

STUDENT PROJECT

CIRCULAR POLARIZED MICROSTRIP PATCH ANTENNAS

Antennas

1. INTRODUCTION

Microstrip antennas, also called patch antennas, are very popular antennas in the microwave frequency range because of their simplicity and compatibility with circuit board technology. The rectangular patch antenna is the one of the most commonly used microstrip antennas. Inset-feed microstrip antennas are suited to direct integration with microstrip circuits, since the antenna can be etched on the same substrate. The inset-feed allows this antenna to be designed for a wide impedance range without using extra impedance matching circuitry. When sharing a substrate with microstrip circuits, the antenna performance is, however, limited by the conflicting substrate requirements for antenna and circuit use. This antenna is popular as an array-element, but for large arrays the feed-network radiation may affect performance considerably.

The patch antenna is designed so its pattern maximum is normal to the patch element. This is accomplished by properly choosing the mode of excitation beneath the patch. For a rectangular patch, the length of the element is usually between a third and half a wavelength in the substrate. Circular and elliptical polarisation may be obtained using various feed arrangements or slight modifications made to the elements, with two orthogonal modes excited with equal amplitudes and 90° time-phase difference. For a square patch, nearly circular polarisation may be achieved by trimming the ends of two opposite corners, to achieve quadrature phase coupling between the orthogonal TM_{01} and TM_{10} cavity modes.

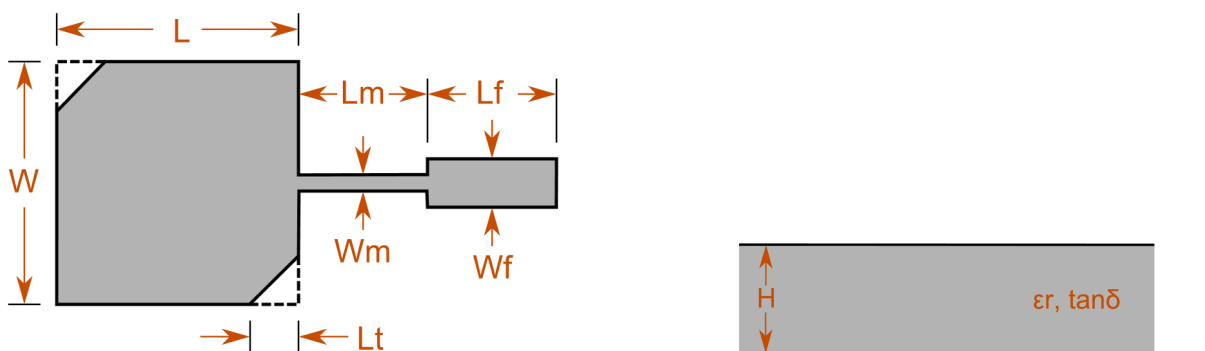


Figure 1. A circular polarized microstrip patch antenna, (left) top view, and (right) side view.

2. DESIGN GUIDELINES

- The centre frequency (resonance) may be increased by decreasing the patch width and patch length. The patch width should be kept equal to the patch length to maintain good circular polarisation.

- The port resistance may be increased by reducing the matching line width, however, care should be taken, since this influences the electrical length of the matching line length.
- Increasing the substrate height will result in a poorer axial ratio. The two truncated corners should always be opposite one another. The position of the truncations will change the handedness of the antenna between LHC and RHC.

Note: Antennas on very thin substrates have high copper-losses, while thicker and higher permittivity substrates may lead to performance degradation due to surface waves.

3. PROJECT PREPARATION

Given: Target frequency f_0 (e.g. 900 MHz or 2400 MHz).

Fixed parameters: Substrate parameters ϵ_r , $\tan\delta$, H . The substrate should be FR4. Thickness ≈ 0.8 mm.

Output: $|S_{11}|$, input impedance Z_{in} , radiation efficiency/gain, resonance frequency f_r , radiation pattern.

STEP 1 — PATCH DESIGN (TOP LAYER)

Task:

- Choose target frequency f_0 (e.g., 2.4 GHz).
- For TM_{10} mode use:
 - $L \approx c / (2 f_0 \sqrt{\epsilon_{eff}}) - 2\Delta L$
 - $W \approx (c / 2 f_0) \sqrt{2 / (\epsilon_r + 1)}$
- Simulate a standalone patch with an ideal slot feed to estimate $|S_{11}|$.
- Design inset feed (W_f , L_f , W_m , L_m) to achieve $|S_{11}| < -10$ dB at f_0 .

Questions:

- Why is $L \approx W$ (square patch) a necessary condition for equal resonant frequencies of TM_{10} and TM_{01} modes?

STEP 2 — CORNER TRUNCATION FOR CP GENERATION

Task:

- Truncate two opposite corners with length L_t .
- Sweep L_t/L .
- Plot Axial Ratio (AR) and $|S_{11}|$ versus frequency.

Questions:

- When L_t increases, does the minimum AR frequency shift upward or downward? Why?

STEP 3 — INSET TUNING FOR AMPLITUDE BALANCE

Task:

- Adjust L_m and W_m (inset length and width) to equalize mode amplitudes.
- Maintain 50Ω feed (set W_f accordingly).
- Target: $|S_{11}| < -10$ dB and AR < 3 dB at f_0 .

Questions:

- Why does L_t mainly affect phase difference while L_m affects amplitude ratio?

STEP 4 — AR BANDWIDTH OPTIMIZATION

Task:

- To broaden the AR < 3 dB bandwidth:
 - Increase H moderately (reduces Q).
 - Optimize L_t for proper Δf .
 - Try rounded or slanted truncations.
- Evaluate AR and $|S_{11}|$ over $\pm 5\%$ around f_0 .

Questions:

- Which design parameter most significantly affects AR bandwidth, and why?

STEP 5 — VERIFICATION OF CP SENSE AND PURITY

Task:

- Simulate far-field radiation along the main beam axis.
- Identify polarization sense (RHCP or LHCP) based on truncated corner orientation.
- Compute RHCP/LHCP ratio (cross-pol) at f_0 .
- Plot AR distribution across the main plane.

Questions:

- If the CP sense is reversed, what simple geometric change can restore the intended rotation?

STEP 6 — ALTERNATIVE CP TECHNIQUES (OPTIONAL)

Task:

- Dual-feed 90° hybrid (no truncation).
- Orthogonal slots on the patch instead of corner cuts.
- Compare AR, matching, and fabrication complexity.

Questions:

- What is the main advantage of single-feed corner-cut CP design compared to dual-feed CP? When is the dual-feed method preferred?

4. FINAL EVALUATION

Acceptance criteria:

$|S_{11}| < -10$ dB across the band, efficiency > 60 %, gain ≥ 6 dBi, dimensions within design limits.

Deliverables: Final geometry table (L , W , L_t , L_m , W_m , H , W_f , L_f). Plots: $|S_{11}|$, gain, Axial Ratio vs f , and RHCP/LHCP patterns. Comparison of simulated and theoretical results. Written answers to all step questions in a report format

5. REFERENCES

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- [3] P.C. Sharma and K.C. Gupta, "Analysis and optimized design of single feed circularly polarized microstrip antennas," *IEEE Transactions on Antennas and Propagation*, vol. AP-31, no. 6, November 1983, pp. 949-955, Section IV.
- [4] R.E. Munson, "Microstrip Antennas", Chapter 7 in R.C. Johnson and H. Jasik (Ed.), *Antenna Engineering Handbook*, Second Edition, 1984.
- [5] P.T. Pussinen & M. Autti, "Patch Antenna for a GPS Receiver", http://oh8ta oulu.fi/palvelut/pdf/GPS-Patch_English.pdf.