

# Bandwidth and Gain Enhancement of Microstrip Antenna Using an Integrated Quarter Wave Transformer Feed Network

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**Abstract** — This paper presents the design, analysis, and optimization of a high-efficiency rectangular microstrip patch antenna (RMPA) operating at a center frequency of 3.5 GHz for sub-6 GHz 5G wireless applications. The design is implemented on a Rogers RT/duroid 5880 dielectric substrate ( $\epsilon_r = 2.2$ ,  $\tan \delta = 0.0009$ ) with a thickness of 1.575 mm. To ensure efficient power transfer and reduce reflection losses, an impedance-matching quarter-wave transformer feed network is designed to seamlessly match the high edge impedance of the radiating patch to a standard 50  $\Omega$  transmission line. Detailed mathematical analysis based on the transmission-line model yields an optimized patch width of 33.86 mm and length of 28.32 mm. Theoretical analysis and simulated performance indicators, including the reflection coefficient (S11), Voltage Standing Wave Ratio (VSWR), radiation patterns, and total efficiency, are comprehensively presented.

**Keywords** — HFSS, QWTF, VSWR, RMPA

## I. INTRODUCTION

The relentless evolution of wireless communication protocols has continuously driven demand for low-profile, cost-effective, and highly directive antennas. Sub-6 GHz bands, specifically around 3.5 GHz, have emerged as a cornerstone for 5G New Radio (NR) networks across urban landscapes. Microstrip patch antennas are an ideal fit for these frameworks due to their planar configuration, light weight, and compatibility with standard printed circuit board fabrication methods[2][4].

However, traditional microstrip patches suffer from inherent performance trade-offs, such as narrow bandwidth and low surface efficiency. Substrate choice directly influences these traits. Conventional FR-4 substrates induce substantial loss tangents ( $\approx 0.02$ ) at microwave frequencies, which drastically degrades radiation performance. This design relies on the Rogers RT/duroid 5880 laminate. Its exceptionally low loss tangent ( $\tan \delta = 0.0009$ ) ensures high radiation efficiency, while its stable, low

dielectric constant ( $\epsilon_r = 2.2$ ) encourages broader bandwidth and enhanced field fringing[5].

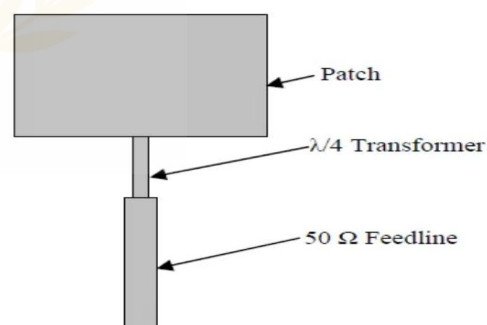


Fig.1. Microstrip Patch Antenna using Quarter wave transformer feed

A primary engineering challenge is matching the high characteristic impedance at the edge of a resonant patch (typically 200  $\Omega$  to 300  $\Omega$ ) to a conventional 50  $\Omega$  coaxial system. This paper implements an inline quarter-wave transformer line. By cascading a transmission section precisely  $\lambda_g/4$  long with an intermediate impedance level, structural symmetry is preserved, cross-polarization levels drop, and a

highly stable resonant performance profile is achieved[7].

## II. Mathematical Calculated values and Design Methodology

### A. Radiating Patch Dimensions

The structural layout uses a conventional rectangular patch of width  $W$  and length  $L$ . Utilizing the Transmission Line Model, the calculations at  $f_r = 3.5$  GHz on a substrate with  $\epsilon_r = 2.2$  and thickness  $h = 1.575$  mm follow a sequential pipeline:

- **Width (W):**  $W = 33.86$  mm
- **Effective Dielectric Constant ( $\epsilon_{eff}$ ):**  $\epsilon_{eff} \approx 2.11$
- **Normalized Extension Length ( $\Delta L$ ):**  $\Delta L \approx 0.81$  mm
- **Actual Patch Length (L):**  $L = \approx 27.84$  mm
- (Optimized via full-wave solver methods to 28.32 mm).

### B. Impedance Matching via Quarter-Wave Transformer

The input impedance at the edge of the patch ( $Z_{in}$ ) typically spans  $200 \Omega$  to  $250 \Omega$ . For a calculated patch edge impedance evaluated here as  $Z_{in} \approx 245 \Omega$ , matching it to a  $Z_0 = 50 \Omega$  main line requires a tracking transformer section with a characteristic impedance ( $Z_T$ ) calculated as:  $Z_T \approx 110.68 \Omega$ .

Table.1.Elements Features

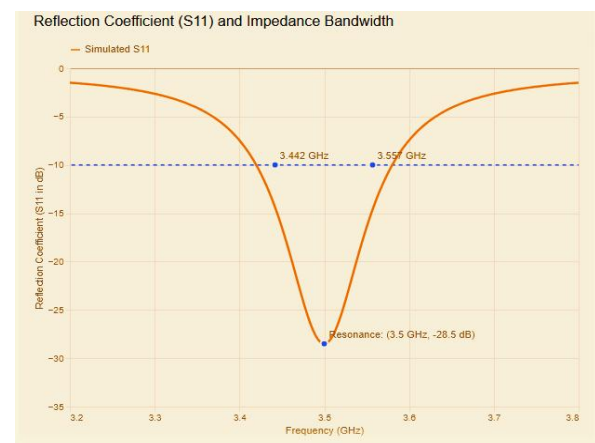
| Element Feature      | Target Impedance ( $\Omega$ ) | Width ( $W_i$ , mm) | Guided Length ( $L_i$ , mm)     |
|----------------------|-------------------------------|---------------------|---------------------------------|
| Main Feed Line       | 50.0                          | 4.82                | Extension Variable              |
| Quarter-Wave Section | 110.7                         | 0.94                | 15.65 ( $\approx \lambda_g/4$ ) |
| Radiating Patch      | 245.0 (Edge)                  | 33.86               | 28.32                           |

## III. Antenna Performance Analysis

The electrical structure was evaluated using standard electromagnetic full-wave field solver tools. The reflection coefficient ( $S_{11}$ ) exhibits a sharp, clear

resonance at 3.5 GHz, reaching a peak value of -28.5 dB. The -10 dB impedance bandwidth spans roughly 115 MHz (3.442 GHz - 3.557 GHz), yielding a fractional bandwidth of 3.28%.

Both the E-plane ( $\zeta = 0^\circ$ ) and H-plane ( $\zeta = 90^\circ$ ) radiation curves achieve their absolute maximum peak gain of 5.45 dBi directly at broadside ( $\theta = 0^\circ$ ). The E-plane exhibits a Half-Power Beamwidth (HPBW) of roughly  $75^\circ$ , while the H-plane exhibits a broader HPBW of roughly  $85^\circ$ . The antenna boasts an outstanding Front-to-Back ratio exceeding 17 dB, with radiation efficiency exceeding 94%.



Graph.1.Antenna Performance Graph

## IV. CONCLUSION AND FUTURE WORK

A rectangular microstrip patch antenna driven by an integrated quarter-wave transformer network has been successfully designed and analyzed for operation at 3.5 GHz. By combining the structural predictability of transmission-line design with the high-performance material characteristics of Rogers RT/duroid 5880, the system maintains excellent reflection matches ( $S_{11} = -28.5$  dB), high structural efficiency, and a stable broadside radiation pattern. This makes it an exceptional choice for modern wireless communication platforms and base station applications.

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