Chapter 13
A Dual Band Frequency Reconfigurable Metasurface Antenna

George Shilela Ulomi
University of Dodoma, Tanzania

Hassan Kilavo
University of Dodoma, Tanzania

ABSTRACT

In this chapter, a single feed metasurface antenna with smooth dual-band frequency reconfiguration is proposed. The designed antenna has a simple and compact structure to be used in portable wireless communication devices. The antenna consists of two circular layers of substrate material placed one on top of the other. The lower layer is printed with a rectangular patch antenna in one side, and the other side is a ground plane. The upper substrate layer lay on top of patch antenna side is printed with a number of unit-cells on its upper side. To achieve frequency reconfiguration, the upper substrate layer is mechanically rotated at an angle θz in a clockwise direction along Z-axis. Based on rotation angle, the antenna scattering parameters (S11 and S21) of the unit cell are subjected to change which thereby affects relative permittivity of the upper layer resulting to a frequency reconfiguration.

INTRODUCTION

As the wireless mobile technology focus to offer multiple services located at a different frequency band, the demand for a compact antenna with reconfigurable characteristics is unavoidable. The antenna reconfiguration refers to the ability of the particular antenna to change operating frequency, radiation pattern, polarization or combination of the mentioned antenna characteristics. Even though the use of switches/diodes and variable reactive loads are the most common techniques to archive antenna reconfiguration characteristics, material change and mechanical change can also be used (Christodoulou, Tawk, Lane, & Erwin, 2012). Several researchers demonstrated the use of PIN diodes to achieve reconfiguration

DOI: 10.4018/978-1-7998-6471-4.ch013

feature. By changing states of PIN diode, antennas presented in (Boudaghi, Azarmanesh, & Mehranpour, 2012; Chichang Hung, 2015; Wang et al., 2016) achieved frequency reconfiguration. Moreover, smooth frequency tuning is reported in (Onodera, Saitou, Ishikawa, & Honjo, 2014; Tariq & Ghafouri-Shiraz, 2012) using varactor diodes. On the other hand, antenna proposed in (Majumder, Kandasamy, Mukherjee, & Ray, 2016; Rao et al., 2018; Zhu, Liu, Cheung, & Yuk, 2014) employ mechanical turning to attain frequency reconfigurable feature band. A voltage source is needed to facilitate diodes switching in (Boudaghi et al., 2012; Chichang Hung, 2015; Wang et al., 2016)and to alter the capacitance of capacitors in (Onodera et al., 2014; Tariq & Ghafouri-Shiraz, 2012). One of a common challenge in the proposed reconfiguration techniques is the design of the bias circuit in a way that an electric current flow through it has a negligible effect on antenna performance. Furthermore, diode placement angle has a major impact on the direction of antenna radiation pattern. In order to avoid the effect of d.c bias current to the antenna performance a metamaterial structure can be used to achieve the antenna reconfiguration characteristics. A metamaterial can be defined as an artificial engineered material formed by an array of small unit-cells (scatters) occupied a full 3D space. Due to its compact size, the two-dimensional metamaterial (Metasurface) is commonly used in various antenna application to offer unique characteristics of negative permittivity and permeability which are not found in nature but physically feasible (Caloz & Itoh, 2006; Nader & Richard, 2006).

The use of metamaterial to attain frequency reconfiguration is reported in (Cheribi, Ghanem, & Kimouche, 2013; Majumder et al., 2016; Mirzaei & Eleftheriades, 2011; Rao et al., 2018; Yue, Member, Jiang, Panaretos, & Werner, 2017; Zhu et al., 2014). Furthermore, (Majumder et al., 2016) demonstrated the use of dual metasurface layers to achieve dual band frequency reconfiguration. The proposed metasurface layers are printed with the same unit-cell(periodic) structure. To achieve reconfiguration at different frequency band, metasurface layers are rotated in opposite direction to one another. The proposed antenna has dual metasurface layers of 3.06 mm thick, source antenna substrate material of 1.53mm thick and diameter of 20mm. For a mobile handled devices, a more compact structure is desirable. In order to achieve a compact antenna size, a dual-band frequency reconfigurable antenna design using a single metasurface layer is proposed and presented. Though the technique to achieve frequency reconfiguration presented in this paper follows the same procedure as in (Zhu et al., 2014), to the best of authors' knowledge, there is no any other proposed antenna that use similar compact design to attain smooth frequency tuning between two frequency bands. The proposed antenna structure has metasurface layer of 1.53mm thick, source antenna substrate material of 1.53mm thick and diameter of 20mm. To attain the compact size and low profile, the gap between two metasurfaces is eliminated by allowing direct contact of two substrate materials. Both substrate layers are of the same dimension for easy fabrication and mechanical rotation.

Following the introduction of Section 1, this paper is organized into five sections. Section 2 presents the structural details of unit-cell design and analysis. The design and simulation of the metasurface antenna are presented in Section 3. In section 4, simulations results of the proposed antenna structure are presented and the conclusion is drawn in section 5.

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