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Microstrip Sierpinski fractal carpet for slot antenna with metamaterial loads for dual-band wireless application

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ABSTRACT

The compact microstrip antennas with the dual-band characteristic and reconfigurable qualification have been noticed and investigated in this paper. We have developed the slot microstrip antenna with Sierpinski carpet and Minkowski formations and then the metamaterial loads are placed on this antenna in the slot area. The reflection/transmission method has considered to obtain the permittivity and permeability of the split ring resonator (SRR) as a metamaterial. Finally, we show that by using some junction in the metamaterial layer, we can obtain reconfigurable characteristic. Both antennas have dual-band characteristic where the first antenna has two resonances at 3.2 and 4.5 GHz and in the second antenna by altering the metamaterial layer both resonances are occurring at 3.5 and 5.8 GHz. We show that the antenna has two resonance frequencies that matched with the metamaterial Double Negative (DNG) characteristic. Both antennas are printed on FR-4 also we compared measurement and simulation results together. Aforementioned antennas cover the main wireless, WiMAX and LTE bands with sufficient gain and high efficiency (more than 80% typically) with a bi-directional radiation pattern for the indoor application. Here, the metamaterial is used for controlling the resonances and Sierpinski carpet is developed for matching.

1. Introduction

One of the most important parameters in modern communication systems and microwave components with high performance and small size is the dimensions of the systems which have been noticed recently. In particular microstrip components because of their light weight and small size are noticed and developed [1]. Despite these improvements, miniaturization of components microstrip remains a challenge and for miniaturization of the microstrip various methods have been developed during past decades such shortening pin [2], fractal formation [3] and metamaterial techniques [4]. For wireless application in laptop and cell phones [5], the requests for compact antennas for deference IEEE protocols such as 802.11a/b/g [6] and other protocol such as LTE [7], Wi-Fi [8] and Bluetooth [9] simultaneously at a one package is increased too fast therefore, the metamaterial and fractal methods are considered too much than other techniques [10–12]. Exactly, the metamaterial are shown special characteristic which cannot find in nature [13]. We should obtain these qualifications artificially [14] by some changing in the physical formation of the metal parts for manipulating the electromagnetic [15], these changes are resulted negative permittivity or permeability [16] which are used for various applications in antenna and microwave devices such as multi band [17] and miniaturization [18]. On the other hand, the fractal techniques are studied in various shapes such as Koch for WLAN [19], Sierpinski for dual band application in PIFA [20] or other stack models [21,22], snowflake for dual band application with metamaterial load [23], Minkowski loop antenna with metasurface [24], and other form [25] which are made based on self-similar shape and repetition.

Additionally, the metamaterial have been noticed in various models and for obtaining the permittivity and permeability of the metamaterial layer different techniques such as Nicolson- rose [26], and reflection/transmission methods have been developed based on two ports ana-

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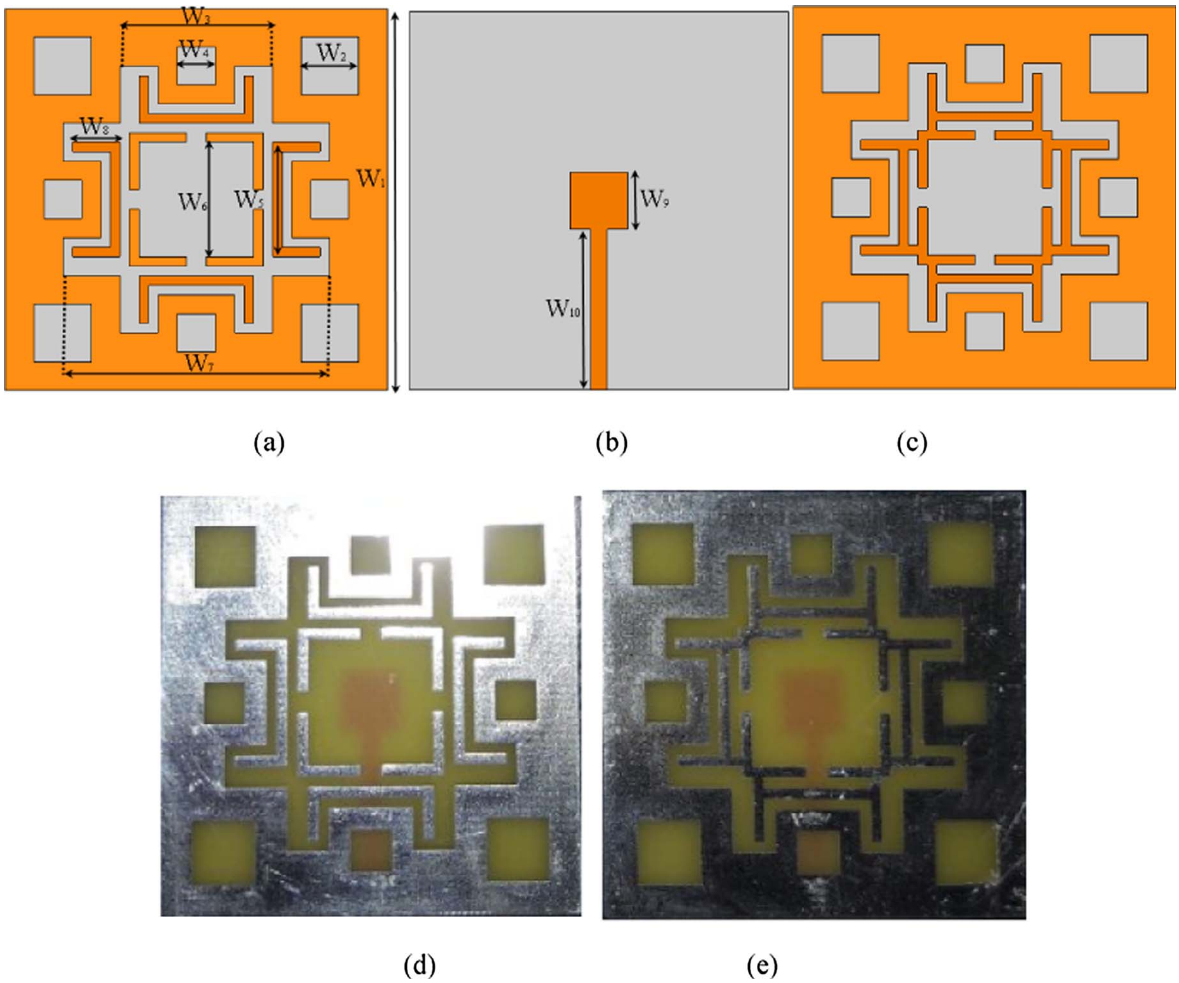

Fig. 1. The designed antenna (a) the geometry of the first antenna (b) the geometry of feed line for both antennas (c) the geometry of the second antenna (d) the first prototype model of the fabricated antenna (e) the second prototype model of the fabricated antenna.

lyzing [27].

The Sierpinski is one of the famous models for fractal antenna based on triangular [20,22], rectangular [28], circular [21] and hexagonal [29] slot in metal layer. In this paper, we have developed a rectangular slot antenna based on Sierpinski model and we have made Minkowski formation for main slot and combined both methods. On the other hand, the metamaterial loads are added to the structure for miniaturization and improve the antenna matching. Moreover, the reconfigurable antennas have attractive for energy saving in microwave systems [30] and in the second suggested model, the metamaterial load is made by some junction at the first metamaterial. We show that these two models can be noticed as a reconfigurable antenna for wireless application. Both final models are fabricated and the experimental results are confirmed simulations. We have checked the effect of the metamaterial layer on return loss and current distribution and the transmission/reflection techniques is used to obtain the permittivity and permeability of the metamaterial layer.

2. The antenna design

The microstrip slot antennas have been developed in various shapes and models of the grounds slots. Because of wider bandwidth which is oriented from the coupling structure these types of antenna get more attention recently. The slot antenna with rectangular Sierpinski fractal structures are developed in this paper and the metamaterial layer is placed in the center part of the slot, here we show that main resonances are obtained by metamaterial layer, and the fractal Sierpinski has used for improving the antenna bandwidth and matching and the Minkowski fractal has used for a main slot to increase the effective area of antenna and the effective length of the metamaterial layer to achieve higher bandwidth.

The geometry of the basic antenna is presented in Fig. 1(a) and a kind of T-shape microstrip line feeds is proposed for prototype antenna, it is connected to the 50-Ω SMA connector as shown in Fig. 1(b). The second type of the metamaterial loaded antenna is shown in Fig. 1(c) where the eight junctions are making a new kind of left hand material.

The both fabricated antennas are presented in Fig. 1(d) and (e). The prototype antenna is printed on a FR-4 low cost substrate with