International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 05 , May - 2026

2L-4H Beams Antenna

Mohammed Yahiya Pasha Gulam[1], Younus Mohammed[2], Syed Ashwaq Hussain[3], Hussam uddin Mohammed[4], Shaikh Noman[5], Asif Khan[6], Abdul Quader Syed[7], Mohammed Moizuddin[8]
Saudi Telecom Company

***Abstract*—This paper presents a comprehensive performance evaluation of 2-Low-Beam, 4-High-Beam (2L–4H) multi-beam antenna solution implemented on a live network. The trail was conducted on congested sites with advanced Massive MIMO has resulted in improved spatial multiplexing,enhanced coverage, and better spectral efficiency. The research concentrates on selected congested sites marked by high Physical Resource Block (PRB) usage and degraded user experience. Performance analysis was carried out using a combination of OSS-based performance indicators (KPIs), user-perceived data rates Signal to Interference-plus-Noise-Ratio (SINR), and cell-edge performance. Pre- and post drive test measurements, and crowd-sourced Ookla speed test data proves that the 2L-4H antenna configuration greatly improved beamforming precision, decreased inter-cell interference, and enhanced load balancing across frequency layers. The results of the study are remarkable traffic gains and capacity improvements determined by amplified SINR distribution and enhanced application of the higher-order modulation scheme such as 256-QAM. Additionally, traffic analysis indicates a clear shift of user load from LTE to 5G. In peak traffic periods,this utilization leads to enhanced user experience ,reduced latency and effective traffic offloading from congested carriers. The results validate that the 2L-4H beamforming antenna solution gives a scalable and organized approach to relieve capacity constraints in high- density 5G networks. This analysis provides hands-on experience to the operators in form of enhanced network performance, support growing traffic demands while guaranteeing consistent service levels.**

***Index Terms*—2L-4H antenna, Multibeam antenna, 5G NR, Mid-band optimization, Low-band enhancement, Coverage optimization, high-gain antenna,side-lobe suppression, Beamforming, Load Balancing.**

I. Introduction

Rapid growth of 5G networks has increased the demand for antenna systems capable of working efficient in low-frequency bands such as n28 (700 MHz) and n71 (600 MHz). These sub-GHz bands are basics for wide range coverage and deep indoor penetration particularly in hotspot locations with high user concentration and high traffic demand. Conventional sector antenna configurations are frequently unable to resourcefully handle peak-hour congestion, causing reduced throughput, low spectral efficiency, and degraded user experience. But, antenna design at sub-GHz frequencies is essentially stimulating because of the larger wavelength, which leads to increased antenna size and reduced radiation efficiency.

Beamforming methods have developed as a critical solution to these trials by enabling directional transmission and reception, thus improving signal strength, enhancing spectral efficiency, and reducing inter-cell interference. At the same time, multilayer antenna designs have gained attention for their ability to enhance electromagnetic performance without expressively growing the antenna footprint. Among these, two-layer (2L) configurations benefits in terms of easiness, density, and ease of manufacture, but their performance is often unnatural by partial gain and insufficient side-lobe suppression.

To overcome these obstacles, advanced multibeam antenna solutions have been developed, such as four-layer (4H) configurations as an operative approach. These improved beamforming performance, capacity utilization and increase traffic distribution without additional site deployment. The integration of of 2L-4H antenna on low-band spectrum such as N28 (700 MHz) and N71 (600 MHz) plays a critical role in extending coverage, improve indoor penetration, and support for cell-edge users and ability to penetrate obstacles more effectively than high frequency bands. By deploying combination 2L-4H beamforming antenna technology with strategic low-band, operators can extend wider coverage, 5G service availability to undeserved areas, including deep indoor locations, dense urban.

This paper presents a comprehensive analysis of 2L and 4H beamforming antennas deployment in a live network environment. The study is based on a combination of OSS key performance indicators, drive test measurements, user data to assess enhancements in coverage and throughput, traffic distribution. The outcomes of this provide quantitative and qualitative insights into the viability of multi-beam antenna solutions for high demand 5G networks.

II. Objective and Trial Setup

A. Objective

The primary objective of this study is to evaluate the capacity gain provided by the configuration of the 2L-4H antenna within a live network environment, with a specific focus on sector throughput, PRB utilization, and traffic offload efficiency against the legacy antenna setup during peak-hour conditions. The study aims to analyze how the introduction of 2L-4H multilayer antenna improved signal strength, traffic distributed across beams and layers, congestion hot-spots, and evaluating the impact on scheduler efficiency and inter-beam inference behavior.

In addition, the study evaluates to measure user experience improvements with statistical depth by analyzing throughput, SINR distribution, cell-edge performance and traffic distribution, user experience, and key performance indicators (KPIs). It also evaluates the readiness of the solution for 5G low-band integration, including its compatibility with non-standalone and standalone 5G NR deployments, with existing LTE layers.

B. Trail Clusters

The trail was conducted across a cluster of five selected sites within a live operational network enviornment. These sites were chosen to represent typical traffic conditions, user

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 05 , May - 2026

scattering, and varying coverage situations, including dense urban , suburban, and rural environments. The deployment was executed in December 2025. This staged implementation enabled a clear comparison between pre- and post-deployment performance, allowing an accurate evaluation of the impact of 2L-4H integration i.e., Low-band (2L) to evaluate coverage driven and High-band (4H) for capacity and beamforming across the cluster.

The network configuration include 5G low band layers, deployed antenna was a MS-MBC-4.2-H4-12-L4-20, and a multi-beam antenna target the low bands N28 and N71. Each beam support 2x2 MIMO and 4x4 MIMO, enable more precise sector coverage optimization. The deployment utilized the antenna's capacity and multi band operation, additional radio units and baseband elements such as AHPMDA for low band (700/900 MHz) layers and baseband upgrade with an ABIO, enhancing overall signal and enabling edge carrier aggregation and MIMO throughput.

Performance evaluation was carried out using a combination of OSS-based KPIs, drive test measurements, and user-experienced data. Drive testing was performed using commercial user equipment under both static and mobility conditions to capture real-world performance scenarios. in addition, throughput measurements where validated using Ookla speed tests and controlled testing environments. This comprehensive setup ensured accurate assessment of both network-level and user-level performance following the 2L-4H antenna deployment.

C. Hardware Configuration

The 2L-4H antenna deployment was carried out using AirScale radio equipment supporting 5G NR technologies within a unified hardware platform. The system configured with dual radio units AHPMDA capable of operation across low-band frequencies (700/900 MHz). Although the hardware supports upto 4x4 MIMO, 2L-4H antenna MS-MBC-4.2-H4-12-L4-20 was deployed using a 2x2 MIMO configuration.

The radio units enable to support the new antenna configuration to utilize more carriers and beams, ability to distribute user traffic across different frequency layers. The transmission power was configured to support wide-area coverage, enabling improved performance in dense urban, sub urban and indoor scenarios.

The overall selected hardware configuration confirmed continuous integration with the existing network infrastructure while providing the essential proficiencies to support 2L-4H multi beam antenna, improved coverage, capacity expansion, and traffic redistribution on the target cluster sites.

D. Tools Used

Performance evaluation of 2L-4H antenna deployment was carried out using a combination of filed test measurement tools and network-levl analysis systems to ensure a comprehensive assessment. Nemo Outdoor was used for conducting drive tests and capturing real-time radio measurements across different coverage conditions. Actix was utilized for post-processing and detailed analysis of the collected drive test data. In addition, OSS-based key performance indicators (KPI) were analyzed to evaluate network-level performance trends over time. Crowd-sourced Ookla speed test data was also combined to assess user-experienced throughput and validate field results. The combination of these tools provided technical and user-centric insights into network performance. Measurements were conducted across different time periods, including peak and non-peak hours, to capture realistic traffic conditions. Overall, the use of multiple tools ensured accurate and consistent evaluation of 2L-4H multi beam antenna.

III. NETWORK CONFIGURATION

When it comes to setting up a 5G network on the low band, using the right antenna configuration is crucial. The 2L-4H antenna setup is a great option, especially for bands like N28 and N71. But what does this setup actually mean? Well, the ”2L” part refers to the two vertical beams that are separated from each other. This allows the network to distinguish users who are close by and those who are farther away, which in turn enables more efficient power allocation and better performance at the edge of the cell. On the other hand, the ”4H” part signifies that the horizontal beams are split, which reduces the angular spread within each beam. This is important because it helps improve the overall performance of the network, especially in areas with a lot of traffic. Using this 2L-4H antenna setup, networks can achieve significant gains in terms of throughput and capacity, particularly useful in dense urban environments where demand traffic is extremely high.

The setup allows for a more efficient use of resources, resulting in better performance and faster data speeds for users. Overall, the 2L-4H antenna configuration is a powerful tool for optimizing 5G network performance, and it's an important consideration for anyone looking to set up a reliable and high-performance network. When a 2L-4H antenna combined, it really helps to spread out the traffic load more evenly across different beams. This is because the antenna can divide the area into multiple layers, allowing the system to dynamically assign users to the best layer based on where they are and what their channel conditions are like. As a result, areas that are normally busy get some, relief and the whole system runs more smoothly.

This approach makes better use of the available radio resources while keeping the user experience consistent. By doing this, it's possible to support more users and give them all a better experience, even in areas with a lot of traffic. Using a 2L low-band 5G layer can really improve how well your network covers an area and keeps a strong signal, even inside buildings. But to get the best results, it's a good idea to have a special NR carrier just for this purpose - it makes things run more smoothly and gives better performance numbers. When set this up, there are some key things to keep an eye on, like how strong the signal. Also,to check device can switch between different connections without losing service, and how long it takes for things to load. Overall, using 2L low-band 5G layer with a 2L-4H antenna solution good way to balance

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 05 , May - 2026

how much data can handle and well to covers an area such as Dense urban, Sub-urban. It's also a practical way to use low-band 5G networks.

IV. THEORETICAL BACKGROUND

Performance improvement observed with the deployment of the 2L-4H antenna described in essential wireless communication principles. These include propagation behavior, antenna diversity, MIMO capability, spectral efficiency, and carrier aggregation. The 2L-4H design combines low-band ports/layers and high-band ports/layers antenna elements. This setup allows the site to handle both coverage and capacity focused on frequency layers. The low-band layers in the 2L-4H antenna are well suited to extend coverage and improve service availability, particularly at cell edges and indoors. The relationship between propagation loss and frequency can be denoted by the free-space path loss equation:

$$FSPL = 32.44 + 20log10(f) + 20Log10(d)(1) \quad (1)$$

Here, FSPL is the free-space path loss in dB, f is the frequency in MHz, and d is the distance in km. It shows that path loss increases as frequency increases. Therefore, low-band layers offer better coverage, especially in tough radio environments such as dense urban, rural areas, cell edges and indoor locations. In contrast, high-band layers in 2L-4H antenna provide extra capacity due to the higher-frequency bands. The 2L-4H antenna design enhances antenna diversity and MIMO performance. MIMO increases throughput by using multiple transmit and receive path, which can be represented as:

$$C_{\text{MIMO}} \propto N \times B \log_2(1 + \text{SINR}) \quad (2)$$

Here N signifies the number of effective spatial layers. By increasing the number of supported antenna ports, the 2L-4H design can improve spatial diversity, beamforming capability, and overall spectral efficiency, depending on device capability and network configuration.

Moreover, the 2L-4H antenna supports multi-band and carrier aggregation, reliant on network and user equipment. Carrier aggregation combines multiple carriers, increasing the total effective bandwidth available to the user. When carrier aggregation is supported, the total effective bandwidth can be expressed as:

$$B_{\text{Total}} = B_1 + B2 + ...B_n \quad (3)$$

Overall, the theoretical principles explain clarify the observed improvements in coverage, uplink performance, capacity and network efficiency after deploying the 2L-H antenna.

V. OOKLA PERFORMANCE ANALYSIS

A. Integration Timeline

The rollout of the 2L-4H antenna was done in stages at selected sites, as shown in Table I. It started with Site 1 on December 6,2025, and then multiple sites were added on December 14,2025 and December 18,2025. The remaining

TABLE I
SITE INTEGRATION TIMELINE

Site ID	Integration Date
Site 1	06-Dec-2025
Site 2	14-Dec-2025
Site 3	18-Dec-2025
Site 4	20-Dec-2025
Site 5	20-Dec-2025

TABLE II
KEY PERFORMANCE SUMMARY

Metric	Value
5G Data Volume	52.5%
5G User	52%
Throughput	109 Mbps
Energy consumtion	6.43%

sites were completed by December 20,2025. This step-by-step approach allowed for a controlled deployment and gave enough time to check how the network was working after each step. The timeline presented in the table gives a clear picture of the rollout sequence and helps to check how the network performance improved during the integration period. In addition, Ookla readiungs showed an improvement of approximately 30%. It also makes it possible to compare the network conditions before and after integration a structured way. Overall,the staged integration caused little disruption and made it possible to accurately evaluate the networks performance.

B. Performance Improvement

Following the integration a significant improvement in 5G network performance was observed. User throughput increased from 88 Mbps to 109 Mbps, reflecting an overall gain of approximately 39% , indicating enhanced capacity and better resource utilization. In addition, the number of 5G users increased by 52%. There is improvement in throughput in both mid and low band. Coverage continued on all bands. Some impact was observed on quality related metrics like SINR, which can be attributed to the traffic increase. Overall, the results confirm that 2L-4H integration shows a critical role in enhancing network performance and user experience while continuing coverage constancy across the cluster.

VI. DRIVE TEST RESULTS

A. Static throughput

Drive test analysis was conducted to evaluate the real-world performance of the 2L-4H antenna under both static and mobility conditions. The results indicate that 2L-4H antenna provides stable and reliable performance, particularly in coverage and capacity. The study showed that the coverage stayed strong across all the routes that were tested, and the performance for getting data throughput was consistent even when things were moving around. When everything was still, the antenna performed really well, helping users get better and faster access to the data they needed, and making sure resources were used in a smart way. Overall, static testing

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

confirms its ability to support enhanced 5G network without compromising coverage stability.

B. Mobility KPIs

Mobility drive test results show the stable and consistent radio performance across the network. Key indicators such as RSRP and SINR were maintained at acceptable levels, with average values around -79 dBm and 7 respectively. The average downlink throughput during mobility was observed to be approximately 96 Mbps. These results confirm reliable performance under mobility conditions, ensuring seamless user experience. The network also maintained stable handovers and connectivity throughput the test routes. Overall, mobility KPIs indicate that 2L-4H antenna integration did not negatively affect the overall network stability.

VII. KPI ANALYSIS

When we looked at the KPI analysis, we wanted to see how the new 2L-4H antenna would effect the overall performance of our network. The introduction of the 2L-4H antenna made a big difference it increased user activity and signaling, which means it's really contributing to the network. In terms of traffic distribution, the 2L-4H antenna helped our 5G n28 traffic grow by 52% and it also helped us extend our 5G coverage to more areas, like dense urban and indoor environment. In our network performance stayed stable, with no degradation observed in accessibility, retainability, or mobility metrics. Overall, our analysis shows that the 2L-4H antenna makes our network more efficient while keeping it stability.

VIII. RESULT SUMMARY

The integration of the 2L-4H antenna has made a big difference in how well the network handles traffic and proved a good user experience. Looking at the key performance indicators, or KPIs are summarized in Tabel II. We observed that the 5G N28 layer has improved traffic by about 52%, and the number of users has also gone-up by 52%. This is a significant increase. Additional, the network has been about to use the low-band 5G frequency while still performing well. We have also seen a reduction in the use of PRB, or physical resource blocks for both downloads and uploads-20% and 39% respectively. Overall, the numbers show that the 2L-4H antenna integration has been as success, improving the network's ability to handle traffic, speed, latency, and resource use, all while supporting many more users. This is a great outcome, and it's clear that the integration has had a positive impact on the network's performance.

IX. DISCUSSION

The results clearly indicate that the deployment of the 2L-4H antenna layer provides significant benefits in terms of coverage enhancement, down-link and up-link performance, complementing the existing low-band 5G layers, helping to improve user experience across the targeted area

When establishing antenna connections to the radio modules, it is essential to strictly follow the method of procedure. This ensures that sector assignments remain accurate and helps prevent cross-beam or incorrect connectivity issues. The antenna N28 and N71 are mainly used to cover big areas, but they can still have some problems working well inside buildings or at the edge of their coverage area. This is because signals can get weaker when they have to travel through walls or when a lot of people are using their phones at the same time. On the other hand, using a special setup with 2 layers and 4 highways for the antenna can really help improve how well the radio signals work. It does this by making sure the signals are spread out evenly, having more space for lots of users, and handling all the phone traffic better across the whole area it serves.

After the integration, we saw some big improvements in how the network was working. There was more traffic, more users, and things were happening faster. We also used our resources better. Even though some quality related KPIs like SINR,CQI and MCS were impacted due to increase in traffic and number of users, the over all network stayed stable and worked well enough.

The roll-out of the 2L-4H antenna layer has really made a big difference in how well out network works. It's improved how reliable our coverage is, helped us handle more traffic, and boosted both our down-link and up-link services. This shows that using the 2L-4H antenna solution is a great way to make our 5G network better, especially in areas such as dense urban, rural or where it's hard to get a good signal inside buildings, or where the signal gets weak at the edge of our coverage area. By adding this antenna, we can give our users a better experience, which is what we're always aiming for.

X. CONCLUSION

This study evaluated the performance impact of integration 2L-4H antenna configure within a live network environment. The results demonstrated that 2L-4H antenna significant improvements in 5G user throughput, traffic volume, number of users, and resource utilization efficiency, particularity in indoor and cell edge scenarios, enabling improved service availability.

The deployment shows improved in low band layers, while coverage was maintained across the targeted area. Drive test results further confirmed stable radio performance, reliable coverage, consistent throughput, and stable handover behavior along the tested routes, capacity and traffic distribution and overall network efficiency following the deployment. The 2L-4H antenna integration was a great way to improve coverage, capacity, and the overall user experience. It works well with the existing low-band 5G layers and provides extra benefits, especially in areas with a lot of traffic, indoors, and at the edge of cells.

To make sure its deployed successfully, it's crucial to follow the method of procedure rules strictly, align parameters accurately, validate neighbors, optimize tilt, verify with drive tests, and assess the structure properly due to the larger size and weight of the multi beam antenna. This is important because the antenna is bigger and heavier, so it needs to be installed correctly to work properly. Overall, 2L-4H antenna deployment represents practical and scalable solution for improving 5G coverage and capacity performance.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 05 , May - 2026

REFERENCES

[1] 3GPP TS 38.300, "NR; Overall Description; Stage-2," Release 17, 2023.
[2] 3GPP TS 38.211, "NR; Physical Channels and Modulation," Release 17, 2023.
[3] 3GPP TS 38.214, "NR; Physical Layer Procedures for Data," Release 17, 2023.
[4] 3GPP TS 38.331, "NR; Radio Resource Control (RRC) Protocol Specification," Release 17, 2023.
[5] 3GPP TR 21.916, "NR Inter-band Carrier Aggregation and Dual Connectivity," Release 16, 2022
[6] Ericsson, Radio Network Design and Optimization Guidelines for LTE and NR Networks.
[7] Ericsson, Antenna System and Site Engineering Guidelines
[8] Nokia, Antenna Line Configuration and RF Connectivity Guidelines
[9] Nokia, AirScale Radio Access Network — Site Engineering and Deployment Guidelines.
[10] Vendor Method of Procedure Documentation, 2L-4H Antenna Integration and Commissioning Guidelines.
[11] Field Drive Test Reports, 2L-4H Antenna Static and Mobility Performance Validation
[12] Approved MOP Documentation, 2L-4H Antenna Integration and Commissioning Procedure
[13] S. Parkvall, E. Dahlman, A. Furuskar, and M. Frenne, "NR: The New 5G Radio Access Technology," IEEE Communications Standards Magazine, vol. 1, no. 4, pp. 24–30, 2017
[14] E. Dahlman, S. Parkvall, and J. Skold, 5G NR: The Next Generation Wireless Access Technology, 2nd ed. Academic Press, 2020.
[15] E. G. Larsson et al., "Massive MIMO for Next Gener- ation Wireless Systems," IEEE Communications Maga- zine, vol. 52, no. 2, pp. 186–195, 2014.
[16] N. H. Mahmood et al., "Multi-channel Access Solutions for 5G NR," IEEE Communications Magazine, vol. 57, no. 3, pp. 90–96, 2019.
[17] A. Gupta and R. K. Jha, "A Survey of 5G Network: Architecture and Emerging Technologies," IEEE Access, vol. 3, pp. 1206–1232, 2015.
[18] H. Zhang et al., "Interference Management in 5G Net- works," IEEE Wireless Communications, vol. 25, no. 3, pp. 24–31, 2018.
[19] G. Fettweis and S. Alamouti, "5G: Personal Mobile Internet Beyond What Cellular Did to Telephony," IEEE Communications Magazine, 2014.
[20] O. N. Ghazanfari et al., "Resource Scheduling in 5G Networks," IEEE Access, vol. 7, pp. 112489–112503, 2019.
[21] C. Liang et al., "Spectrum Sharing and Resource Opti- mization for 5G Systems," IEEE Transactions on Com- munications, vol. 67, no. 9, pp. 6242–6256, 2019.
[22] T. Koon et al., "5G NR Signal Design and Waveform Optimization," IEEE Transactions on Wireless Commu- nications, 2018.
[23] R. Khan et al., "Performance Analysis of 5G NR Scheduling Algorithms," IEEE Access, vol. 9, pp. 102345–102356, 2021.
[24] J. Heo et al., "Throughput Enhancement Techniques in 5G NR," IEEE Communications Letters, vol. 24, no. 8, pp. 1782–1786, 2020.
[25] L. Xia et al., "Carrier Aggregation for Sub-6 GHz Deployments," IEEE Network, vol. 33, no. 4, pp. 88–94, 2019.
[26] H. Zhang et al., "Resource Allocation for 5G NR Carrier Aggregation," IEEE Transactions on Vehicular Technology, vol. 70, no. 5, pp. 4894–4906, 2021.

(This work is licensed under a Creative Commons Attribution 4.0 International License.)