Compact Dual-Band Dielectric Resonator Antenna

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1. Introduction

The dielectric resonator antenna (DRA) [1, 2] has been of interest due to their low loss, high permittivity, light weight and ease of excitation. In addition, wide bandwidth, low dissipation loss at high frequency, and high radiation efficiency due to the absence of conductors and surface wave losses are inherent advantages of DRAs. In the past few years, theoretic and experimental investigations have been reported by many researchers on DRAs of cylindrical, rectangular, and hemispherical shapes [1-15]. The use of dielectric resonators in feeding circuits requires accurate knowledge of the coupling between the resonator and circuits. In order to match the DR to the feed line and to excite the desired mode in the resonator, the most common method of feeding techniques is aperture-coupled arrangement [3-5]. Recently, hybrid dielectric resonator antennas have attracted extensive attentions due to their dual-band and wideband operation without increasing antenna volume. The hybrid structure can be considered as the combination of a DRA and another radiating resonator of the resonant feeding structure. These two radiating resonators are tightly stacked together and resonate at different frequencies. By arranging for the radiating resonators' position, a compact dual-band [6-9], wideband [10-13] or frequency tunable [14, 15] hybrid DRA can be designed. However, the resonant feeding structure adopted in these reported designs such as microstrip-fed aperture-coupled, loop slot or CPW-fed slot arrangement offer more flexibility and is directly compatible with different mounting surfaces.

In this letter, in order to avoid via holes and for ease of fabrication, the microstrip line feed to DRA is adopted as shown in Fig. 1. The DRA is operated in its fundamental HEM_{11} mode, and it is used as the parasitic c-slot feeding structure at the same time. It will be fond that by varying the size of the parasitic c-slot, the operating frequency of the slot mode can be adjusted easily. This design has the advantage of simple structure, compact size and can achieve dual-band with different radiating patterns. These proposed DRA is suitable to be mounted above the system circuit board of the mobile communication device, and are very suitable for application in mobile communication systems.

2. Antenna Structure

The proposed dual-band DRA structure is shown in Fig. 1. It consists of a circular disk DR and a center-fed microstrip line which is printed on an FR4 substrate of thickness h = 1.6 mm and relative permittivity ε_r = 4.2. The ground plane is printed on the FR4 substrate with dimension of $L \times W$ (40 × 40 mm^2). The DRA has diameter of D = 14.8 mm, height of h_d = 3.3 mm and a relative permittivity of ε_d = 25, its $HEM_{11\delta}$ resonance mode can be excited for the aspect ratio ($2h_d/D$) less than unity [2]. The center point of DR is placed above the center line of the ground plane with an offset distance S_1 which is used to adjust the coupling energy between the microstrip-fed line and dielectric resonator. The 50-Ω feeding line has a length of L_f = 18.5 mm and a width of W_f = 3.0 mm. In this letter, a new approach that utilizes a parasitic c-slot etched in the ground plane is investigated experimentally. The c-slot consists of three parts of rectangular slot of length L_1, L_2, L_3, and a fixed width of W_s = 0.5 mm. The center point of c-slot is fixed to half of ground plane and kept constant (S_2 = 20 mm). The total length of the perimeter of the c-slot resonates at approximately one guide wavelength ($\approx \lambda_g$) where λ_g is the guide wavelength of the c-slot with DR placed on it. In addition, the c-slot dimension was found to be effective in controlling the resonant frequency of the slot mode. In order to reduce experimental cut-and-try design cycles, the simulation software HFSS is used to guide fabrication. By carefully adjusting the c-slot dimension, the proposed antenna can operate in two bands and good impedance match for the operating frequencies can easily be obtained.

3. Experimental Results and Discussions

Based on the optimized parameters, an antenna prototype was fabricated and measured as shown in Fig. 2. The optimal design parameters are: ε_d = 25, h_d = 3.3 mm, D = 14.8 mm, S_1 = 22 mm, S_2 = 20 mm, L_1 = 18 mm, L_2 = 4 mm L_3 = 6 mm and W_s = 0.5 mm. Fig. 3 shows the measured and simulated return loss of the proposed DRA. The lower excited band is due to the c-slot while the higher band is due to the DR. A measured resonance with good impedance matching can be seen. As a result, a measured lower band achieves impedance bandwidth of 3.3% (for $S_{11} < -10$ dB) ranging from 2382 to 2461 MHz with respect to the centre frequency at 2422 MHz, and the measured bandwidth for the higher band reaches 324 MHz (5532-5856 MHz), or about 5.7% corresponding to the centre frequency at 5694 MHz. Note that there are no frequencies to be excited without the presence of DR, that is, the resonant slot mode is caused by the DR. In addition, the total length of the perimeter of the c-slot ($2L_1 + 4L_2 + 4L_3 - 6W_s$) is about 73 mm, that is, we have

$$f = \frac{c}{(2L_1 + 4L_2 + 4L_3 - 6W_s)\sqrt{\varepsilon_{eff}}}$$

where c is the speed of light in free space, f is the fundamental frequency of the slot resonator, ε_{eff} is the effective dielectric constant considering the presence of the different dielectric material on the two sides of the c-slot.

Fig. 4(a) shows the measured and simulated radiation patterns at 2.4 GHz. It is observed that the radiation patterns are similar to a half wavelength dipole antenna in the two radiating planes. The simulated x-z pattern is larger than the measured pattern because the dielectric and conductor losses are not considered in the simulation. The patterns in the yz-plane are near omnidirectional when compared to the conventional dipole antenna because the asymmetric DR loading on the c-slot. In addition, the proposed antenna radiates a maximum in the broadside direction in the xz- and yz-planes at 5.6 GHz, which corresponding to the far-field radiation from the resonant mode HEM_{11} of the DRA and as shown in Fig. 4(b). It should be mentioned that the radiating patterns in the two planes along the back side have large back radiation, which is because of the effect of bidirectional radiations for the slot antenna. The measured gain was obtained using the gain transfer method where a standard gain horn antenna was used as a reference. The measured peak gain is about 3 dBi for 2.36-2.5 GHz band, and in the 5.4-5.8 GHz band, the antenna peak gain is about 3.5 dBi.

4. Conclusion

A miniature dual-band dielectric resonator antenna with a parasitic c-slot fed by a microstrip line has been proposed and tested. A parametric study is carried out to investigate the antenna design parameters. The prototype has been designed and fabricated and found to have a bandwidth and antenna peak gain of 3.3%, 4.3 dBi and 5.7%, 3.8 dBi at the resonant frequencies of 2450 and 5640 MHz, respectively. The proposed antenna has a small size, effective feeding structure and adequate operational bandwidth, such that it is suitable for use in communication system applications.

Acknowledgments

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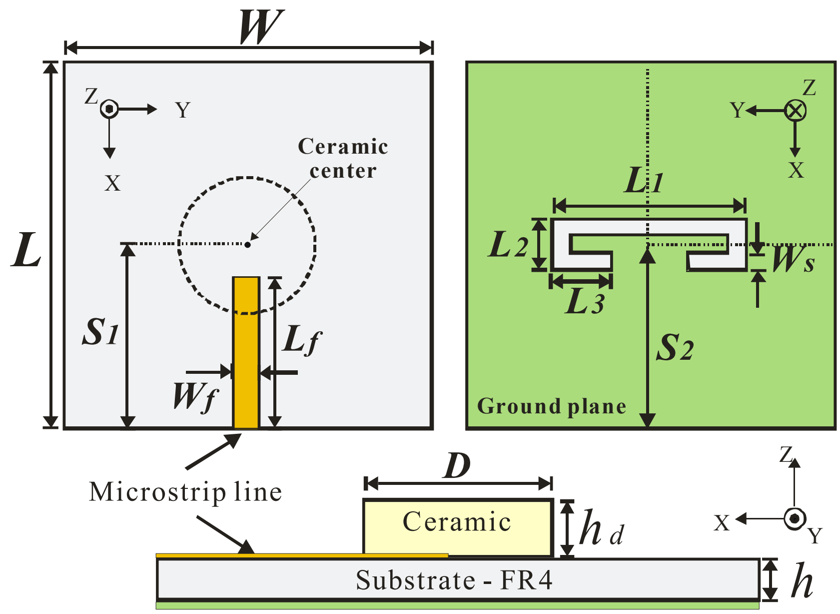
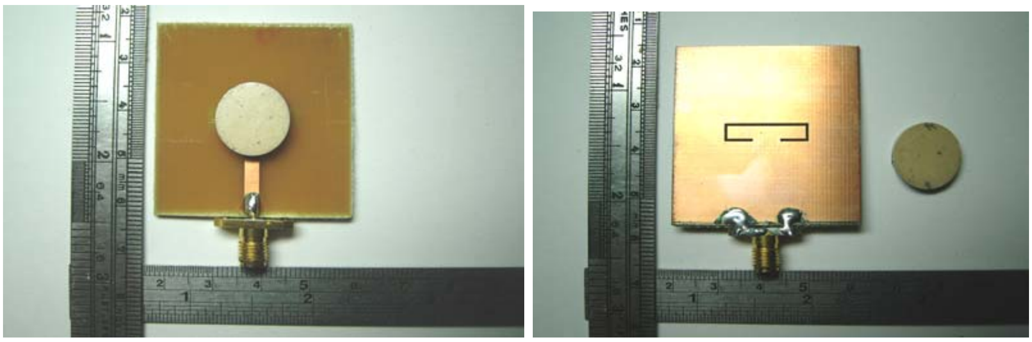


Figure 1: Top view and side view of the dual-frequency DRA



(a) (b)

Figure 2: Prototype of the proposed DRA; (a) top side, (b) bottom side.

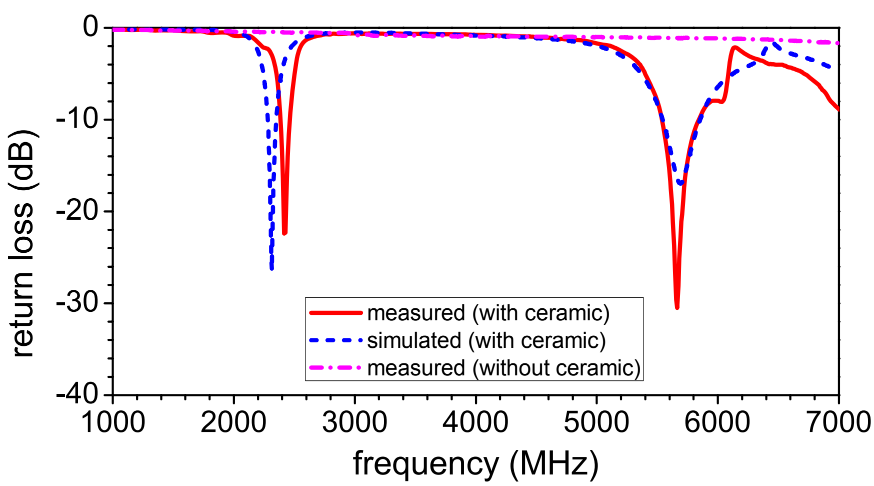
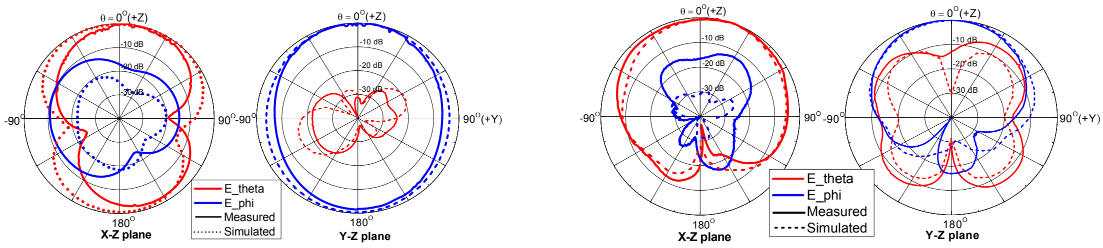


Figure 3: Measured and simulated return for the proposed DRA.



(a) (b)

Figure 4: Measured and simulated x-z plane and y-z plane radiation patterns at (a) 2.4 GHz; (b) 5.6 GHz.

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