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Design of circularly polarized hexagonal patch antenna with perturbations in 3D printed substrate

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Abstract

This paper presents the design and implementation of a novel single-fed microstrip hexagonal patch antenna, which operates on 2.4 GHz by employing three-dimensional (3D) printing technologies for circular polarization (CP) with wide 3 dB beamwidth. It was fabricated using a thermoplastic polymer-based material through a 3D printer and subsequently coated with copper. The design of the antenna consists of identical hexagonal slots in mesh grid fashion. These slots are filled with air and perturbations are introduced, by partially filling them with rectangular chunks of the polymer. This produces asymmetry in the substrate layer which leads to the splitting of the degenerate modes of the patch antenna, thus producing CP waves. The presence of volume fraction of air influences the effective permittivity and as a result the axial ratio beamwidth enhances to 176°. The substrate was created as a double layer, lightweight unit using fused deposition modeling. A copper layer was then added to the underside of the lower substrate to serve as ground. The 3D gain of the antenna is found to be 7.01 dB. The proposed low-profile antenna has the potential to be incorporated in IoT and smart devices, intelligent transport systems, and GPS tracking.

Introduction

The gain of a transmitting antenna in a wireless communication system can be increased to expand wireless coverage range, lower error rates, achieve higher bit rates, and require less battery life from wireless communication devices. Aligning the polarization of the transmitting and receiving antennas is a critical component that enhances this gain. To guarantee this kind of polarization alignment, the transmitter and the receiver must have the same axial ratios, spatial orientations, and polarization sensors. However, maintaining constant spatial orientation alignment becomes almost impossible in mobile and portable wireless applications, as devices regularly change positions and orientations. Because the radiated waves oscillate in a circular pattern perpendicular to the propagation direction, circularly polarized (CP) antennas provide an alignment option for a broad range of orientations.

CP microstrip antenna development involves a number of design stages and obstacles. The antenna must first be built to operate at a particular frequency. It then achieves CP by either adding a perturbation segment to a basic single-fed microstrip antenna or using two feeds of the same magnitude but physically 90° phase offset. To ensure that the antenna attains an axial ratio of less than 3 dB at the intended design frequency, the shape and dimensions of perturbation must be optimized.

It has been observed that three different approaches have been used to increase the 3 dB axial ratio bandwidth of patch antennas that are CP. The antenna aperture area is used in the first method [1, 2]. A suspended structure that has a lower effective permittivity to define the radiating area is proposed in [2]. But this architecture is extremely susceptible to mistakes in the installation height of the suspension. Furthermore, this method uses a dual-fed methodology to accomplish CP, requiring a sophisticated supplementary feed network. In order to offset radiation gain at low elevations, the next technique adds more radiation components, such as surface waves [3] and vertical currents [4]. Regrettably, unregulated surface waves have a detrimental effect on the wireless communication system as a whole, and the radiators vertical components result in a design that is high profile. The third is the application of enhanced ground structures, like cavity-backed [5] and three-dimensional (3D) ground configurations [6]. Nonetheless, the high-profile design is the outcome of these nonplanar grounds.