Design and Simulation of Circularly Polarized Conical Beam Microstrip Patch Antenna for C Band Applications

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ABSTRACT

A compact circularly polarized microstrip patch antenna(CP-MPA)capable of generating a stable conical beamin the C-band (5.85-6.425 GHz) is presented. The radiatingelement comprises a circular patch with diagonal truncations and four linefed slots to excite orthogonal modes. A partial ground plane and optimized feed position further enhance impedance matching (|S11| < -10 dB) and axialratio bandwidth(AR < 3 dB). Fullwave simulations in CST Studio Suite demonstrate a 28% impedance bandwidth (4.9-6.5 GHz)and 14.4% AR bandwidth (5.8-6.7 GHz), with peak gain of 4.9 dBic and halfpower beamwidth 60 degrees. Such performance makes the design suitable for mobile satellitecommunications and other C-band applications.

1. INTRODUCTION

Microstrip antennas are increasingly favored in modern wireless systems due to their low profile, light weight, and ease of integration with planar circuits. However, they typically suffer from narrow bandwidth and limited gain. Circular polarization mitigates multipath fading and improves link reliability in satellite and mobile communications, especially in the C-band (5.85-6.425 GHz) where many commercial and defense systems operate. Conicalbeam patterns further ensure omnidirectional coverage in azimuth, essential for moving platforms. This work proposes a novel CP-MPA design combining diagonal truncations and linefed slots to achieve broadband circular polarization and stable conical radiation.

1. ANTENNA DESIGN

1.1 GEOMETRY AND SUBSTRATE

The antenna is realized on a 1.6 mm thick FR-4 substrate (e = 2.2, tan = 0.02) with a partial ground plane to enhance bandwidth. The radiating element is a circular copper patch of radius a = 17.39 mm, with four symmetrically positioned rectangular slots of width w = 3.08 mm to generate orthogonal field components. Two opposite diagonal corners of the patch are truncated by L to facilitate mode-phase balance for circular polarization.

1.2 FEEDING AND MATCHING

A 50 microstrip feed line of width Wx = 3.08 mm is connected coaxially at an optimized location (r,) to excite the TM11 and TM21 modes with 90 degrees phase difference. The feed position was determined via parametric sweep in CST, resulting in reflection coefficient |S11| < -10 dB over 4.9-6.5 GHz. A quarter-wavelength inset of length Lx = 8.93 mm further improves impedance matching at the center frequency (4 GHz).

2. SIMULATION METHODOLOGY

Full-wave electromagnetic simulations were conducted using **CST Studio Suite 2021**, leveraging the **time-domain solver** to accurately model the transient behavior of the antenna structure. The simulation utilized **adaptive mesh refinement** to ensure precision in regions with rapid field variation,particularly near the feed and edges of the patch. The antenna was excited using a **waveguide port**, which allowed for accurate characterization of input impedance and the reflection coefficient (S_{11}). Additionally, **open boundary conditions** (often implemented as perfectly matched layers, or PMLs) were applied to emulate radiation into free space, preventing artificial reflections that could distort the results.

Throughout the simulation process, several key **performance parameters** were extracted and analyzed. These included **S-parameters** to evaluate impedance matching, **axial ratio (AR)** to confirm the presence and bandwidth of circular polarization, **realized gain** to assess the directional efficiency, and **3D far-field radiation patterns** to visualize the beam shape and verify the conical nature of the antenna's emission. These results were critical in validating the design's suitability for C-band applications, particularly in satellite and IoT communications where stable circular polarization and wide coverage are essential.

3. RESULTS AND DISCUSSION

3.1 IMPEDANCE BANDWIDTH

The Simulated reflection coefficient shows |S11| < -10 dB from 4.9 to 6.5 GHz, Corresponding to a fractional bandwidth of 28%. the inset feed and a partial ground plane effectively broaden theimpedance response compared to conventional circular patches.

3.2 POLARIZATION BANDWIDTH

The axial ratio remains below 3 dB between 5.8 and 6.7 GHz (14.4% bandwidth), covering the C-band uplink. Diagonal truncations and slot placement ensure equal amplitude and quadraturephase TM modes over this range.

3.3 RADIATION CHARACTERISTICS

At 6 GHz, the antenna exhibits a conicalbeam pattern in the azimuthal plane (phi = 0-360 degrees) with halfpower beamwidth 60 degrees and peak gain of 4.9 dBic. The fronttoback ratio exceeds 15 dB, and the pattern remains stable across the operating band, satisfying mobile satellite requirements.

4. CONCLUSION

A **compact circularly polarized microstrip patch antenna (CP-MPA)** capable of producing conical-beam radiation in the C-band has been successfully designed and validated through simulation. The design employs a circular patch configuration enhanced by **diagonal truncations** and **line-fed slots**, which effectively generate orthogonal modes necessary for achieving circular polarization.

Additionally, the incorporation of a **partial ground plane** plays a critical role in extending the antenna's impedance bandwidth and stabilizing the radiation pattern. Simulation results indicate a **28% impedance bandwidth** and a **14.4% axial ratio (AR) bandwidth**, confirming the antenna's capability to maintain circular polarization across a broad frequency range. These enhancements are vital for ensuring efficient operation within the 5.85–6.425 GHz C-band spectrum.

The antenna exhibits a **stable conical radiation pattern** with a peak gain of approximately **5 dBic**, making it highly suitable for **mobile satellite communication systems**, **aerospace applications**, and **IoT-based telemetry**. Its combination of compact size, polarization purity, and omnidirectional coverage renders it an ideal candidate for real-world deployment in C-band environments where reliability and consistent signal coverage are paramount.

REFRENCES

[1] Adachi, S., & Mushiake, Y. (1957). Directive loop antennas. Res. Inst. Sci. Rep., B9(2), 105- 112.

[2] Kawakami, H., Sato, G., & Wakabayashi, R. (1997). Research on circularly polarized conicalbeam antenna.