

Small Multi-Band Rectangular Dielectric Resonator Antennas for Personal Communication Devices

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Article Info

Article history:

Received Sep 30, 2013
Revised Nov 5, 2013
Accepted Nov 20, 2013

Keyword:

Dielectric resonator antenna
Multi-band antenna
Quad-band antenna

ABSTRACT

The design of a novel rectangular dielectric resonator antenna (DRA) for multi-band application has been presented in this paper. The presented antenna has been composed of very low cost and relatively low dielectric constant substrate materials while three-segment thin dielectrics with different sizes have been used and separated by two metal plates in order to set the four different frequency bands. The proposed quad-band antenna operates at 2.4/3.5/5.2 & 5.8 GHz. The radiation pattern, gain and VSWR of this antenna show very good operation for this antenna in all frequency bands. The first method based on finite element method (FEM) and the second one based on finite integral technique (FIT) have been used to analyze antenna structure, and subsequently the Genetic Algorithm (GA) has been applied by using HFSS simulator to obtain the optimized parameters.

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1. INTRODUCTION

Need for compatibility with microwave integrated circuits (MICs) has resulted in development of antennas that can be embedded into wireless products [1, 3]. Reducing the number of antenna has been strongly required because of the physical limits for Installation space. Since the last two decades two classes of antennas i.e., the microstrip patch antenna and the dielectric resonator antenna have been under investigation for modern wireless applications. The DRA is an open resonating structure, fabricated from a low loss microwave dielectric material and have several merits including high radiation efficiency, flexible feed arrangement, simple geometry, and compactness [4].

To obtain a reasonable antenna size in such bands, very high dielectric constant would be required, thus resulting in an unacceptable reduction in bandwidth [5]. As the dielectric constant increases, in fact, the Q of the antenna increases as $\epsilon_r^{3/2}$, leading to very narrow band behavior [6]. Further reduction in volume can be achieved by using metalized face(s) of DRAs. Furthermore, investigations carried out by [7, 8] showed that by using an extra metallic plate in a conventional DRA, which acts as an electric wall, the size of the DRA has been reduced approximately by half. Also it was shown in [6, 9] that by covering the top surface of the rectangular DRA with a metallic patch, the resonant frequency can be reduced by 10%. It is very clear that rectangular DRAs offer more design flexibility because two of the three of its dimensions can be varied independently in order to fix resonant frequency with known dielectric constant of the material.

On the other hand, in recent years, the global success of wireless communication has increased frequency spectrum demands such as Blue-tooth, WIFI and WIMAX. In most of these systems, small terminals and base stations have to work simultaneously with more than one frequency band, therefore multi-band antennas are required [10, 11].

In this paper, a new rectangular dielectric resonator antenna is presented for low VSWR and Omni-directional operation in four frequency bands. The proposed antenna is composed of three rectangular

sections with different size which are separated by two metal plates. The proposed arrangement emphasizes the multi-band operation of DRAs and also tries to design DRAs that are sufficiently compact and in addition have proper impedance bandwidth for use in wireless communications.

2. THE PROPOSED METHOD

Figure 1(a) and 1(b) show the geometries of the proposed DRA. The proposed antenna is designed on a FR4 substrate with thickness of $h=1.6$ mm and relative permittivity of 4.4. An open circuit microstrip line is considered as a feed-line to excite the DRs whereas the width and length of this feed line are w_f and l_f , respectively as shown in Figure 1. The dielectric constants for all the DRs are chosen to be the same ($\epsilon_r=11.9$). Also, three different stubs connected to this feed line in three different situations to tune and increase the bandwidth of the desired frequency bands. This antenna is designed to cover the frequency range of 2.400-2.483 GHz (WLAN), 3.30-3.69 GHz (WiMAX), 5.150-5.350 GHz and 5.725-5.825 GHz (WLAN).

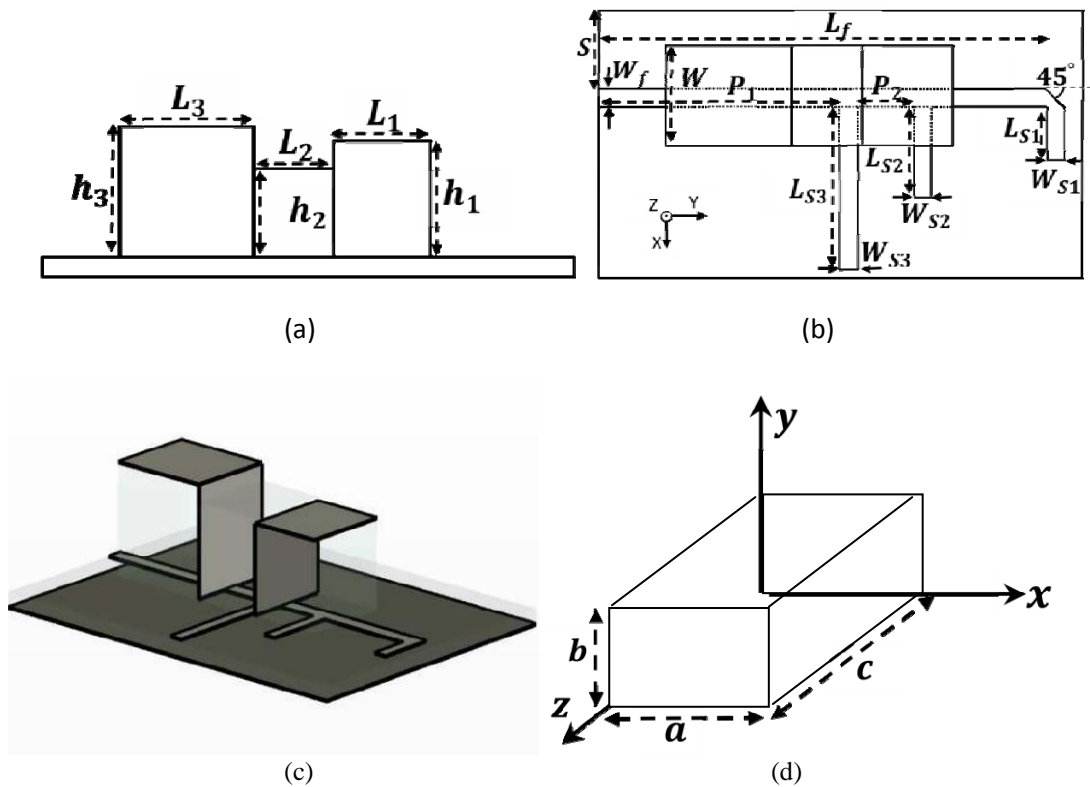


Figure 1. The geometry of the proposed multi-band DRA (a) Side view (b) Top view (c) Metalized plates (d) Dielectric Guide

As shown in the Figure 1(c) there are two metal plates on top of the first and third DRs. Actually we investigated the use of metallic sheets on the top surface of the DRA in order to make the antenna more compact [8]. On the other hand, the use of the vertical metal plate can be compared to the shortening post used in patch antennas to reduce their length from $\lambda/2$ to $\lambda/4$ [7] (This idea was our initial idea in order to design the new DRA). As is well known, the dielectric waveguide, having a rectangular cross-section of width a in the X-direction, height b in the Y-direction and the waves propagating in the Z-direction (Figure 1(d)). The lowest order mode of the rectangular DR that is commonly used is the TE_{111} mode. After solving boundary condition at the surfaces of the DR, the following equations are obtained for the wave-numbers and the dominant mode resonance frequency [6].

$$K_x^2 + K_y^2 + K_z^2 = \epsilon_r K_0^2$$

$$f_0 = \frac{c}{2\pi\sqrt{\epsilon_r}} \sqrt{K_x^2 + K_y^2 + K_z^2}$$

$$K_x = \frac{\pi}{a}, K_y = \frac{\pi}{b}, K_z \tan\left(\frac{K_z d}{2}\right) = \sqrt{(\epsilon_r - 1)K_0^2 - K_z^2}$$

Where K_x , K_y and K_z are the wave numbers along the x, y, and z, respectively. The initial dimensions of the proposed antenna were determined using the above equations developed for a rectangular resonator in free space. Then the appropriate dimensions of the DRA were determined with trial optimization. The values of the design parameters are as follows: $W=8.86$, $L_1=8.01$, $L_2=6.75$, $L_3=11.77$, $h_1=10.00$, $h_2=8.00$, $h_3=12.40$, $L_{s1}=5.86$, $L_{s2}=8.27$, $L_{s3}=15.30$, $P_1=22.81$, $P_2=2.66$, $W_{s1} = W_{s2} = W_{s3} = W_f=1.44$, $S=7.29$, $L_f=42.05$ mm.

3. RESULTS AND DISCUSSION

The proposed antenna was simulated using Ansoft HFSS based on finite element method (FEM). Likewise, the simulation results were confirmed using CST Microwave Studio 2009 which is based on finite integral technique (FIT). A plot of the return loss for the proposed antenna versus frequency is provided in Figure 2(a). This figure shows that our proposed antenna can fully cover the frequency band of 2.400-2.483 GHz (WLAN), 3.30-3.69 GHz (WiMAX), 5.150-5.350 GHz and 5.725-5.825 GHz (WLAN). Obviously, good agreement between HFSS and CST has been obtained. Also the peak gain variations for all the operating bands of the proposed antenna are depicted in Figure 2(b). The agreement between the results of HFSS and CST is quite good. Figure 2(c)-2(f) show the current distribution on the metal plats and stubs.

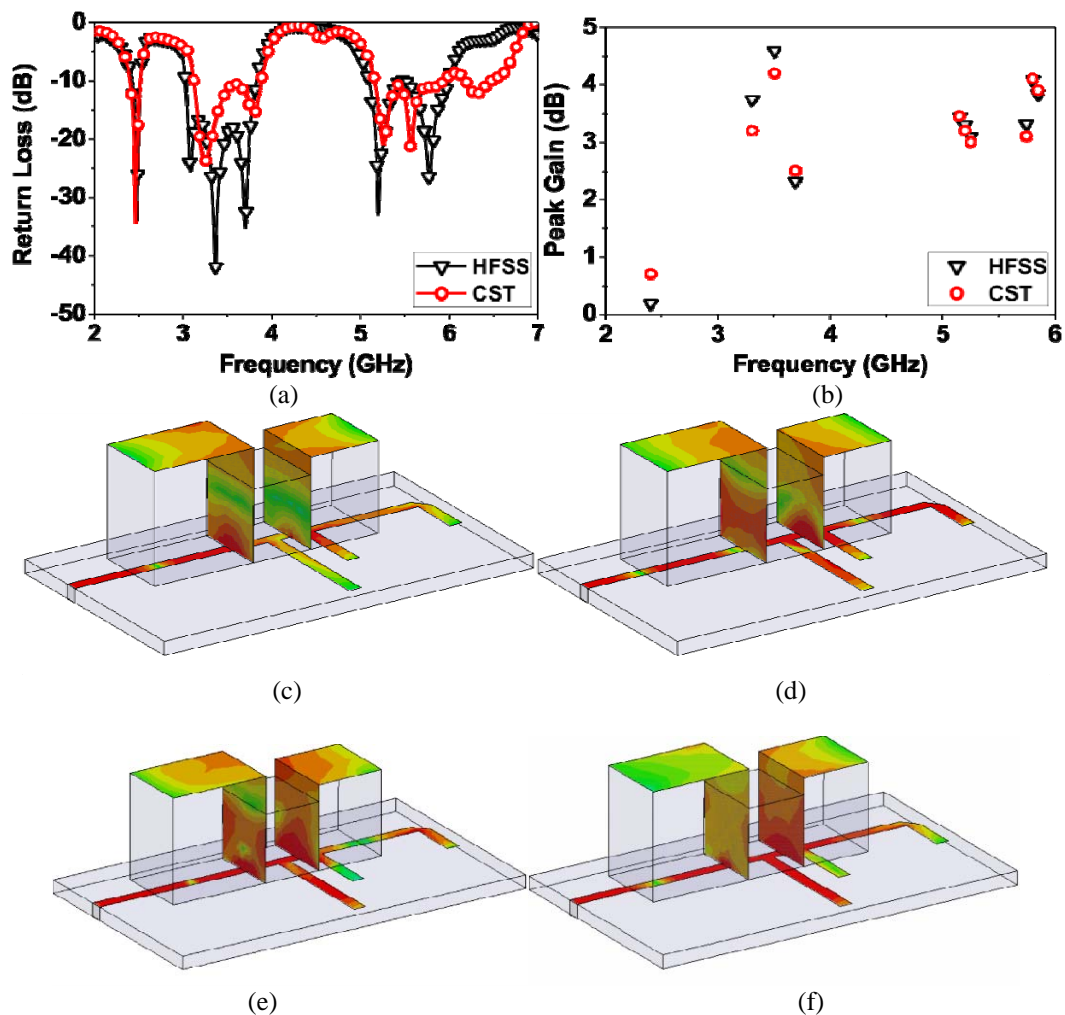


Figure 2. (a) Return loss (b) Peak gain of the propose dielectric resonator antenna and Simulated surface current distribution on the metal plats and stubs at (c) 2.44 GHz (d) 3.50 GHz (e) 5.20 GHz (f) 5.80 GHz.

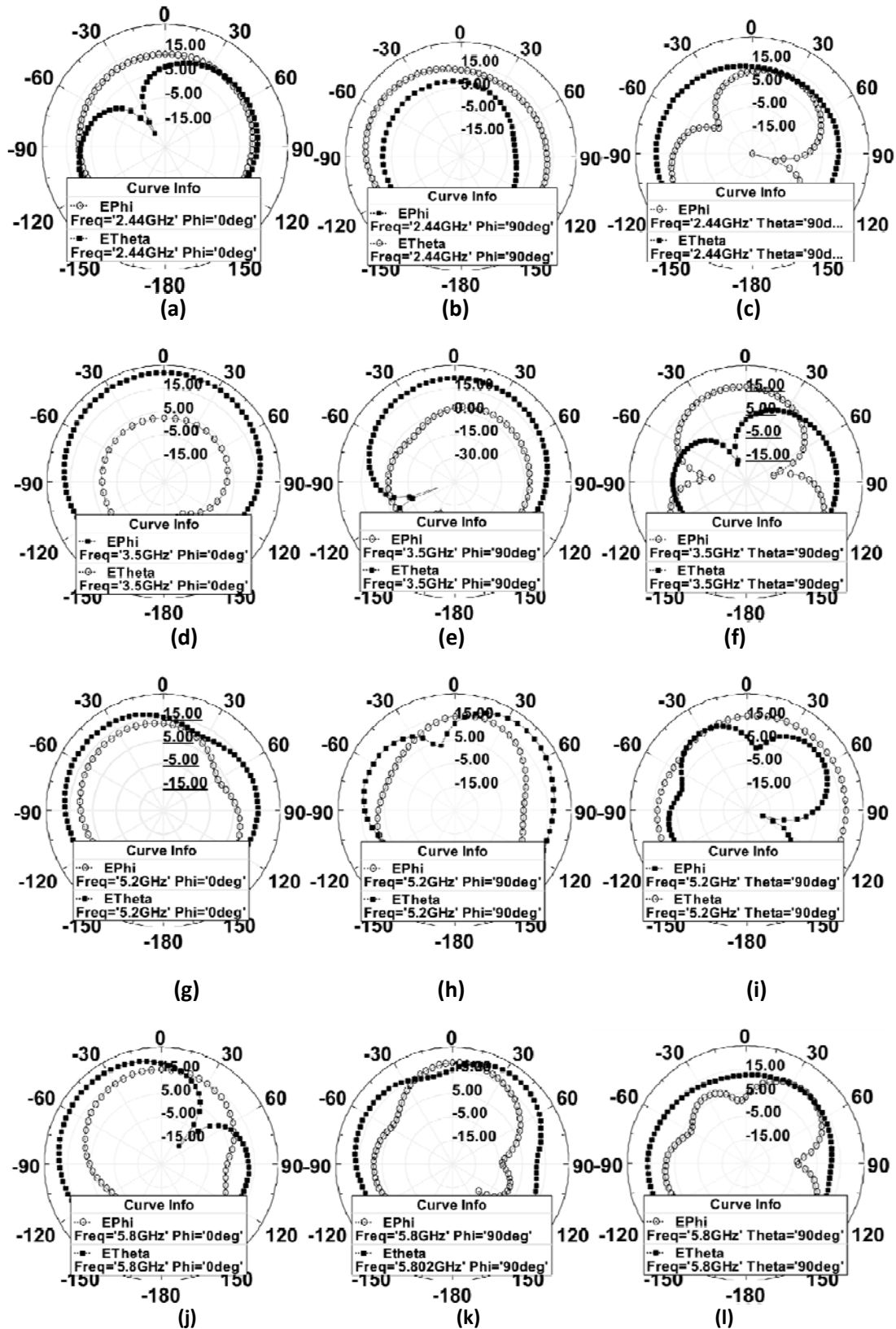


Figure 3. Radiation patterns of the proposed antenna at (a)-(c) 2.44 GHz (d)-(f) 3.50 GHz (g)-(i) 5.20 GHz (j)-(l) 5.80 GHz.

The radiation characteristics of the designed multi-band dielectric resonator antenna were also studied. Figure 3 presents the radiation characteristics of the proposed antenna at three principal planes for four frequency band. Because the radiation patterns for each operating band are generally similar, it indicates that stable radiation patterns are achieved over the frequency bands. In all frequencies, a near omnidirectional pattern is observed.

4. CONCLUSION

The presented multi-band rectangular dielectric resonator antenna covers the required operating frequency bands for internet services such as WLAN 2.4/5.2 & 5.8 GHz and WiMAX 3.5 GHz. This antenna has been simulated using HFSS. The results of HFSS were confirmed by CST commercial software. The return loss of the antennas shows the good operation of antenna in all the above bands. It is observed that the radiation patterns of this antenna in all operating bands and in all planes are quasi-omnidirectional. Also, this antenna has a nearly stable radiation patterns over the operating bands, thus, this antenna is extremely suitable for wireless communication devices.

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Hemn Younesiraad was born in Iran in 1985. He received the BS and MS degrees in electrical engineering from the University of Tabriz, Tabriz, Iran, in 2010 and 2012, respectively. His research interests include antenna and radio wave propagation, metamaterial structures, dielectric resonator antennas, composite right and left-handed structures and negative-refractive-index transmission lines.



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