievable capacity.

$$C = B \log_2(1 + \text{SINR}) \quad (3)$$

where C is the channel capacity, B is the channel bandwidth, and SINR is the Signal-to-Interference-plus-Noise Ratio. The equation illustrates that higher SINR values generally enable higher theoretical throughput. Consequently, accurate SINR prediction is an important objective during the radio planning stage.

D. Spectral Efficiency, RSRP, and SINR

Reference Signal Received Power (RSRP) is widely used to evaluate network coverage by measuring the average received power of reference signals transmitted by the serving cell. In contrast, Signal-to-Interference-plus-Noise Ratio (SINR) reflects the quality of the received signal by considering both interference and background noise. Together, RSRP and SINR provide complementary information regarding coverage and signal quality.

Spectral efficiency represents the amount of information successfully transmitted per unit bandwidth and is commonly expressed in bits/s/Hz. Higher spectral efficiency indicates more effective utilization of available spectrum resources and is one of the primary performance objectives of Massive MIMO deployments.

$$\eta = \frac{C}{B} \quad (4)$$

where η denotes the spectral efficiency, C is the achievable channel capacity, and B is the transmission bandwidth.

III. Methodology

A. Objective and Scope

The objective of this study is to evaluate and compare the design-stage Key Performance Indicator (KPI) predictions of conventional 4T4R MIMO and 64T64R Massive MIMO for a 5G New Radio (NR) stadium deployment using a commercial RF planning tool. The analysis focuses on the KPIs generated during the network planning phase under identical design assumptions, enabling a consistent and objective comparison of the two antenna configurations.

The scope of this work is limited to the evaluation of design-stage predictions, including Reference Signal Received Power (RSRP), Signal-to-Interference-plus-Noise Ratio (SINR), coverage, and interference. No field measurements, drive tests, or post-deployment network performance data are included in this study. The predicted results are interpreted using established wireless communication theory and relevant 3GPP specifications to assess how conventional planning models represent different antenna technologies.

B. Test Environment and System Setup

The comparative assessment was performed using a commercial RF planning tool configured for a representative high-density 5G NR stadium deployment. Both the conventional 4T4R MIMO and the 64T64R Massive MIMO configurations were evaluated using identical network planning parameters to ensure a fair comparison. The planning assumptions included the same carrier frequency, channel bandwidth, antenna locations, antenna heights, sector layout, propagation model, and environmental conditions. The only intentional variation between the two scenarios was the antenna configuration.

The planning scenario was configured to represent a high-capacity outdoor stadium environment operating in the 3.5 GHz frequency band with a channel bandwidth of 100 MHz. Multiple sectors were deployed to provide complete coverage across the stadium while maintaining consistent planning assumptions for both antenna configurations. The generated KPIs were used to compare the predicted radio performance under identical deployment conditions.

C. Data Collection and Processing

The RF planning tool was used to generate design-stage predictions for both antenna configurations. The primary KPIs evaluated in this study include Reference Signal Received Power (RSRP), Signal-to-Interference-plus-Noise Ratio (SINR), coverage distribution, and interference characteristics. These metrics were extracted directly from the planning tool following completion of the prediction process.

The generated KPI distributions were analyzed and compared to identify differences between the 4T4R MIMO and 64T64R Massive MIMO configurations. The comparison focuses exclusively on the planning-stage predictions without attempting to infer actual network performance after deployment. The predicted results are interpreted in the context of established Massive MIMO principles, recognizing that conventional RF planning tools primarily rely on propagation-based models and may not fully capture dynamic features such as adaptive beamforming, Multi-User MIMO (MU-MIMO), channel state information (CSI)-based precoding, and scheduler-dependent spatial multiplexing.

IV. RESULTS AND DISCUSSION

The design-stage performance of conventional 4T4R MIMO and 64T64R Massive MIMO was evaluated using a commercial RF planning tool under identical network planning assumptions. The comparison focused on the predicted Key Performance Indicators (KPIs), including Reference Signal Received Power (RSRP) and Signal-to-Interference-plus-Noise Ratio (SINR), to assess how different antenna configurations are represented during the planning phase. The analysis is limited to the predictions generated by the planning tool and does not include field measurements or post-deployment network performance evaluation.

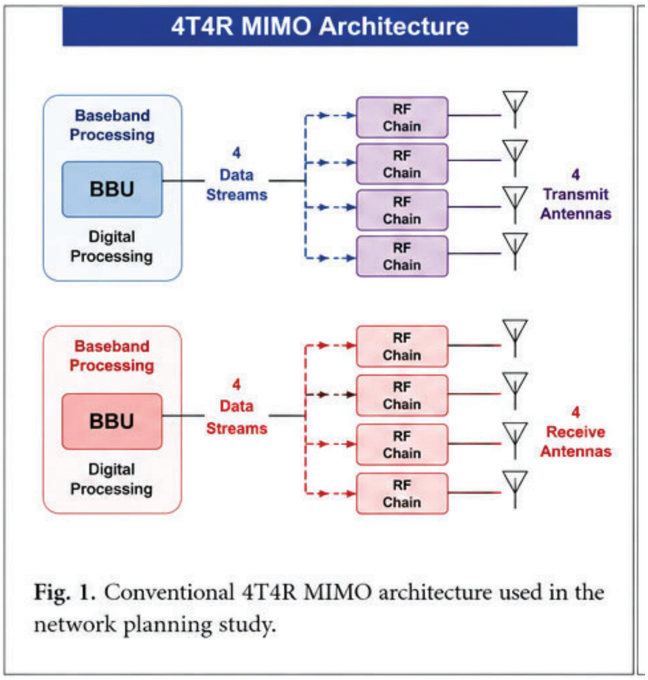

Fig. 1: Conventional 4T4R MIMO architecture used in the network planning study.

A. Conventional 4T4R MIMO Architecture

Conventional Multiple-Input Multiple-Output (MIMO) technology improves wireless communication performance by employing multiple transmit and receive antenna elements to exploit spatial diversity and increase spectral efficiency. In fifth-generation (5G) New Radio (NR) systems, the 4-Transmit 4-Receive (4T4R) configuration is widely adopted because it provides a practical balance between coverage enhancement, implementation complexity, and deployment cost. Compared with earlier antenna configurations, 4T4R MIMO improves signal reliability, increases cell capacity, and enhances user throughput while maintaining relatively simple hardware architecture.

Figure 1 illustrates the conceptual architecture of a conventional 4T4R MIMO system. The baseband processing unit generates four independent digital data streams, each of which is processed by an individual radio-frequency (RF) chain before transmission through four antenna elements. At the receiver, the incoming signals are processed using four corresponding receive RF chains, enabling spatial diversity and improved reception quality. Since each antenna element operates with a fixed radiation pattern, the transmitted energy is distributed over a relatively broad coverage area without dynamically adapting to the locations of individual users.

The simplicity of the 4T4R architecture allows conventional RF planning tools to model its propagation characteristics with relatively high accuracy. Coverage prediction, Reference

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

Signal Received Power (RSRP), and interference estimation are primarily determined by the antenna radiation pattern, transmit power, propagation model, and environmental characteristics. Consequently, the predicted design-stage KPIs produced for conventional MIMO deployments generally exhibit good agreement with the expected coverage behaviour, making 4T4R a suitable baseline for comparison with more advanced Massive MIMO systems.

B. 64T64R Massive MIMO Architecture

Massive Multiple-Input Multiple-Output (Massive MIMO) extends the conventional MIMO concept by employing a significantly larger number of transmit and receive antenna elements to improve spectral efficiency, network capacity, and user experience. In 5G NR deployments, the 64-Transmit 64-Receive (64T64R) configuration enables advanced beamforming and spatial multiplexing techniques, allowing the radio system to concentrate transmission energy toward individual users while simultaneously serving multiple users within the same time-frequency resources. These capabilities are particularly beneficial in high-density environments, such as stadiums, airports, and large public venues, where high traffic demand and severe interference conditions exist.

Figure 2 illustrates the conceptual architecture of a 64T64R Massive MIMO system. Unlike the conventional 4T4R architecture, the baseband processing unit is connected to sixty-four independent RF chains, each driving a dedicated antenna element. The large antenna array provides additional spatial degrees of freedom, enabling narrow beam generation, adaptive beam steering, and simultaneous transmission to multiple users through Multi-User MIMO (MU-MIMO). Consequently, the transmitted energy can be dynamically focused toward active users rather than being uniformly distributed across the entire coverage area.

Compared with conventional MIMO systems, Massive MIMO offers substantial improvements in array gain, beamforming accuracy, interference suppression, and spectral efficiency. However, these performance enhancements rely on dynamic radio processing functions, including channel state information (CSI)-based precoding, adaptive beamforming, user scheduling, and spatial multiplexing. Since conventional RF planning tools primarily perform static propagation analysis, many of these dynamic behaviours cannot be fully represented during the network planning stage.

As a result, design-stage KPI predictions generated for Massive MIMO deployments should be interpreted with appropriate engineering consideration. While coverage-related metrics such as Reference Signal Received Power (RSRP) can generally be estimated with reasonable accuracy, performance indicators that depend heavily on real-time beam management and user distribution, such as Signal-to-Interference-plus-Noise Ratio (SINR), may not fully reflect the operational behaviour observed after network deployment. This limitation forms the basis of the comparative analysis presented in the subsequent sections of this paper.

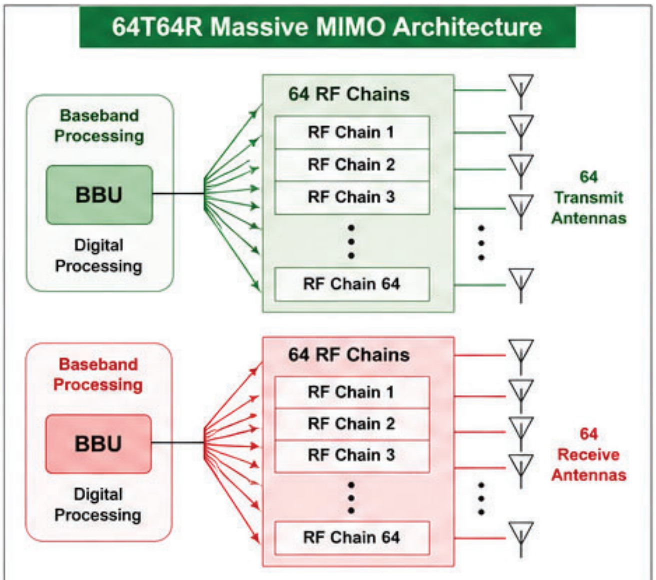

Fig. 2. Conceptual architecture of the 64T64R Massive MIMO system.

Fig. 2: Conceptual architecture of the 64T64R Massive MIMO system.

C. Test Environment and System Setup

To ensure a fair and objective comparison between the conventional 4T4R MIMO and 64T64R Massive MIMO configurations, both deployment scenarios were developed using identical network planning assumptions within a commercial RF planning tool. The evaluation was performed for a representative high-density outdoor stadium environment, where network performance is primarily constrained by the large concentration of simultaneous users and the high traffic demand generated during major events.

Figure 3 illustrates the network planning scenario adopted in this study. The stadium was divided into multiple sectors to provide complete radio coverage while maintaining overlapping service areas for mobility and capacity enhancement. Each sector was configured using the same site locations, antenna heights, azimuth orientations, propagation model, carrier frequency, channel bandwidth, and environmental parameters. This approach ensured that any observed differences in the predicted Key Performance Indicators (KPIs) resulted solely from the antenna configuration rather than changes in the network design.

The planning scenario was configured for operation in the 3.5 GHz frequency band using a channel bandwidth of 100 MHz, representing a typical enhanced Mobile Broadband (eMBB) deployment for high-capacity venues. The propagation prediction model, terrain characteristics, clutter information, and simulation resolution were maintained consistently across both scenarios to eliminate external variables that could influence the comparison.

Two independent prediction cases were generated. In the

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

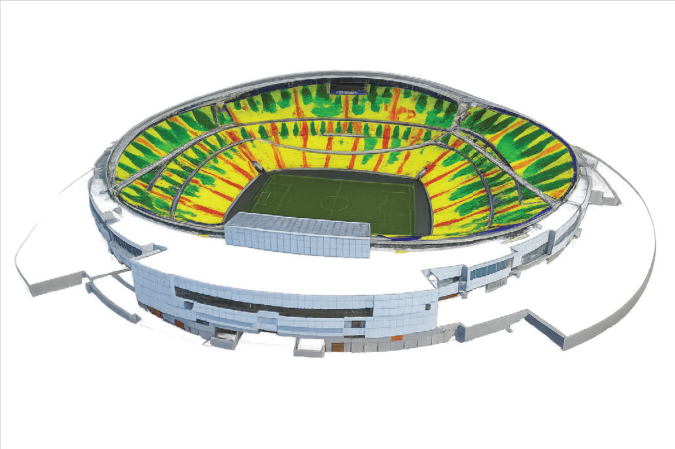

Fig. 3: Network planning scenario for the high-density 5G NR stadium deployment.

first case, all sectors employed conventional 4T4R MIMO antennas, while in the second case the antenna configuration was replaced with 64T64R Massive MIMO. Apart from the antenna architecture, all remaining planning parameters were kept identical. This controlled methodology enabled a direct comparison of the predicted design-stage KPIs and isolated the impact of the antenna technology on network coverage and signal quality.

The RF planning tool generated prediction maps for Reference Signal Received Power (RSRP) and Signal-to-Interference-plus-Noise Ratio (SINR), which form the basis of the comparative analysis presented in the following section. Since the study is limited to the network planning stage, the generated KPIs represent theoretical predictions derived from propagation modelling rather than measurements collected from an operational network. Consequently, the results should be interpreted as indicators of expected planning performance and not as validated field performance after deployment.

V. RESULTS AND DISCUSSION

The predicted network performance of the conventional 4T4R MIMO and 64T64R Massive MIMO configurations was evaluated using the RF planning methodology described in the previous section. The comparison focuses on the design-stage Key Performance Indicators (KPIs) generated by the planning tool under identical deployment assumptions. The primary objective is to investigate how the two antenna architectures influence the predicted coverage and signal quality within a high-density 5G NR stadium environment.

A. *Design-Stage RSRP Analysis*

Reference Signal Received Power (RSRP) is one of the most important coverage indicators in cellular network planning because it represents the average received power of the reference signals transmitted by the serving cell. During the planning stage, RSRP is extensively used to evaluate coverage continuity, determine cell boundaries, identify weak coverage regions, and verify whether the designed network satisfies

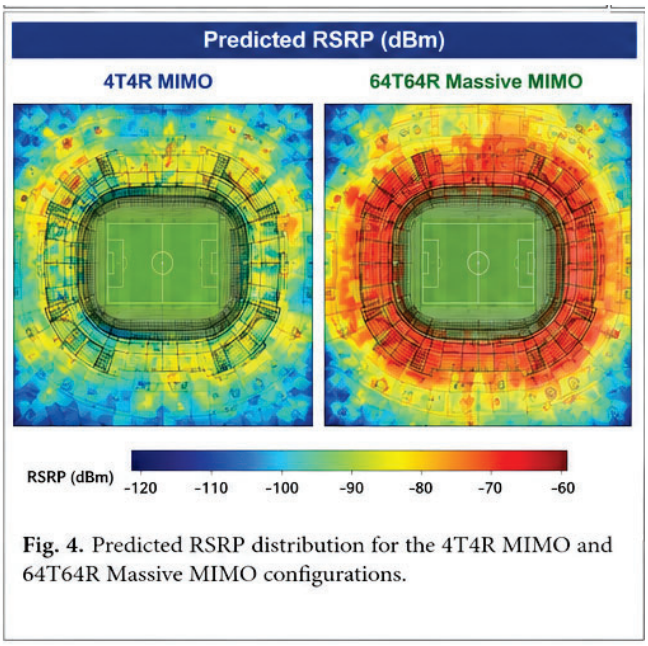

Fig. 4: Predicted RSRP distribution for the conventional 4T4R MIMO and 64T64R Massive MIMO configurations.

the required service objectives. Since RSRP is primarily determined by the link budget, antenna characteristics, and propagation environment, it is generally considered one of the most reliable KPIs generated by conventional RF planning tools.

Figure 4 compares the predicted RSRP distributions for the conventional 4T4R MIMO and 64T64R Massive MIMO configurations under identical network planning assumptions.

As illustrated in Fig. 4, the 64T64R Massive MIMO configuration produces a noticeably stronger predicted RSRP distribution across the stadium coverage area compared with the conventional 4T4R deployment. The improvement is observed not only in the regions immediately surrounding the serving sectors but also across the outer coverage boundaries, where higher received signal levels contribute to improved coverage uniformity. This behaviour is consistent with the theoretical advantages of larger antenna arrays, which provide increased array gain and more efficient utilization of transmitted energy.

The planning results further indicate that the conventional 4T4R configuration exhibits a wider distribution of lower RSRP values near the sector boundaries, whereas the 64T64R deployment maintains stronger received signal levels throughout most of the service area. The higher predicted RSRP achieved by the Massive MIMO configuration can be attributed to the increased effective antenna gain provided by the larger antenna array. Consequently, the radio signal experiences lower propagation loss from the perspective of the receiving user equipment, resulting in improved predicted coverage performance.

It is important to note that the planning tool estimates RSRP using deterministic propagation models, antenna radiation characteristics, terrain information, and network configuration parameters. Unlike dynamic performance indicators,

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

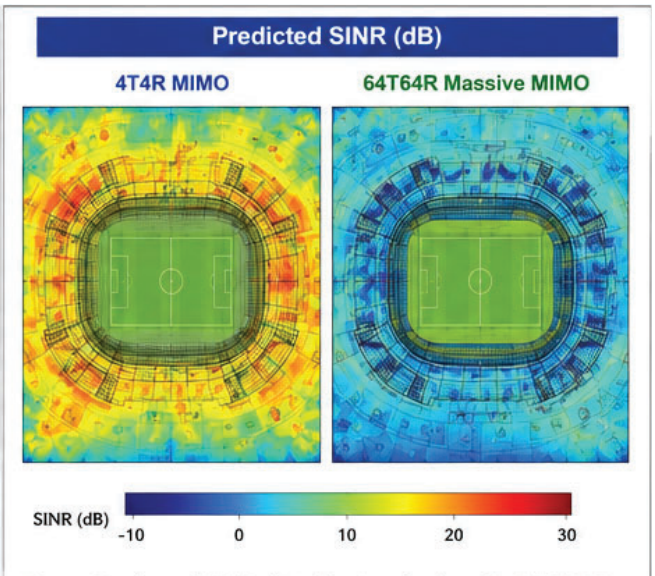

Fig. 5. Predicted SINR distribution for the 4T4R MIMO and 64T64R Massive MIMO configurations.

Fig. 5: Predicted SINR distribution for the conventional 4T4R MIMO and 64T64R Massive MIMO configurations.

RSRP prediction does not depend significantly on real-time scheduling decisions or instantaneous user distribution. Therefore, conventional RF planning tools are generally capable of providing reliable design-stage RSRP predictions for both conventional MIMO and Massive MIMO deployments.

Overall, the RSRP comparison demonstrates that the transition from a conventional 4T4R architecture to a 64T64R Massive MIMO system significantly enhances the predicted coverage performance within the stadium environment. These findings confirm that larger antenna arrays provide measurable coverage benefits during the planning stage and establish a strong foundation for evaluating the corresponding signal quality results discussed in the following subsection.

B. Design-Stage SINR Analysis

Signal-to-Interference-plus-Noise Ratio (SINR) is a fundamental performance indicator that reflects the quality of the received radio signal by considering both interference from neighbouring cells and background noise. Unlike RSRP, which represents only the received signal strength, SINR directly influences the achievable modulation and coding scheme (MCS), spectral efficiency, user throughput, and overall network capacity. Consequently, accurate SINR prediction is essential during the network planning stage to estimate the expected quality of service and user experience.

Figure 5 presents the predicted SINR distributions for the conventional 4T4R MIMO and 64T64R Massive MIMO configurations under identical planning assumptions.

As shown in Fig. 5, the planning tool predicts lower SINR values for the 64T64R Massive MIMO deployment compared with the conventional 4T4R configuration, despite the improved RSRP observed in the previous subsection. At first glance, this result appears counterintuitive because Massive MIMO is widely recognized for improving signal quality, increasing network capacity, and enhancing spectral efficiency in operational 5G networks.

The observed difference can be explained by the methodology employed by conventional RF planning tools. During the planning stage, SINR is typically estimated using deterministic propagation models, antenna radiation patterns, transmit power, and static interference calculations. Although these models accurately represent large-scale propagation characteristics, they do not fully account for the dynamic radio resource management techniques that distinguish Massive MIMO from conventional antenna systems.

In practical 5G deployments, Massive MIMO continuously adapts its transmission characteristics based on Channel State Information (CSI) obtained from active user equipment. Advanced beamforming algorithms dynamically steer narrow beams toward individual users while minimizing interference to neighbouring users. In addition, Multi-User MIMO (MU-MIMO), adaptive precoding, and scheduler-controlled spatial multiplexing enable multiple users to be served simultaneously using the same time-frequency resources with reduced mutual interference. These real-time processing functions significantly improve operational SINR but cannot be fully represented using static propagation-based planning models.

Another contributing factor is that planning tools generally assume broad coverage predictions rather than user-specific beam allocation. Consequently, the predicted interference generated by neighbouring sectors may appear higher than would actually occur in a live Massive MIMO network, where adaptive beamforming continuously suppresses inter-cell interference and concentrates transmission energy toward intended users. As a result, the design-stage SINR prediction represents a conservative estimate of network performance rather than the expected operational behaviour after deployment.

Therefore, the lower predicted SINR observed for the 64T64R configuration should not be interpreted as an indication of inferior radio performance. Instead, it highlights an inherent limitation of conventional RF planning methodologies when evaluating advanced antenna systems. While propagation-based planning models effectively estimate coverage-related KPIs such as RSRP, they are less capable of accurately representing the dynamic interference mitigation and spatial processing techniques that define Massive MIMO operation in commercial 5G networks.

These findings demonstrate that SINR predictions generated during the planning stage should be interpreted together with engineering knowledge of Massive MIMO technology rather than being considered as absolute indicators of post-deployment network performance. Consequently, design-stage SINR results should be complemented by system-level simulations, field measurements, or operational network data whenever comprehensive performance evaluation is required.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

KPI Summary (Design-Stage Prediction)

KPI	4T4R MIMO (Design Prediction)	64T64R Massive MIMO (Design Prediction)	Difference
Average RSRP (dBm)	-74.6	-67.5	+7.1 dB
Coverage (≥ -95 dBm)	95.4 %	99.0 %	+3.6 %
Average SINR (dB)	18.7	14.2	-4.5 dB
SINR ≥ 10 dB Coverage	88.0 %	74.3 %	-13.7 %

Note: Results are based on design-stage predictions from the RF planning tool under identical network planning assumptions.

Fig. 6. Comparison of predicted design-stage KPIs for the evaluated antenna configurations.

Fig. 6: Comparison of the predicted design-stage KPIs for the conventional 4T4R MIMO and 64T64R Massive MIMO configurations.

C. Comparative Discussion

The comparative evaluation presented in Figs. 4, 5, and 6 provides valuable insights into the capabilities and limitations of conventional RF planning tools when assessing advanced antenna technologies. Although both deployment scenarios were developed using identical planning assumptions, the predicted KPIs reveal distinct performance characteristics for the conventional 4T4R MIMO and 64T64R Massive MIMO configurations.

The RSRP prediction demonstrates a clear coverage advantage for the 64T64R Massive MIMO deployment. The larger antenna array provides higher array gain and enables more efficient utilization of transmitted energy, resulting in stronger received signal levels throughout the stadium coverage area. Since RSRP prediction primarily depends on deterministic propagation modelling and antenna characteristics, the planning tool successfully captures the expected improvement in signal strength provided by the larger antenna configuration.

From a network planning perspective, these findings emphasize that design-stage KPI predictions should be interpreted with appropriate engineering judgement rather than being considered as absolute representations of operational performance. RF planning tools remain highly effective for site selection, coverage verification, and preliminary network dimensioning. However, the evaluation of advanced Massive MIMO features should be complemented by system-level simulations, field measurements, or post-deployment performance analysis to fully capture the benefits of adaptive beamforming and spatial multiplexing.

Overall, the results confirm that the transition from conventional 4T4R MIMO to 64T64R Massive MIMO significantly enhances predicted coverage performance while simultaneously exposing the limitations of conventional planning methodologies in estimating quality-related KPIs. These observations provide practical guidance for radio network planners and highlight the importance of combining design-stage predictions with operational performance evaluation when planning next-generation 5G networks.

REFERENCES

1) T. L. Marzetta, “Noncooperative Cellular Wireless with Unlimited Numbers of Base Station Antennas,” *IEEE Transactions on Wireless Communications*, vol. 9, no. 11, pp. 3590–3600, Nov. 2010.
2) E. G. Larsson, O. Edfors, F. Tufvesson, and T. L. Marzetta, “Massive MIMO for Next Generation Wireless Systems,” *IEEE Communications Magazine*, vol. 52, no. 2, pp. 186–195, Feb. 2014.
3) T. S. Rappaport, Y. Xing, G. R. MacCartney Jr., A. F. Molisch, E. Mellios, and J. Zhang, “Overview of Millimeter Wave Communications for Fifth-Generation (5G) Wireless Networks—With a Focus on Propagation Models,” *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 12, pp. 6213–6230, Dec. 2017.
4) X. Lin *et al.*, “5G New Radio: Unveiling the Essentials of the Next Generation Wireless Access Technology,” *IEEE Communications Standards Magazine*, vol. 3, no. 3, pp. 30–37, Sept. 2019.
5) E. Dahlman, S. Parkvall, and J. Sköld, *5G NR: The Next Generation Wireless Access Technology*, 2nd ed. Academic Press, 2020.
6) E. Björnson, J. Hoydis, and L. Sanguinetti, *Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency*. Boston, MA, USA: Now Publishers, 2017.
7) H. Tataria, M. Shafi, A. F. Molisch, M. Dohler, H. Sjöland, and F. Tufvesson, “6G Wireless Systems: Vision, Requirements, Challenges, Insights, and Opportunities,” *Proceedings of the IEEE*, vol. 109, no. 7, pp. 1166–1199, Jul. 2021.
8) M. Shafi *et al.*, “5G: A Tutorial Overview of Standards, Trials, Challenges, Deployment, and Practice,” *IEEE Journal on Selected Areas in Communications*, vol. 35, no. 6, pp. 1201–1221, Jun. 2017.
9) S. Sun, T. S. Rappaport, R. W. Heath Jr., A. Nix, and S. Rangan, “MIMO for Millimeter-Wave Wireless Communications: Beamforming, Spatial Multiplexing, or Both?” *IEEE Communications Magazine*, vol. 52, no. 12, pp. 110–121, Dec. 2014.
10) D. Tse and P. Viswanath, *Fundamentals of Wireless Communication*. Cambridge, U.K.: Cambridge University Press, 2005.
11) A. Goldsmith, *Wireless Communications*. Cambridge, U.K.: Cambridge University Press, 2005.
12) A. F. Molisch, *Wireless Communications*, 3rd ed. Hoboken, NJ, USA: Wiley, 2023.
13) R. W. Heath Jr. and A. Lozano, *Foundations of MIMO Communication*. Cambridge, U.K.: Cambridge University Press, 2018.
14) C. Cox, *An Introduction to 5G: The New Radio*, 2nd ed. Hoboken, NJ, USA: Wiley, 2023.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 07 , July - 2026

15) 3GPP TR 38.901, “Study on Channel Model for Frequencies from 0.5 to 100 GHz,” Release 19, 2025.