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Design of Dual Band Dielectric Resonator Antenna with Serpentine Slot for WBAN Applications

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ABSTRACT

To achieve dual frequency operation for wireless body area network (WBAN) applications, a hybrid dual-band dielectric resonator antenna with serpentine slot fed by a microstrip line is proposed. The proposed antenna structure consists of cylindrical dielectric resonator and serpentine slot resonator. The serpentine slot is etched on the ground plane of the dielectric resonator antenna (DRA). By adjusting the structure parameters, the cylindrical dielectric resonator operates at higher band (2.4 GHz) and serpentine slot operates at lower band (403 MHz), both resonators are radiating with two different radiation patterns. The proposed antenna structure is suitable for WBAN applications.

Key words : Ceramic dielectric material, dielectric resonator antenna (DRA), slot antenna, dual-frequency operation.

1. INTRODUCTION

Recently, dielectric resonator antennas (DRAs) [1] have attracted broad attention in modern wireless communication system due to their many attractive features in terms of low loss, high permittivity, light weight, low profile, ease of excitation, small size and ease of fabrication. The DRA antenna is a very attractive alternative for applications at wireless communications. The different types DRAs such as cylindrical, rectangular, and hemispherical shapes [2]-[10] have been presented in literature. Cylindrical dielectric resonator antenna having attractive features over the rectangular and hemi sphere shapes.

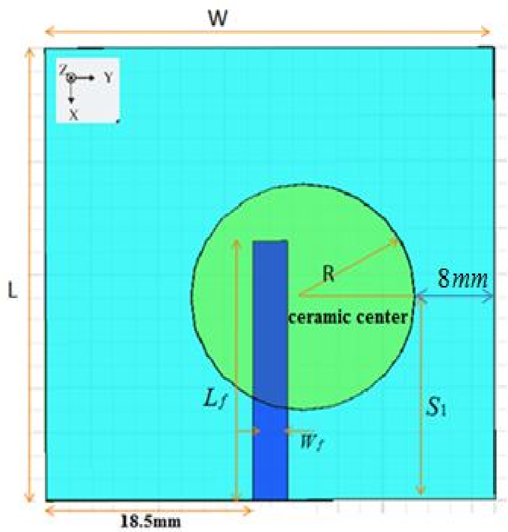
A new dual band hybrid structure [2] to achieve dual frequency operation for WBAN applications is proposed in this paper. The proposed structure can be considered as the combination of DRA and other radiating resonator, such as a serpentine slot resonator [3]-[9]. These two elements are tightly stacked together and resonate at two different frequencies. The resonant modes corresponding to each resonant frequency is different from each other. Their radiation patterns have different performance for WBAN applications.

In this paper, in order to avoid via holes, the microstrip feed line is proposed [10]. The microstrip line [11] printed on the same substrate excites a dielectric resonator (DR) that could be placed directly over the feed line. The advantage of microstrip feed is easy to fabricate, simple to match by controlling the inset feed position, low spurious radiation and easy to model.

To demonstrate the idea, the proposed hybrid dual-band antenna [12] is designed for wireless body area networks. It consists of upper (2.4 GHz) and lower (403 MHz) frequencies of the dual-band antennas are primarily controlled by the DRA and serpentine slot respectively. This design has the advantage of small size, simple structure and can achieve dual frequency operation with different radiation patterns.

2. ANTENNA CONFIGURATION

The proposed hybrid dielectric resonator antenna [13], [14] structure is as shown in Figure 1. It consist of cylindrical dielectric resonator antenna (CDRA) and serpentine slot, the CDRA is laying on the dielectric substrate and serpentine slot is etched on ground plane, these radiating resonators are tightly stacked together and resonate at upper and lower frequencies respectively. The microstrip feed line is etched on the substrate at center position. The proposed structure has the dimensions of 40 mm × 40 mm × 9 mm, a dielectric substrate RT duroid 6010 with a relative permittivity of $\varepsilon_r = 10.2$ and substrate thickness is 1.6 mm.



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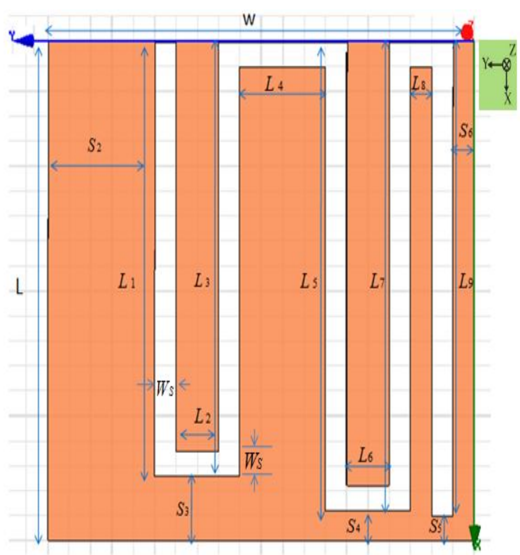

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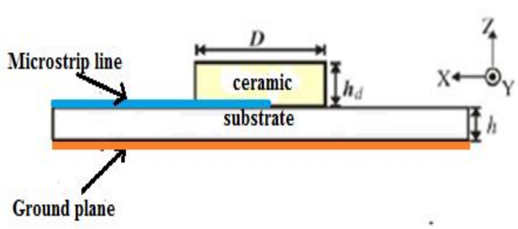


(c)

Figure 1: Proposed dual band DRA with serpentine slot: (a) Top view; (b) Bottom view; (c) Side view

The CDRA with ceramic material has a diameter of D=20 mm, height of h_d=7.4 mm, and relative permittivity of $\mathcal{E}_d$ = 42 as shown in Figure 1. The centre point of dielectric resonator is placed below the centre line of the ground plane with an offset distance S_1 = 18 mm which is used to adjust the coupling energy between the microstrip-fed line and dielectric resonator. The dimension of the 50-Ω feeding line has a length of L_f =18.5 mm and a width of W_f =3.0 mm.

The theoretical resonant frequency of the DRA is calculated [5] by the following equation and equal to 2.4 GHz which is well suited for industrial, scientific, medical(ISM) applications.

$$f_r = \frac{c}{2\Pi R}\left(\frac{1.6 + 0.513x + 1.392x^2 - 0.575x^3 + 0.088x^4}{\mathcal{E}_d^{0.42}}\right)$$

where x = R/2h_d; c is the speed of light in free space; R, h_d and $\mathcal{E}_d$ are the radius, height and relative permittivity of the DRA, respectively.

In this paper, a new type of resonator such as serpentine slot etched in ground plane is proposed to achieve lower frequency (403 MHz) band. The structure of serpentine slot is as shown in Figure 1. The lower excited band is due to the serpentine-slot. It is well-known that by choosing a high permittivity substrate, a greater size reduction can be achieved. For this reason, the substrate selected for the antenna has been RT duroid 6010 ($\mathcal{E}_r$=10.2). The design consideration for the lower excited serpentine slot antenna is consists of nine rectangular slots with different length and fixed width W_S=2 mm as shown in Figure 1, the serpentine slot on the ground plane with different offset distances are S_2 = 10 mm , S_3=5.1 mm, S_4=2.4 mm, S_5=1.9 mm and S_6=2 mm, different rectangular slot lengths are L_1=33.5 mm, L_2=4 mm, L_3=34.8 mm, L_4=8 mm, L_5=37.5 mm, L_6=4 mm, L_7=37.5 mm, L_8=2 mm, L_9=38 mm. The design of serpentine slot on the ground plane with different slots, L_1, L_3, L_5, L_7, L_9 are starts with 0.1 mm offset distance from top side of the ground plane.

By optimizing the structure parameters, the DRA and serpentine slot resonates at 2.4 GHz and 403 MHz respectively.

3. SIMULATED RESULTS AND DISCUSSIONS

Figure 2 shows the simulated return loss of the proposed hybrid DRA. The lower excited band is due to the serpentine slot while the higher band is due to the DR. As observed in Figure 2, the return loss of the proposed antenna at two different bands is MICS (403 MHz) & ISM (2.4 GHz).

It is observed -26 dB return loss at MICS band and -28 dB return loss at ISM band. As a result, a simulated lower band achieves an impedance bandwidth of 4.46 % (for S_{11} < -10 dB) ranging from 396 to 411 MHz with respect to the centre frequency at 403 MHz and the simulated bandwidth for the higher band reaches about 3.75 % (for S_{11} < -10dB) corresponding to the centre frequency at 2.4 GHz. Note that there are no frequencies to be excited without the presence of DR, the resonant slot mode is caused by the DR.

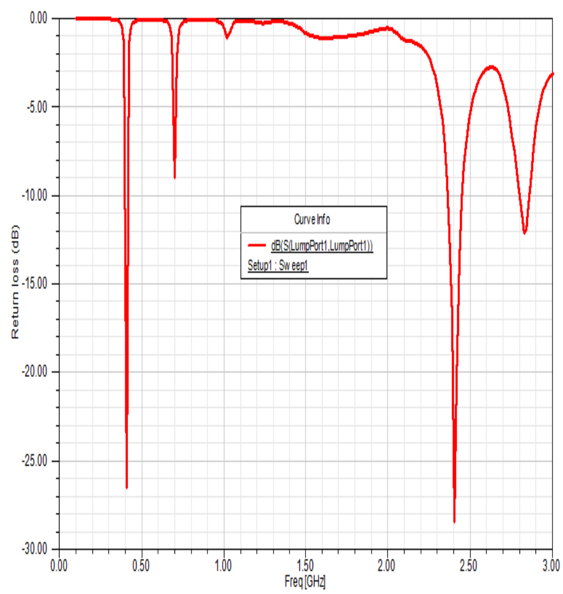
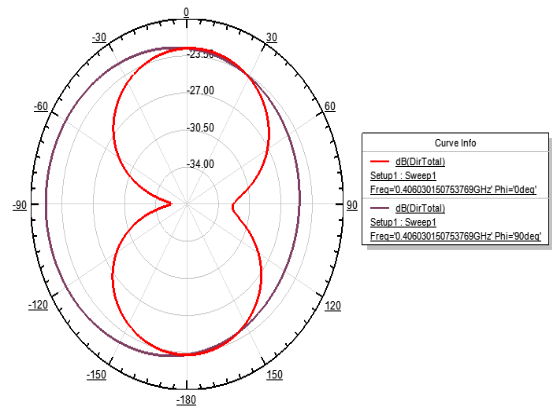


Figure 2: Simulated return loss for the MICS and ISM band

The radiation patterns of the simulated antenna structure for the MICS (403 MHz) and ISM (2.4 GHz) bands with phi=0 (deg) and phi = 90 (degree) are shown in Figure 3. The proposed antenna radiates a maximum radiation in the broadside direction at 2.4 GHz, which corresponds to the far-field radiation from the resonant mode of the DRA as shown in Figure 3. 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 serpentine slot antenna at resonant frequency 403 MHz.



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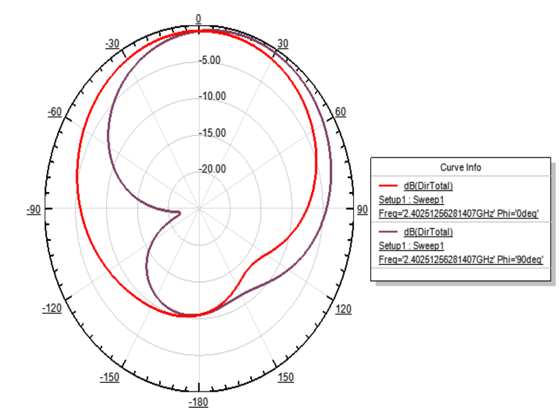
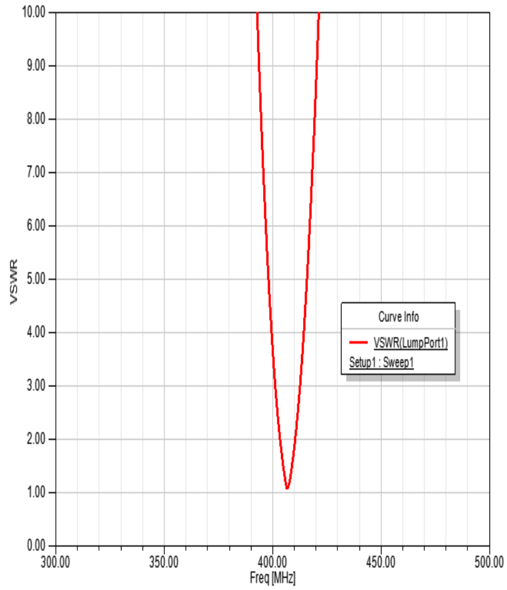


(b)

Figure 3: Simulated radiation patterns at: (a) MICS band; (b) ISM band

The voltage standing wave ratio (VSWR) of the proposed structure is as shown in Figure 4, the VSWR of the proposed structure is close to 1.2 in the MICS (403 MHz) band. As it is less than 2 it can be said that the antenna offers good impedance matching characteristics for the MICS band. As well as for the proposed structure simulated VSWR at ISM (2.4 GHz) band is very close to 1.1, as it is less than 2 as shown in Figure 4 and it will said that proposed lower band antenna offers good impedance matching characteristics.



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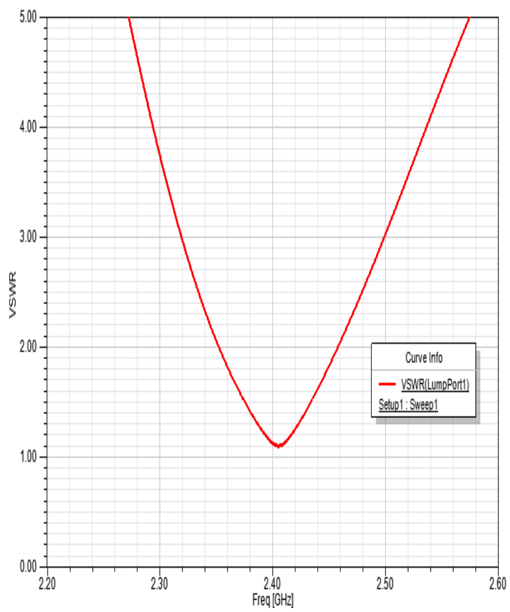

(b)

Figure 4: Simulated VSWR at: (a) MICS band; (b) ISM band

4. CONCLUSION

A hybrid antenna structure combining a dielectric resonator antenna and serpentine-slot has been proposed to achieve dual frequency operation. The lower band (403 MHz) and upper band (2.4GHz) of the hybrid structure is excited by the serpentine-slot and DRA respectively. The proposed antenna has been simulated and it is observed that a bandwidth of 4.46% for MICS and 3.75% for ISM bands, and a return loss of -27 dB and -29 dB respectively. The bandwidths of the proposed antenna were wide enough to cover the MICS (402–405 MHz) and ISM bands (2380–2485 MHz). The proposed hybrid structure takes a low profile, compact size and simple shape, such that it is suitable for wireless body area networks.

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