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Simulation and Analysis of Antenna Used for
AR/VR Applications

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This paper presents the design, simulation, and analysis of a slotted square microstrip patch antenna operating at 26 GHz for millimeter-wave (mmWave) frequencies, aimed at augmented reality (AR) and virtual reality (VR) applications. The increasing demand for compact, lightweight, and efficient antennas in wearable devices motivated this work. The proposed antenna was designed on a Rogers RT/Duroid 5880 substrate with a dielectric constant of 2.2 to reduce losses and enhance bandwidth. A rectangular slot was incorporated into the radiating patch to improve impedance matching and overall antenna performance. Instead of relying solely on theoretical calculations, systematic parametric sweeps and simulation-based optimization were carried out using Ansys HFSS 202425 (Student Version) to achieve the desired resonance and radiation characteristics. The antennas performance was evaluated by observing key parameters such as return loss (S11), directivity, radiation pattern, bandwidth, and radiation efficiency. The simulated results showed a wide impedance bandwidth, stable radiation patterns, and high efficiency at 26 GHz. These characteristics make the antenna highly suitable for integration in next-generation AR/VR systems operating in the mmWave band, where high data rates and reliable wireless connectivity are essential. The design provides a compact and effective solution for modern communication devices.. Keywords:Microstrip Patch Antenna, AR/VR, mmWave, Return Loss, Bandwidth, Slot Design, Wearable Antenna, Compact Antenna Design, Antenna Simulation, Antenna Performance Analysis.

I. INTRODUCTION

With the increasing demand for immersive experiences in augmented reality (AR) and virtual reality (VR) applications, efficient and compact antennas have become crucial components of wearable technology. Historically, antennas have undergone significant advancements, evolving from traditional bulky structures to miniaturized high-performance designs

suitable for modern electronic devices. Among these, microstrip patch antennas have emerged as the preferred choice for AR/VR systems, owing to their lightweight nature, ease of integration, and directional radiation characteristics. A microstrip patch antenna is a type of radio antenna consisting of a thin metallic patch placed on a dielectric substrate with a ground plane positioned beneath it. The dielectric substrate plays a critical role in determining the electrical properties of an antenna, including its efficiency and bandwidth. The patch, which is typically made of copper, can be fabricated on substrates such as Rogers RT/Duroid, depending on the required performance parameters. The key characteristics of microstrip patch antennas include their lightweight design, directional radiation, ease of integration, and high-frequency
operation, making them highly suitable for wearable AR/VR applications. Several studies have explored the performance of microstrip patch antennas in various communication systems. Research has indicated that these antennas provide satisfactory
directivity, efficient radiation patterns, and wide operational bandwidth, making them ideal for wearable AR/VR devices. However, existing studies primarily focus on traditional ap-
plications, such as satellite communication and mobile networks. Despite their advantages, microstrip patch antennas still face certain challenges when used in wearable applications, particularly in terms of performance stability under dynamic
movements, signal interference, and material limitations. This presents a research gap in optimizing the antenna performance for dynamic and flexible AR/VR environments, ensuring seamless connectivity and reduced interference. The objective of this study is to analyze, simulate, and optimize microstrip patch antennas specifically for AR/VR applications, addressing the existing challenges in efficiency, bandwidth, and material adaptability. By bridging the identified research gap, this study aims to contribute to the development of high-performance antennas that enhance immersive experience in next-generation AR/VR systems. . II. MATERIALS ANDMETHODS
The design, simulation, and analysis of the proposed microstrip patch antenna for AR/VR applications were conducted using systematic steps, as outlined in this section. A. Materials Used
The materials used for designing and simulating the antenna are listed in Table I.2
TABLE I

MATERIALS ANDPARAMETERSUSED INANTENNADESIGN
Material/Parameter Value
Substrate MaterialRogers RT/Duroid 5880
Dielectric Constant (r) 2.2
Substrate Thickness 0.65 mm
Patch Material Copper
Operating Frequency 26 GHz
Bandwidth 1.8 GHz
Feeding Technique Microstrip Line
B. Methodology
The methodology for designing and analyzing the antenna is as follows:1) Antenna Design and Data Preparation:The proposed antenna is a slotted square microstrip patch antenna designed to operate at 26 GHz within the millimeter-wave (mmWave) frequency band for AR/VR applications. The Rogers RT/Duroid 5880 substrate was selected for its low dielectric constant (r 2.2), low loss tangent, and suitability for high-frequency antenna designs, resulting in minimal dielectric losses and improved bandwidth. The antenna structure comprises a ground plane, dielectric substrate, radiating patch, microstrip feedline, and a rectangular slot to enhance bandwidth and impedance matching. The design dimensions for each antenna element were initially calculated based on standard transmission line models and cavity model equations. Instead of solely relying on closed-form equations, the design process further involved systematic parametric sweeps and simulation-based optimization in Ansys HFSS to achieve the desired resonance frequency, return loss, and radiation characteristics at 26 GHz. A microstrip feedline was chosen as the excitation method due to its simplicity, ease of fabrication, and compatibility with AR/VR system integration. 2) Simulation Setup and Computational Methods:The antenna design was simulated using Ansys Electronics Desktop HFSS 202425 (Student Version). The simulation setup included: Lumped-Port Excitation:Applied at the microstrip feedline to accurately simulate input signal behavior. Perfect Electric Conductor (PEC) Boundary Conditions:Used to model ideal conductive surfaces and ensure accurate wave propagation. Finite Element Method (FEM) Solver:Employed with adaptive meshing and frequency-domain analysis for accurate and convergent solutions across the frequency sweep. The simulation frequency range was set from 24 GHz to 28 GHz to capture the antennas performance around the target resonance. Adaptive meshing was used to refine the solution until convergence criteria were met, ensuring reliable and

repeatable results. 3) Data Collection and Processing:The following key
performance parameters were extracted from the simulation
results: S-parameters (S11):Used to evaluate impedance match-
ing and reflection loss, targeting a return loss of less than
-10 dB within the operational frequency band. Directivity:Measured to assess the antennas ability to
focus radiation in a desired direction, critical for targeted
AR/VR communication. Radiation Pattern:Both 2D and 3D far-field patterns
were plotted to visualize field distribution, beamwidth, and directional behavior. Bandwidth:The -10 dB bandwidth was determined to
confirm the usable frequency range and ensure compli-
ance with mmWave communication standards. Radiation Efficiency:Evaluated to determine the per-
centage of input power effectively radiated by the an-
tenna, ensuring minimal losses and stable performance
for wearable and portable AR/VR applications. 4) Analysis Techniques and Validation Methods:Post-
simulation, all results were analyzed through graphical rep-
resentation and performance evaluation. Convergence checks
were performed to verify solution stability, and mesh refine-
ment ensured result accuracy. The simulated performance was
cross-checked against theoretical predictions and supported
by reference literature to validate the designs reliability and
practical applicability for AR/VR devices operating at 26 GHz. III. RESULTS
Fig. 1 presents the unified antenna structure combining all
individual components. Fig. 2 displays the substrate that provides mechanical support and
electrical insulation for the antenna elements. Fig. 3, Fig. 4, and Fig. 5 show the progressive addition of circular
cuts in the
patch to further tune frequency response and optimize gain. Fig. 6 presents the final optimized structure after all slots. 3
Fig 7: Geometry of proposed antenna structure. The S11 parameter indicates
how much power is reflected back from the antenna, where
lower values (more negative dB mean better impedance match-
ing and less reflection. - The x-axis the frequency range from
20GHz to 32 GHz. - The y-axis represents the return loss in
dB. - The sharp dip at 27 GHz (-40 dB) signifies the resonant
frequency, where maximum power is transmitted and minimal
reflection occurs. - Outside this resonant frequency, the return
loss is higher, indicating poorer impedance matching. This
analysis is crucial for antenna design in AR/VR Applications
to ensure efficient signal transmission and reception in the
mmWave band. Fig2 :Radiation Pattern of the Proposed Antenna 5mm
The given plot represents the radiation pattern of an antenna
in polar coordinates. This pattern illustrates the directional

gain of the antenna. The red curve peaks around 16.517 dB. The angle () represents the direction of radiation. This
peak occurs at 0, indicating that the antenna radiates
strongest in the forward direction. The plot exhibits a directional pattern meaning the an-
tenna radiates more power in a specific direction rather
than equally in all directions. The small Lobe at 180 represents a minor back lobe, indicating that some radiation is directed backward. This type of analysis is particularly useful in AR/VR
applications, where controlled radiation is required for
efficient signal transmission. TABLE III
COMPARISON OFOBSERVEDRESULTS WITHTHEORETICAL
EXPECTATIONS
Parameters Observed vs Theoretical Expectations
Bandwidth 2.5 GHz (6.5% of center frequency) VS
GHz (8% of center frequency)
Return Loss -22 dB VS -20 dB
Slot Design EffectivenessEnhanced bandwidth and reduced surface
wave VS. Theoretical enhancement in per-
formance
Practical FeasibilityCompact design suitable for wearable ap-
plications vs. Theoretical integration with
mmWave devices. A. Bandwidth and Return Loss
The observed bandwidth of 2.5 GHz (6.5% of center
frequency) falls slightly short of the theoretical expectation
of 3 GHz (8% of center frequency). This variation is within
an acceptable range and demonstrates that the antenna design

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meets the target specifications with minor deviations. The
return loss observed was -22 dB, which is better than the
theoretical target of -20 dB, indicating effective impedance
matching and minimal signal loss. B. Effectiveness of Slot Design
The inclusion of the slot in the patch antenna design has
shown to improve the bandwidth performance, with the
observed increase in bandwidth being consistent with
theoretical expectations. The slot helps in reducing surface
waves, thus improving the antennas efficiency and gain, particularly in the targeted mmWave frequency range. C. Practical Feasibility and Integration with mmWave
Devices
The compact design of the antenna makes it feasible for
integration into wearable applications such as AR/VR
devices. The small form factor allows for efficient placement
on lightweight, flexible substrates, which is essential for

wearable technology. Additionally, the antennas performance at mmWave frequencies ensures that it is compatible with next-generation wireless communication systems, particularly for AR/VR applications. IV. RESULTS ANDDISCUSSION
The designed slotted square microstrip patch antenna was simulated using Ansys HFSS 2024-25 (Student Version). The key simulation results are presented below: TABLE IV
OBSERVATION OFSIMULATIONRESULTS
Parameter Observed Value
Resonant Frequency 26 GHz
Return Loss (S11) Less than -10 dB
Bandwidth [1.8 GHz]
Directivity []
Radiation Efficiency [100%]
Radiation PatternStable 2D and 3D plots
The simulated antenna shows good impedance matching at 26 GHz with wide bandwidth and high efficiency. The directivity and radiation patterns confirm stable performance, making the design suitable for AR/VR applications in the
mmWave band. V. DISCUSSION
The performance of the designed microstrip patch antenna for AR/VR applications has been evaluated based on the observed results and theoretical expectations. The key aspects such as bandwidth, return loss, slot design effectiveness, and practical feasibility for wearable integration are discussed. VI.
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