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Cell Phone Tower Design

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Abstract: ***Telecommunication towers are essential for reliable wireless communication and are commonly installed on the ground or on building rooftops. Their structural performance under wind and seismic loads is critical to ensure uninterrupted network services. This paper reviews previous studies on four-legged telecommunication towers, focusing on structural behavior, load response, and tower placement. The review identifies research gaps in evaluating tower location on supporting structures and highlights the need for optimized placement to improve safety, stability, and overall structural performance.***
Keywords: Telecommunication Tower, ETABS, Seismic Analysis, Response Spectrum Analysis, Lateral Displacement, Base Shear, Seismic Zone II, Seismic Zone V, IS 1893:2016.

I. INTRODUCTION

The increasing demand for wireless communication has led to the widespread installation of telecommunication towers on the rooftops of multi-storey buildings, especially in urban areas where land availability is limited. Although rooftop towers improve network coverage and optimize space utilization, they also increase the structural load and modify the dynamic behavior of buildings, particularly under seismic loading.

The additional mass and stiffness of rooftop towers can amplify inertial forces, increase stress concentrations, and induce torsional effects, thereby affecting the seismic performance of the supporting structure. Since many existing buildings were not originally designed to support these additional loads, evaluating the structural response of rooftop telecommunication towers has become essential for ensuring safety and serviceability.

This study investigates the seismic behavior of multi-storey buildings with rooftop telecommunication towers and evaluates the influence of tower placement on the structural performance. The findings aim to support the safe and efficient design of telecommunication tower–building systems.

A. Key Design Components

A telecommunication tower consists of several essential components that ensure reliable operation. These include antenna arrays for signal transmission, a Base Transceiver Station (BTS) for radio communication, power supply and cooling systems for uninterrupted service, and reinforced concrete foundations for structural stability. The most commonly used tower types are lattice towers, monopole towers, and guyed towers, selected based on height, load requirements, and site conditions.

B. History and Evolution of Cell Phone Towers

The concept of cellular communication was first proposed in 1947 and later developed into practical mobile networks. The first handheld cellular call was made by Martin Cooper in 1973, while the first commercial cellular network was launched in Japan in 1979. Since then, telecommunication towers have evolved with each generation of wireless technology (1G to 5G), leading to improved network coverage, capacity, and efficiency. Recent developments include stealth towers and tower-sharing techniques, which reduce visual impact, construction costs, and land requirements.

C. Lattice Tower

A lattice tower is a freestanding, self-supporting steel structure consisting of interconnected members that form an open framework. Its high strength, stability, and load-carrying capacity make it suitable for supporting multiple antennas and communication equipment. The open-frame configuration reduces wind resistance, allowing the tower to perform efficiently under severe environmental conditions.

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Features,

- Triangular or square base configuration.
- High structural stability and wind resistance.
- Self-supporting without guy wires.
- Fabricated from galvanized steel for corrosion resistance and long service life.

II. LITERATURE REVIEW

Oleksandr Kozak, Andrii Velychkovych, and Andriy Andrusyak (2025) proposed an optimized design methodology for a 42 m lattice telecommunication tower intended for mountainous regions. The study evaluated the influence of the transition between the pyramidal and prismatic sections on structural performance using finite element analysis. The results showed that placing the transition at approximately 78–80% of the tower height (about 33 m) provided the best balance between stiffness and weight while maintaining a safe natural frequency of 1.68 Hz. The proposed design improves structural efficiency, reduces material consumption, and ensures reliable performance under combined wind and dynamic loading conditions.

Shantilal Katare and Prof. Prachi Chincholikar (2024) presented a comprehensive review of telecommunication towers installed on multistory buildings, focusing on structural behavior, tower placement, and seismic performance. The study emphasized the importance of evaluating the host structure, selecting appropriate tower locations, ensuring uniform load distribution, and complying with seismic design codes. It also highlighted the need for detailed soil investigations and comparative structural analyses before tower installation. The authors identified a significant research gap, noting that previous studies primarily considered optimal tower locations while neglecting worst-case placement scenarios. They recommended further research to evaluate unfavorable tower locations and develop strategies for improving the structural safety and performance of rooftop telecommunication towers.

Janella Erika A. Medina, Regine V. Atienza, Danica S. Laxamana, Gilbert P. Maglanque, Erriel B. Mangalindan, Benz Marc L. Salva, Marvin D. Basea, and Irene R. Roque (2024) designed and analyzed a three-legged cellular tower using hot-dip galvanized steel (HDGS) to improve network connectivity at Don Honorio Ventura State University, Philippines. The study adopted TIA-222-G and LRFD design standards and performed structural analysis using Microsoft Excel and STAAD.Pro. The results showed that HDGS provides excellent corrosion resistance, structural stability, and durability under various loading conditions. The proposed tower design satisfied safety requirements and demonstrated its suitability for reliable and long-term telecommunication infrastructure.

Bharat Singh Uikey and Dr. Umesh Pendharkar (2024) presented a comprehensive review on the seismic performance of multistory buildings with rooftop telecommunication towers. The study examined key structural parameters, including storey drift, nodal displacement, base shear, and axial force, under earthquake loading. It highlighted the importance of accurate structural modeling, material selection, and seismic design to ensure the safety and stability of tower–building systems. The authors concluded that rooftop telecommunication towers significantly influence the seismic response of buildings and recommended advanced analytical methods and mitigation strategies to improve structural resilience in earthquake-prone regions.

Hritik Gupta, Aditi Chourasia, Dr. Chaitanya Mishra, and Dr. Parikhsit Joshi (2023) reviewed the structural challenges associated with installing telecommunication towers on multistory buildings. The study emphasized the importance of selecting appropriate tower locations, evaluating the host structure, ensuring proper load transfer through structural members, and complying with seismic design codes. It also recommended soil investigation and comparative analysis of different tower placement scenarios. The authors identified a significant research gap, as previous studies focused mainly on optimal tower locations while neglecting the structural effects of unfavorable or worst-case placements. They suggested that future research should investigate these scenarios to improve the safety and performance of rooftop telecommunication tower systems.

III. OBJECTIVES

The objective of the current research study is

1) Geometric Modeling and Configuration Study.
2) To develop a detailed 3D mathematical model of a steel telecommunication tower in ETABS.
3) Implementation of IS 875 (Part 3): 2015.

4) To evaluate the vertical distribution of wind forces acting on the tower structure.
5) To design and verify the structural integrity of critical load cases.

IV. METHODOLOGY

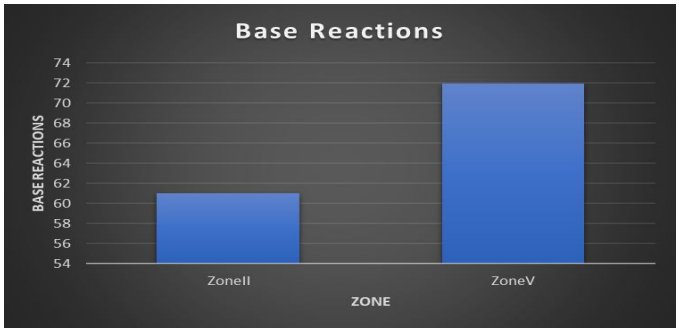
The lattice telecommunication tower was modelled and analysed using ETABS by representing the structure as a three-dimensional steel frame system. The modelling procedure was carried out systematically to ensure accurate simulation of the tower's structural behaviour under gravity, wind, and seismic loading conditions. The adopted methodology is described below.

1) Step 1: Model Initialization and Grid Definition A new ETABS model was created by selecting the appropriate unit system (kN–m). The steel design was carried out in accordance with IS 800:2007 (Limit State Design) and the loading provisions of IS 802:1995 for steel transmission and telecommunication structures. A Cartesian grid system was established corresponding to the four-legged tower configuration. The total tower height was divided into multiple panel levels, with each bracing panel represented as an individual storey to simplify modelling and member connectivity.
2) Step 2: Material and Section Definition Structural steel material properties were defined according to the selected steel grade. Frame sections were assigned based on the functional requirements of individual members. Heavier angle or tubular sections were adopted for the main legs to resist axial compression and bending, while comparatively lighter angle sections were assigned to horizontal and diagonal bracing members. These properties were defined using the Frame Section library available in ETABS.
3) Step 3: Three-Dimensional Structural Modelling The four main legs of the tower were modelled first by placing frame elements at the grid intersections. The lower portion of the tower was modelled with a tapered (pyramidal) geometry, gradually transitioning into a prismatic section toward the top. Horizontal and diagonal bracing members were then introduced using appropriate bracing configurations to provide lateral stability and load transfer. Since the bracing members primarily resist axial forces, end moment releases (pinned-end conditions) were assigned to simulate truss behaviour and improve modelling accuracy.
4) Step 4: Loading and Load Combinations The self-weight of the tower was automatically considered by ETABS as dead load. Additional dead loads representing antennas, platforms, cable trays, and other accessories were applied at the appropriate locations. Wind loads were assigned according to the provisions of IS 875 (Part 3):2015, considering the relevant wind zone and terrain category. Seismic loads in the principal horizontal directions (EQX and EQY) were defined in accordance with IS 1893 (Part 1):2016 for both Seismic Zone II and Seismic Zone V. Appropriate load combinations were generated to evaluate the critical structural response under different loading scenarios.
5) Step 5: Structural Analysis and Design Verification Linear static and response spectrum analyses were performed using ETABS to evaluate the structural performance of the tower. Key response parameters such as lateral displacement, storey drift, base shear, axial force, and member forces were extracted and compared for different seismic zones. The steel design module of ETABS was subsequently used to verify the adequacy of all structural members in accordance with IS 800:2007. Members that did not satisfy the design requirements were identified through the design check and revised until all members met the prescribed safety criteria.

V. RESULTS AND DISCUSSION

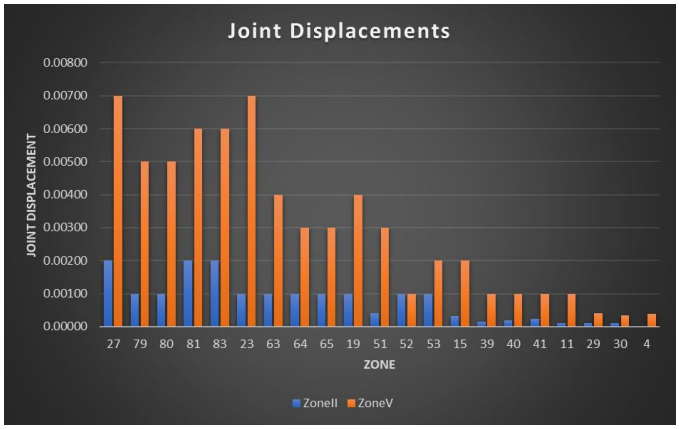
A. Base Shear

The base reactions obtained from the response spectrum analysis for the load combinations 1.2(DL + LL + RSX) and 1.2(DL + LL + RSY) are presented in below graph respectively. The results indicate that the total base reaction increased from 60.996 kN in Seismic Zone II to 71.984 kN in Seismic Zone V. This corresponds to an increase of approximately 18.0%, reflecting the greater seismic forces associated with the higher seismic zone factor.



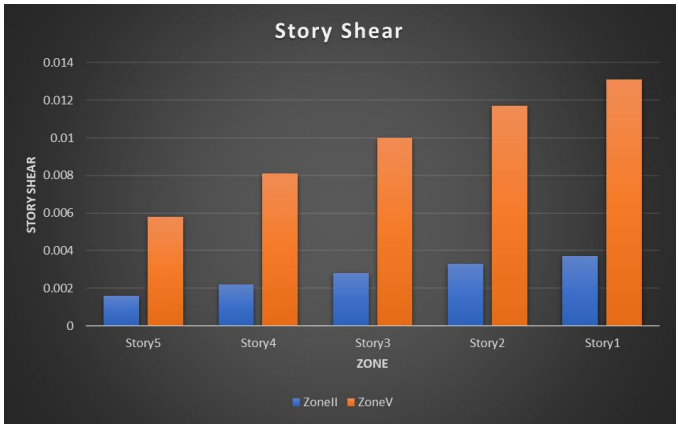
B. Joint Displacement

The joint displacements in the X- and Y-directions for Seismic Zones II and V. The maximum displacement was observed at Node 27, increasing from 20×10^{-4} mm in Zone II to 70×10^{-4} mm in Zone V. The displacement gradually decreased towards the base, with the minimum value recorded at Node 4 due to the fixed support condition. Similar displacement patterns in both directions indicate the symmetric behaviour of the tower. The increased displacement in Zone V is due to the higher seismic intensity, while all values remain within the permissible design limits, confirming the satisfactory lateral stability of the tower.



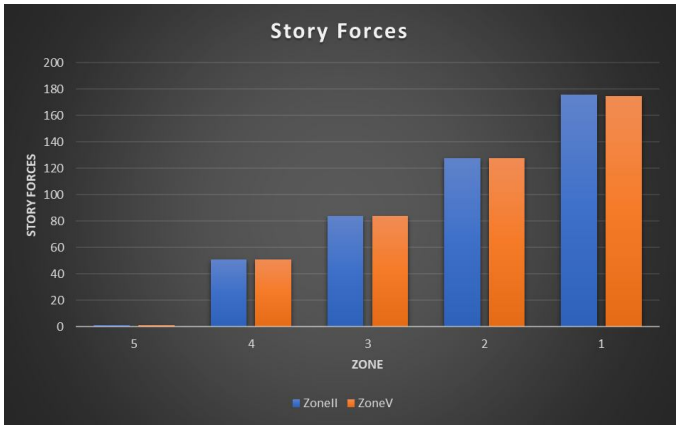
C. Story Shear

The story shear values in the X- and Y-directions for Seismic Zones II and V. The maximum story shear was observed at Story 1, while the minimum occurred at Story 5. Story shear increased from the top to the base due to the accumulation of seismic forces along the tower height. Higher story shear values were obtained in Seismic Zone V compared to Zone II, indicating greater seismic demand. Similar results in both directions confirm the symmetrical structural behaviour of the telecommunication tower.



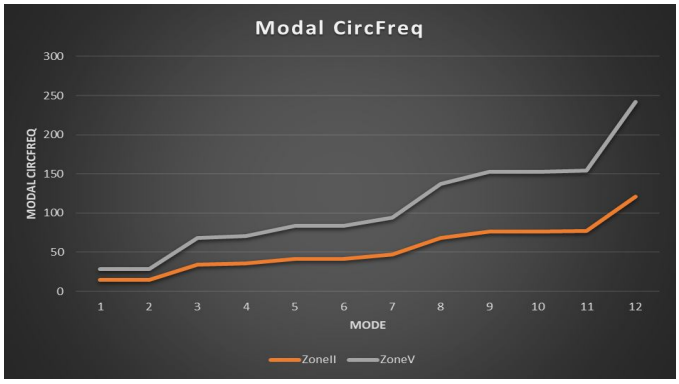
D. Story Forces

The story forces were evaluated for the load combinations 1.2 × (D + LL + RSX) and 1.2 × (D + LL + RSY) for seismic Zones II and V. The results show that the maximum story force occurs at the lower story level due to the accumulation of seismic inertia forces from the upper floors. The story force decreases gradually towards the top of the structure. For the X-direction, the maximum story force obtained is 176.0943 kN in Zone II and 174.6765 kN in Zone V. Similar behavior is observed in the Y-direction, indicating a uniform distribution of seismic forces along both principal directions. The comparison shows that the structure exhibits nearly similar force response under different seismic zones.



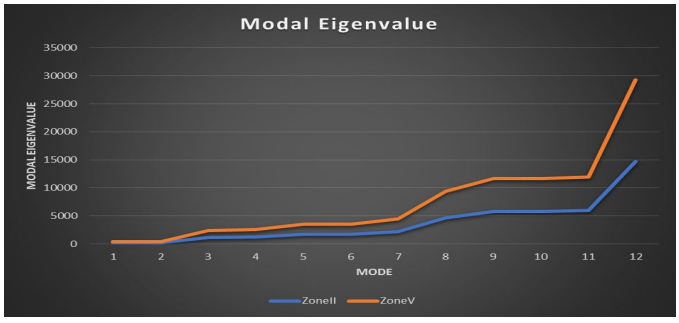
E. Circular Frequency

The fundamental circular frequency is observed as 14.3496 rad/sec for Zone II and 14.347 rad/sec for Zone V. The close agreement between both seismic zones indicates that the structural dynamic characteristics remain nearly unchanged under different seismic conditions.



F. Eigenvalue

The fundamental eigenvalue obtained is 205.9099 rad²/sec² for Zone II and 205.837 rad²/sec² for Zone V. The close similarity in eigenvalues for both seismic zones indicates that the dynamic characteristics of the structure remain almost unchanged under different seismic conditions.



VI. CONCLUSION

The 46.2 m high self-supporting lattice communication tower was analysed and designed for Seismic Zone 2 and Zone 5 of India using etabs. The tower geometry, loading, and member design were checked as per IS 800:2007 (LSD), IS 875 Part 3:2015. All structural members consist of IS angle sections. The following conclusions are drawn based on the results.

1) Structural Adequacy & Code Compliance: All IS angle sections provided for legs, bracings, and horizontals were found to be safe and sufficient as per IS 800:2007 LSD method. Utility check ratios for axial + bending interaction remained < 1.0 for all members under the governing load combinations.

2) Deflection & Drift Within Permissible Limits: Maximum lateral deflection at tower top under service earthquake load was 0.004XH (0.004 X 46200 mm = 184 mm) for both zones, which is within the permissible limit specified in IS 1893. Obtained values are 20mm in zone 2 and 70mm in zone 5 in our case.

3) Governing Load Case: Earthquake load computed as per IS 1893 Part 4:2015 was found to govern the design for both Seismic Zone 2 and Zone 5. The base reaction due to earthquake in Zone 5 was 18% more that in Zone 2.

4) Slenderness and Stability Requirements: The slenderness ratio `KL/r` for all compression members was within the permissible limits specified in Table 3 of IS 800:2007. This ensures that no member fails due to buckling under factored loads. Effective length factor was adopted as 1.0.

5) Serviceability Criteria: The maximum horizontal deflection at the tower top under service earthquake load was less than the allowed limit of H/100 specified for microwave towers in IS 5613 Part 2.

VII. OVERALL SUMMARY

The cell phone tower designed with IS angle sections is structurally safe, serviceable, and economical for both Seismic Zone 2 and Zone 5 as per relevant Indian Standards. Earthquake load is the governing criterion, and all codal provisions related to strength, stability, and deflection are satisfied.

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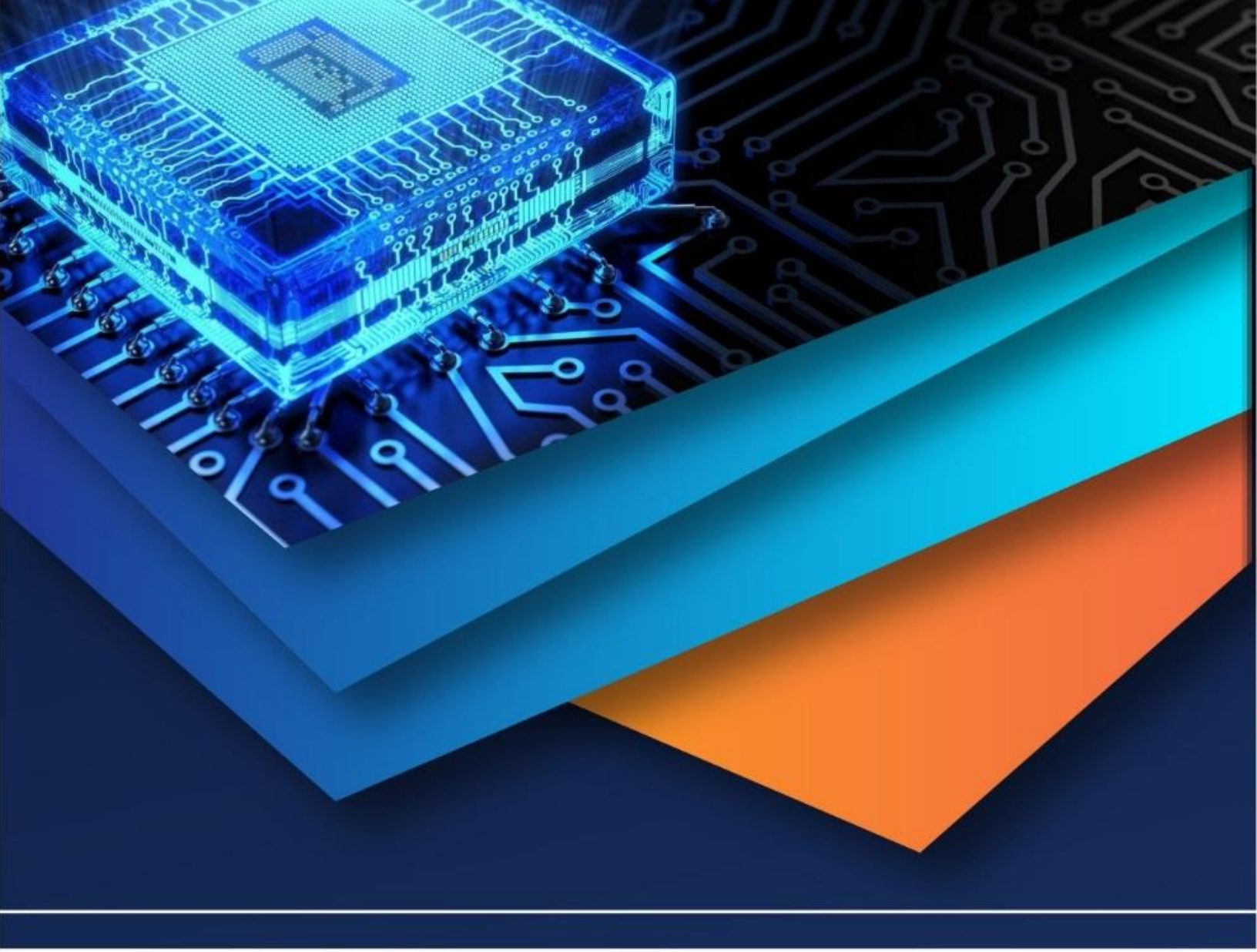
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