Design and Analysis of a Low-profile Microstrip Antenna for 5G Applications using AI-based PSO Approach

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https://doi.org/10.26636/jtit.2023.3.1368

Abstract — Microstrip antennas are high gain aerials for low-profile wireless applications working with frequencies over 100 MHz. This paper presents a study and design of a low cost slotted-type microstrip patch antenna that can be used in 5G millimeter wave applications. This research focuses on the effect of ground slots and patch slots which, in turn, affect different antenna parameters, such as return loss, VSWR, gain, radiation pattern, and axial ratio. The working frequency range varies from 24 to 28 GHz, thus falling within 5G specifications. A subset of artificial intelligence (AI) known as particle swarm optimization (PSO) is used to approximatively solve issues involving maximization and minimization of numerical values, being highly challenging or even impossible to solve in a precise manner. Here, we have designed and analyzed a low-profile printed microstrip antenna for 5G applications using the AI-based PSO approach. The novelty of the research is mainly in the design approach, compactness of size and antenna applicability. The antenna was simulated with the use of HFSS simulation software.

Keywords — 5G applications, high gain, low profile, microstrip patch antenna, PSO

1. Introduction

A low-profile micro strip or patch antenna (MPA) is created by mounting a metal patch plane over the ground level with a dielectric separator between them. Typically, the feed lines and the radiating patch are manufactured of a dielectric substrate using the PCB process. The patch is often square, rectangular, circular, triangular, or elliptical in shape to meet performance-related requirements. For a rectangular patch, length L of the patch is usually in the $0.33\lambda_0 \ldots 0.5\lambda_0$ range, where λ_0 represents the free-space wavelength. The patch must be very thin, hence the thickness of the copper foil used is less than λ_0. The dielectric substrate's height is in the $0.003\lambda_0 \ldots 0.05\lambda_0$ range, while the dielectric constant ranges between 2.2 and 12.

Due to their small size and low profile, microstrip patch antennas have become increasingly popular in smartphones and other consumer electronics devices relying on wireless communications. The benefits of microstrip patch antennas are in their compact size, simple manufacturing methods, low weight, and easy design. This has led to the replacement of traditional antennas used in mobile devices [1]. Selection of the substrate and determination of the patch proportions depend on the operating frequency and on the specification of the dielectric material used. Significant parameters, such as length and width of the patch and substrate, as well as the location and length of the feed network can be estimated employing equations given in [2]–[5]. The available dielectric materials have their unique conduction characteristics and vary in dielectric constants and other parameters that influence the fringing waves in the antenna patch [2]–[5].

Because of the cost factor, the most popular dielectric materials include bakelite, FR4 glass epoxy, Rogers RO4003, Taconic TLC, and Rogers RT/Duroid [6]–[8]. When feeding the signal to the antenna, many techniques, including proximity-coupled, inset feed, aperture-coupled, as well as coaxial probe feed methods, are used [3]–[4], [9].

2. Related Work

Many researchers have used various feeding techniques in recent years to develop MPAs of various shapes and used them in various applications. Sharma proposed, in [10], a small, high gain multiband antenna with a glass-shaped radiating patch and a rectangular ground plane. A unique rectangular-shaped, DGS-based effective multi-band frequency reconfigurable antenna was proposed by Sathikbasha *et al.* in [11]. A portable multi-band MPA with resonances at 23.9, 35.5, and 70.9 GHz, suitable for 5G mobile applications, was demonstrated by Punith *et al.* [12].

A graphene-packed dual band mmWave antenna for 28.1 GHz and 37.4 GHz with a DC bias was proposed by Luo *et al.* [13]. A tiny, portable ultra-wideband microstrip antenna for 5G applications was developed by Araujo *et al.* [14], while a small and dual-polarized triple-band antenna for sub-6 GHz 5G applications was created by Alieldin *et al.* [15].