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DUAL-BAND MONOPOLE ANTENNA WITH OMEGA PARTICLES FOR WIRELESS APPLICATIONS

M. A. Abaga Abessolo[1, *], A. El Moussaoui[2], and N. Aknin[1]

[1]Information and Telecommunication Systems Laboratory, Physical Department, Faculty of Sciences, Abdelmalek Esaadi University, BP 2121 Tetuan, Morocco

[2]Faculty of Sciences, Abdelmalek Esaadi University, BP 2121 Tetuan, Morocco

Abstract—A new design of dual-band antenna for DCS/PCS/UMTS/WLAN/WiMAX applications is proposed. Using two metamaterials omega-shaped structures, a good impedance matching the dual-band mode is obtained. The proposed prototype antenna is fabricated on a 1.5 mm thick FR4 epoxy substrate with a relative dielectric permittivity $\varepsilon_r = 4.4$ and a loss tangent $\tan\sigma = 0.02$. Good monopole-like radiation patterns and antenna gains over the operating bands have also been observed. Effects of each omega particle on the antenna performance and their coupling are all examined and discussed.

1. INTRODUCTION

Multiband operations of wireless communication systems have been developed rapidly, increasing the need for low-profile, low-cost, multiband antennas for mobile terminals. Modern mobile equipments are often required to operate at multiple frequency bands to facilitate the application for various communication needs. Thus, many antennas with broadband and multiband functionality, monopole antennas, planar antennas and slot antennas, have been described in recent years [1–5]. Printed antennas with moderate radiating characteristics can be operated at multiple frequency bands. They support dual-band operation in the wireless local area network (WLAN) communication systems [1–3]. However, in other antenna designs, a slot patch and a broad ground plane are

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* Corresponding author: Michel Audrey Abaga Abessolo (michelabaga1@yahoo.fr).

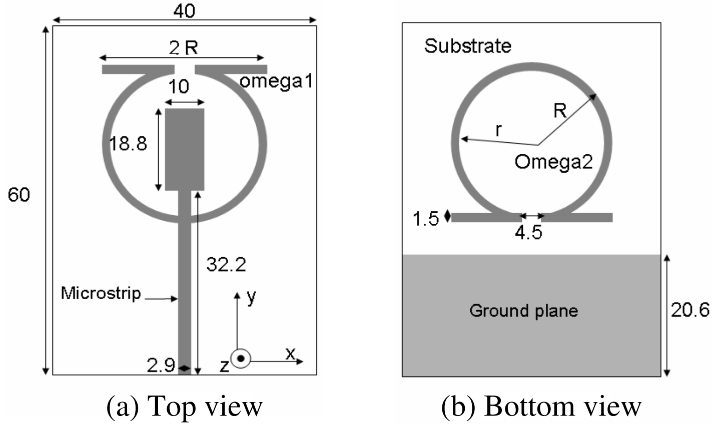
required for broadband and multiband systems, including the digital communication system (DCS), the personal communication system (PCS), the universal mobile telecommunication system (UMTS) and the 2.4- and 5-GHz WLAN bands. [4, 5]. Also, antenna with a novel tuning branch protruding from the resonant branch [6] and a loop antenna comprising a folded uniform loop strip attached on a foam base with a tuning pad connected to the loop strip [7] are proposed for multiband operations.

This paper presents a new design of a miniaturized dual frequency band antenna for DCS (1710–1880 MHz), PCS (1850–1990 MHz), UMTS (1920–2170 MHz), WLAN (2400–2484 MHz) and WiMAX (2500–2690/3400–3600 MHz) applications. It is accomplished by using two omega particles, the first one printed on the top and the second on the bottom side of the monopole antenna. The omega particles are used for their metamaterials properties characterized by an ability to focus the electromagnetic wave [8] and to improve antenna's performances [9–11]. In [10], it is shown that by implementing omega-like elements and split-ring resonators into the design of an antenna for an UHF RFID tag, the overall size of the antenna can be significantly reduced to dimensions of less than $0.15\lambda_0$, while preserving the performance of the antenna. Metamaterials are artificially structured materials providing electromagnetic properties that not encountered in nature. The electrodynamics of hypothetical materials having simultaneously negative permittivity and permeability in the same range frequency were first theoretically predicted by Veselago [12]. In 1999, Pendry et al. proposed a first artificial negative magnetic permeability resonant particle referred as split rings resonator (SRR) [13] and a left-handed material that was first implemented in a two dimensional periodic array of split ring resonators and a long wire strips by Smith et al. in 2000 [14]. Three new structures were proposed in 2005, starting with a symmetrical ring structure, then an omega structure, and finally an S structure [15].

The proposed antenna with a simple structure can be implemented easily and provides improved impedance bandwidths for practical application. The paper is organized as follows: Section 2 describes the dual frequency bands antenna, Section 3 presents the results of a prototype of the new antenna and Section 4 presents the main conclusions of this work.

2. ANTENNA DESIGN

Figure 1 presents the geometry of the proposed antenna. The radiating element is composed by a rectangular patch and two omega particles.



(a) Top view (b) Bottom view

R=18; r=16.5

Figure 1. Configuration of the proposed antenna (Unit: mm) 21.6.

The size of the rectangular patch is 18.8 mm × 10 mm, the outer and inner radiuses of the two omega particles are respectively 18 mm and 16.5 mm. The proposed prototype antenna is fabricated on a 1.5 mm thick FR4 epoxy substrate with relative dielectric permittivity $\varepsilon_r = 4.4$ and loss tangent $\tan\sigma = 0.02$. It can be seen from Fig. 1 that the rectangular patch, the omega1 particle and the feed line are printed on the top side of substrate, while the omega2 and a rectangular ground plane placed under the omega1 and the feed line are, respectively, printed on the bottom side of substrate.

3. SIMULATION AND EXPERIMENTAL RESULTS

Based on the design considerations given in Section 2, we used CST Microwave Studio software based upon the Finite Difference Time Domain (FDTD) method to design and optimize the antenna. The measurement was conducted with the sampling scopes designed by Geozondas Ltd. which uses Time Domain measurement (TDM). The TDM allows eliminating the reflections from adjacent objects using sufficient time window. Therefore it is possible to carry out TDM indoors without anechoic chamber. The proposed antenna was fabricated and tested at the Faculty of sciences of Tetuan, and the prototype is shown in Fig. 3.

The antenna performance was investigated by both simulation and measurement. In order to provide design criteria for the proposed antenna, the effects of omega particles are analyzed. Fig. 4 presents

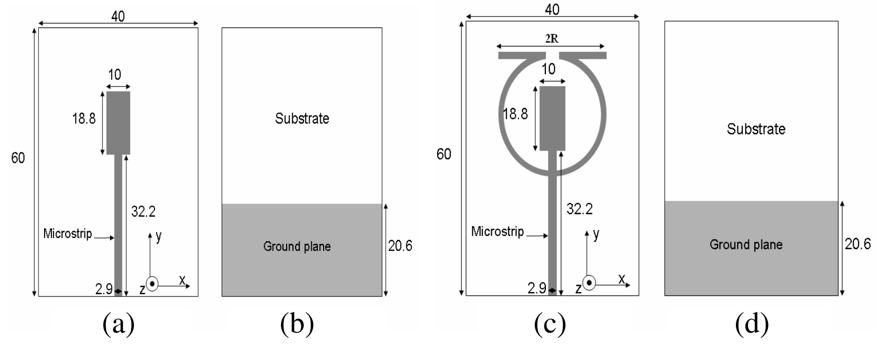


Figure 2. Geometry of antenna1 (without omega) and antenna2 (with omega1). (a) Top view antenna1. (b) Bottom view antenna1. (c) Top view antenna2. (d) Bottom view antenna2.

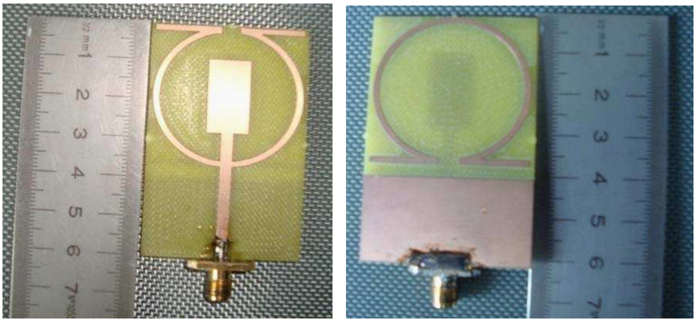


Figure 3. Illustration of the fabricated prototype antenna: left picture refers to the top view of the designed antenna whereas the left one is the bottom view.

the design flow of this proposed antenna, beginning with only a single rectangular radiating patch (antenna1 in Fig. 2), whereby a single lower resonant frequency of around 1.5 GHz (mode 1) is initially observed from the simulation. By loading the omega1 on the top of antenna (antenna2 in Fig. 2), an additional upper resonant frequencies at around 2.8 GHz (mode 2) is excited due to the 1/4 wavelength current distribution along omega1. The antenna2 can also generate a quarter-wavelength mode (mode 3 as shown in Fig. 4) at 4.9 GHz. The second resonance of Antenna2 is the consequence of physical properties that characterized Omega particle metamaterials. Therefore, to be able to operate in the DCS/PCS/UMTS/WLAN and WiMAX bands with sufficient bandwidth, we embed parasitic coupling omega2 on

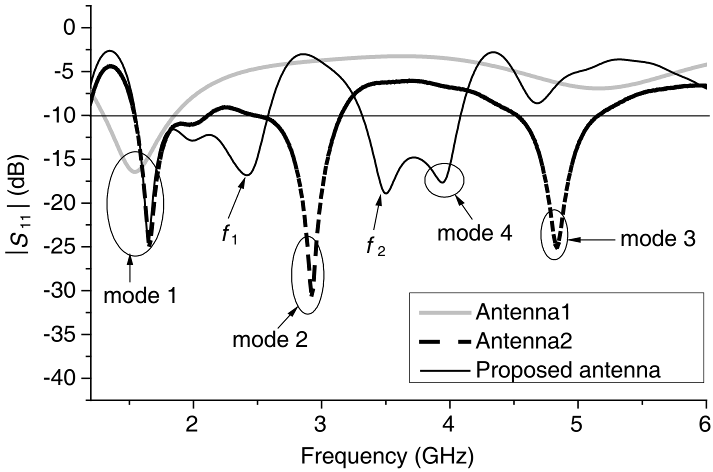


Figure 4. Simulation return losses for various configurations of antenna.

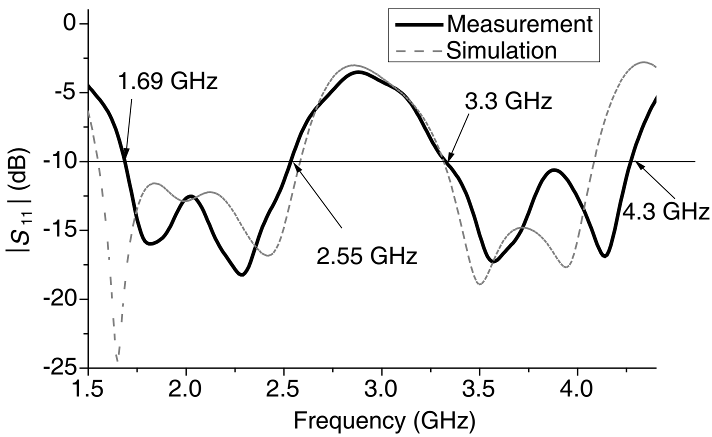


Figure 5. Simulated and measured return losses of proposed antenna.

the bottom side of antenna. Indeed, the loading of omega2 causes a slight shifting of the second and third resonant frequencies (mode 2 and mode 3), 2.8 GHz and 4.9 GHz, to the lower band at 2.4 GHz (f_1) and 3.5 GHz (f_2), respectively. Furthermore, omaga2 shifts two frequencies generating a quarter-wavelength mode (mode 4).

Figure 5 shows the measured and simulated return loss for the fabricated antenna. In this study, the lower band, a wider bandwidth is obtained, that reaches 860 MHz (1.69 GHz–2.51 GHz) and

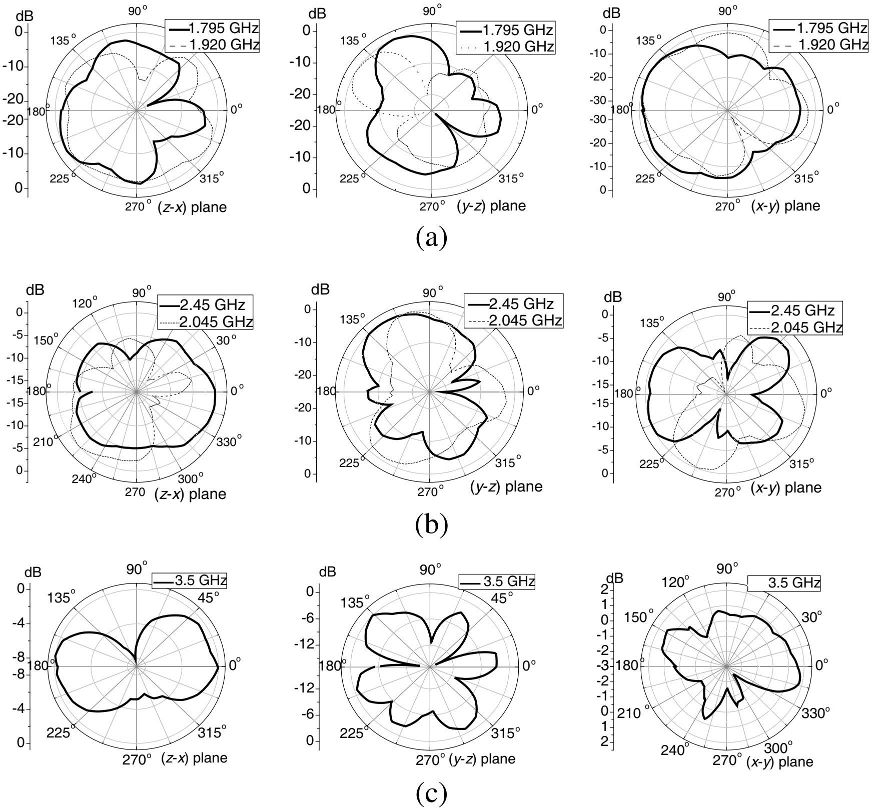


Figure 6. Measured directivity pattern of the proposed antenna: (a) 1.795 GHz and 1.920 GHz, (b) 2.045 GHz and 2.45 GHz, (c) 3.5 GHz.

satisfies the operating bandwidth of DCS/PCS/UMTS band (1710–2170 GHz), WLAN (2400–2484 MHz) and WiMAX (2500–2690 MHz). For the upper band, we also obtained a wider bandwidth that reaches 1000 MHz (3.3 GHz–4.3 GHz) and satisfies the operating bandwidth of WiMAX (3400–3600 MHz). We observed a good agreement between the measured data and the simulated results obtained by using Computer Simulation Technology (CST microwave studio).

Figures 6(a) to 6(c) show the measured directivity patterns at 1.795 GHz, 1.920 GHz, 2.045 GHz, 2.45 GHz and 3.5 GHz, which are centre frequencies of the DCS, PCS, UMTS, WLAN and WiMAX bands, respectively. Very monopole-like radiation patterns with nearly omnidirectional radiation in the azimuthal plane (z-x) of Fig. 6(a) and Fig. 6(b) are observed. The measured peak gains for frequencies

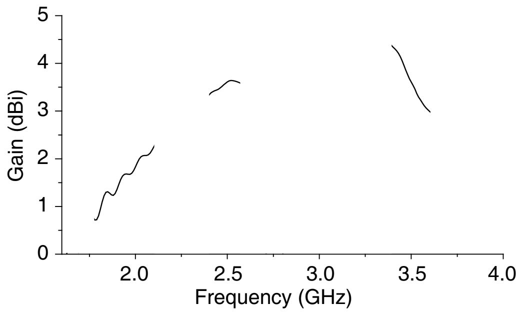


Figure 7. Measured antenna gains of the proposed antenna for frequencies across the 1.8, 1.9, 2.45, 2.6, and 3.5 GHz.

across the operating bands are depicted in Fig. 7. On average, 1.5 dBi (1.8 GHz), 2.2 (1.9 GHz), 3.5 dBi (2.45 GHz) and 3.5 dBi (3.5 GHz) can be achieved.

4. CONCLUSION

We have designed and implemented a compact dual-band internal antenna by combining a monopole antenna with two omega particles. The proposed antenna generates resonant modes covering the multi-operation bands for DCS/PCS/UMTS/WLAN and WiMAX operations. In spite of very small volume, good radiation patterns as well as wide bandwidth characteristics over the entire operation bands have been observed.

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