

Circularly Polarized Dipole Antenna Incorporated with Metasurface and Cavity Reflector

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The growing demand for high-gain circularly polarized (CP) antennas in satellite communication systems has driven significant research toward achieving wideband and efficient designs. CP antennas are favored over linearly polarized (LP) antennas due to their ability to mitigate polarization mismatches and reduce multipath effects. Among the various approaches explored, metasurfaces emerged as a powerful solution for generating CP waves due to their capability to manipulate polarization through precise amplitude and phase control. Multiple approaches have been explored to enhance the performance of CP antennas using metasurfaces, including Fabry-Pérot designs, which use metasurface polarization converters with an air gap above the LP source. Other methods involve integrating an LP source with either a transmissive or a reflective metasurface polarization converter positioned above or beneath the LP source. However, these designs often face challenges, such as narrow impedance and axial ratio (AR) bandwidths, low radiation efficiency, and bulky profiles. A cavity-backed antenna, incorporating an LP source combined with a polarization converter on the top side, has been investigated to improve AR bandwidth and achieve high gain. Despite their advantages, this design also suffers limitations, including narrow AR bandwidth and increased profile size due to the double-cavity structure.

This paper proposes a novel antenna design to overcome the aforementioned challenges. It incorporates a modified dipole structure with a complementary-shaped LP-to-CP metasurface converter and cavity reflector. The dipole antenna is integrated with two parasitic patches in a coplanar configuration. It is placed at the bottom side of the substrate, while the metasurface consists of four modified square metal plates arranged in a 2×2 layout with a cross stub at the center placed on the top side of the substrate. A modified cavity reflector with truncated corners and triangular extensions is incorporated into the metasurface dipole antenna, which focuses energy in the broadside direction, enhancing gain and efficiency. The proposed antenna achieves a global bandwidth of 49.2% (4–6.64 GHz), satisfying impedance matching, AR, and gain requirements. It achieves exceptional performance, including a wide AR bandwidth of 49.2% (4 to 6.64 GHz), an impedance bandwidth of 68.8% (3.48 to 7.08 GHz), a 3-dB gain bandwidth of 61.1% (3.68 to 6.92 GHz), a peak gain of 10.9 dBic at 5.2 GHz, and radiation efficiency exceeding 92%. The antenna has compact dimensions of $80 \times 80 \times 15.508$ mm ($1.36 \times 1.36 \times 0.26 \lambda_0$ at 5.1 GHz).

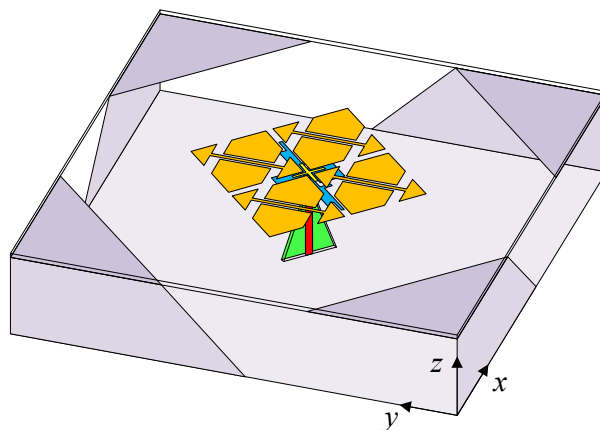


Figure 1. Geometry of the antenna with a cavity reflector and complementary-shaped metasurface.