Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406
International Journal of Advance Engineering and Research Development
Volume 4, Issue 10, October -2017

A Compact Dual Band Rectangular Dielectric Resonator Antenna with slot for WBAN

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Abstract — *Dual band antennas are in great demand due to the rapid development of the modern wireless communications towards the body area networks. Therefore in this paper, a compact dual-band dielectric resonator antenna with a slot sustained by a microstrip line that is reasonable for wireless body area network is intended. In this structure, the dielectric resonator performs the functions of an effective radiator along with the feeding configuration and the parasitic slot in the ground plane. By adjusting the structural parameters, the antenna is made to resonate at two various frequencies; one is from the dielectric resonator antenna (DRA) and the other from the parasitic slot. The configuration involves a dielectric resonator with the resonant frequency of 2.4 GHz (Industrial, Scientific and Medical) and a parasitic slot with a resonant frequency of 403 MHz (Medical Implantable Communication Service). The physical and geometrical parameters of these resonators are oscillating to achieve the required performance parameters. In order to the performance of the intended antenna, functional parameters such as return loss, bandwidth, voltage standing wave ratio (VSWR), and radiation pattern are investigated by the simulation of the structure with high frequency structure simulator (HFSS).*

Keywords- *Ceramic dielectric material, dielectric resonator antenna (DRA), dual band operation, microstrip feed line, WBAN.*

I. INTRODUCTION

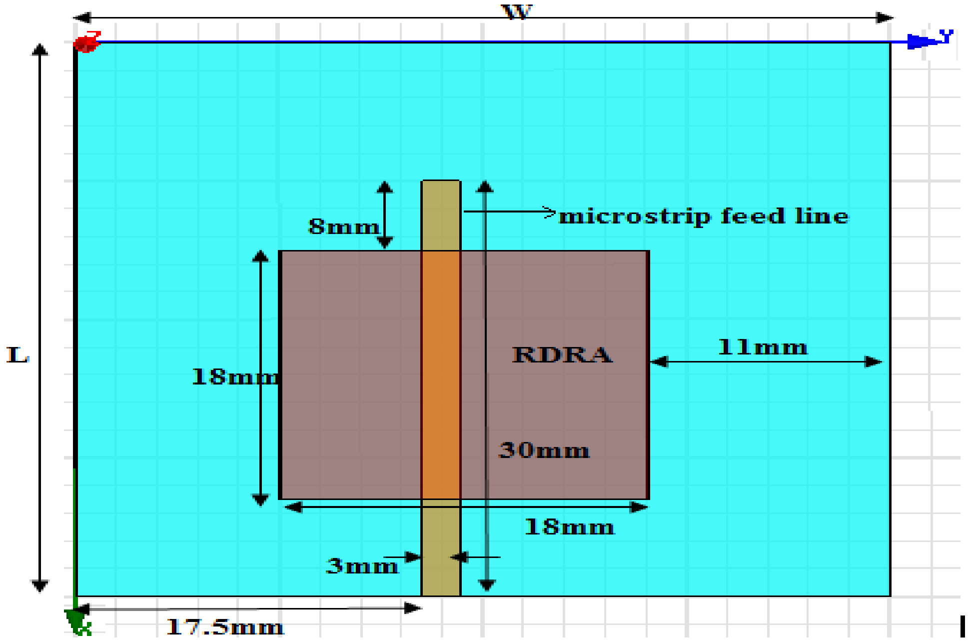
The DRA antenna is a very attractive alternative for applications at wireless communications. The different types DRAs such as cylindrical, rectangular, and hemispherical shapes [2]-[10] have been presented in literature. Cylindrical and rectangular dielectric resonator antennas are having attractive features over the triangular and hemi sphere shapes. A new dual band hybrid structure [2] to achieve dual frequency operation for WBAN applications is proposed. The proposed structure can be considered as the combination of DRA and other radiating resonator, such as a slot resonator [3]. 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.

The use of dielectric resonators [4] in feeding circuits requires accurate knowledge to couple the resonators and circuits. In order to match the DR to the feed line and to excite the desired mode in the resonator, the most common feeding technique is the aperture-coupled [5] arrangement. However, the resonant feeding structure adopted in these reported designs, such as microstrip-fed aperture-coupled, co-axial probe coupling, co planar slot feed and CPW-fed slot arrangement offers more flexibility and is directly compatible with different mounting surfaces. In this letter, in order to avoid via holes, the microstrip feed line is proposed [6]. 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 [7] is designed for wireless body area networks. It consists of upper (2.4 GHz) and lower (403 MHz) frequencies of the dual-band antennas [8] are primarily controlled by the DRA and slot respectively. The designed dual-band antenna has the maximum radiation directed toward the inside of the human body in the medical implantable communication service (MICS) [18]-[20]band in order to collect vital information from the human body [9], and directed toward the outside in the industrial, scientific and medical (ISM) band to transmit that information to a monitoring system. This design has the advantage of small size, simple structure and can achieve dual frequency operation with different radiation patterns.

The physical and geometrical parameters of these elements are to be tuned accordingly to obtain the desired performance parameters. In this project, development of a dual band antenna to be implanted for the body which will be suitable for both MICS range and ISM range is aimed at. This design has the advantage of simple structure, compact size, and can achieve dual band with different radiating patterns. This proposed DRA is suitable to be mounted on the body, and is very suitable for applications for wireless body area network.

II. ANTENNA CONFIGURATION



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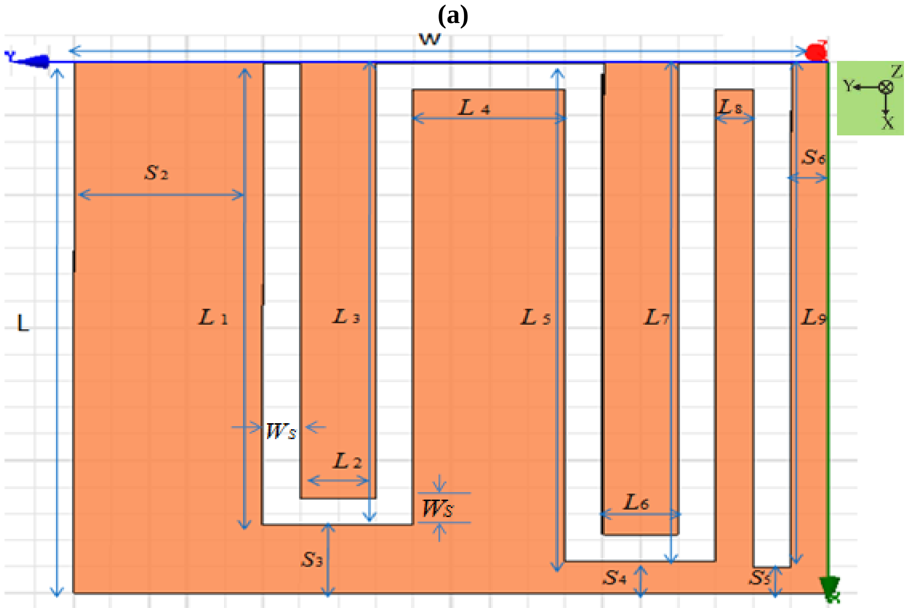

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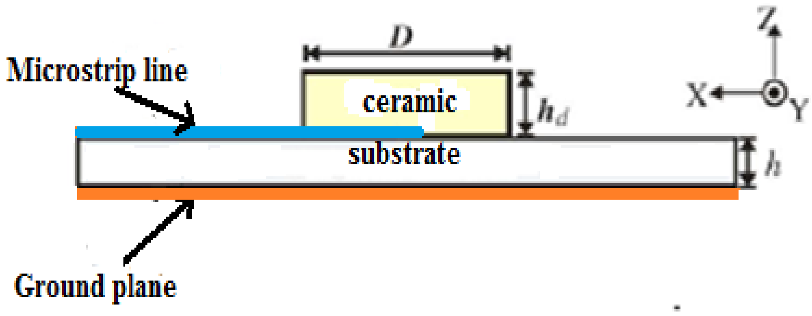

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Figure 1: Proposed DRA with slot: (a) Top view; (b) Bottom view; (c) Side view

The dual band dielectric resonator antenna with serpentine slot fed by microstrip line is proposed. Hybrid structure is combination of two different types of resonators; it consists of rectangular dielectric resonator and serpentine slot. The proposed hybrid structure, the rectangular dielectric resonator antenna resonates at 2.4 GHz (ISM) and slot resonates at 403 MHz (MICS) which is suitable for wireless body area networks. These two radiating resonators are tightly stacked together and resonate at different frequencies. By arranging for the radiating resonators' position, a compact dual-band or frequency-tunable hybrid DRA can be designed. The dual band hybrid DRA is consist of two different resonators one is rectangular dielectric resonator which is printed on the RT Duroid 6010(M) substrate and another resonator is serpentine slot which is etched on the ground plane, these radiating resonators are tightly stacked together.

Figure 1 shows the side view of the proposed antenna for a WBAN. The proposed antenna has the dimensions of 40 mm × 40 mm × 11.1 mm, and a RT duroid 6010 dielectric with a relative permittivity of 10.2 is used as a substrate. The top resonator is used to suppress the radiation towards the outside of the body in the MICS band and transmit signals to external devices in the ISM band. The proposed dual-band DRA structure is shown in Figure 1. It consists of a rectangular DR and a center-fed microstrip line which is printed on an RT druid 6010 substrate of thickness 1.6 mm and relative permittivity ε_r =10.2. The ground plane is printed on the RT duroid 6010 substrate with a dimension of 40x40 (LxW) mm^2. The DRA with ceramic material has a length L_d=18 mm, width W_d=18 mm and height of h_d=9.5 mm, and a relative permittivity of ε_d =37 as shown in Figure 1. The 50-Ω feeding line has a length of L_f =30 mm and a width of W_f =3.0 mm.

The theoretical resonant frequency of the RDRA [14] is calculated by the following equation and equal to 2.4 GHz which is well suited for industrial, scientific, medical(ISM).

$$f_0 = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{k_x^2 + k_y^2 + k_z^2}$$

$$k_x = -\frac{\Pi}{a}, k_z = \frac{\Pi}{2b}$$

$$\text{d} = \frac{2}{k_y}\tan^{-1}\left(\frac{k_{y0}}{k_y}\right), k_{y0} = \sqrt{k_x^2} + \sqrt{\ } k_z^2$$

Where, f_0=resonant frequency of the DRA, c=speed of light, $\varepsilon_{r=}$ dielectric constant of the resonator,
a= length of the resonator, d= width of the resonator, b= height of the resonator,
Kx= coefficient in the x direction, $K_{Y=}$coefficient in the y direction, K_z= coefficient in the z direction.

In this letter, 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 3.13, 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.

In addition, the serpentine 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 serpentine-slot dimension, the proposed antenna can operate in two bands, and a good impedance match for the operating frequencies can be easily obtained. The bottom of the slot is designed to communicate with the implanted devices in the MICS band, and to reduce the human body effects of the ISM band. By optimizing the structure parameters, the DRA and serpentine slot resonates at 2.4 GHz and 403 MHz respectively.

III. SIMULATED RESULTS AND DISCUSSIONS

Figure 2 shows the simulated return loss of the proposed hybrid DRA. The primary excited band is due to the parasitic - slot while the secondary band is due to the rectangular resonator. It is observed-24 dB return loss at 0.403 GHz and-26 dB return loss at 2.4 GHz. Note that there are no frequencies to be annoyed outwardly the existence of rectangular resonator, that is, the full resonate slot mode is induced by the rectangular resonator.

The return loss is another way of expressing mismatch. It is a logarithmic ratio measured in dB that compares the power reflected by the antenna to the power that is fed into the antenna from the transmission line. The relationship between SWR and return loss is the following:

$$\text{Return}loss(dB) = 20\log_{10}\frac{SWR}{SWR-1}$$

The term bandwidth simply defines the frequency range over which an antenna meets a certain set of specification performance criteria. The important issue to consider regarding bandwidth is the performance tradeoffs between all of the performance properties described above. There are two methods for computing an antenna bandwidth. An antenna is considered broadband if $f_H/f_L \geq 2$.

Narrowband by %

$$BW = \frac{f_H - f_L}{f_0} x100\,\%$$

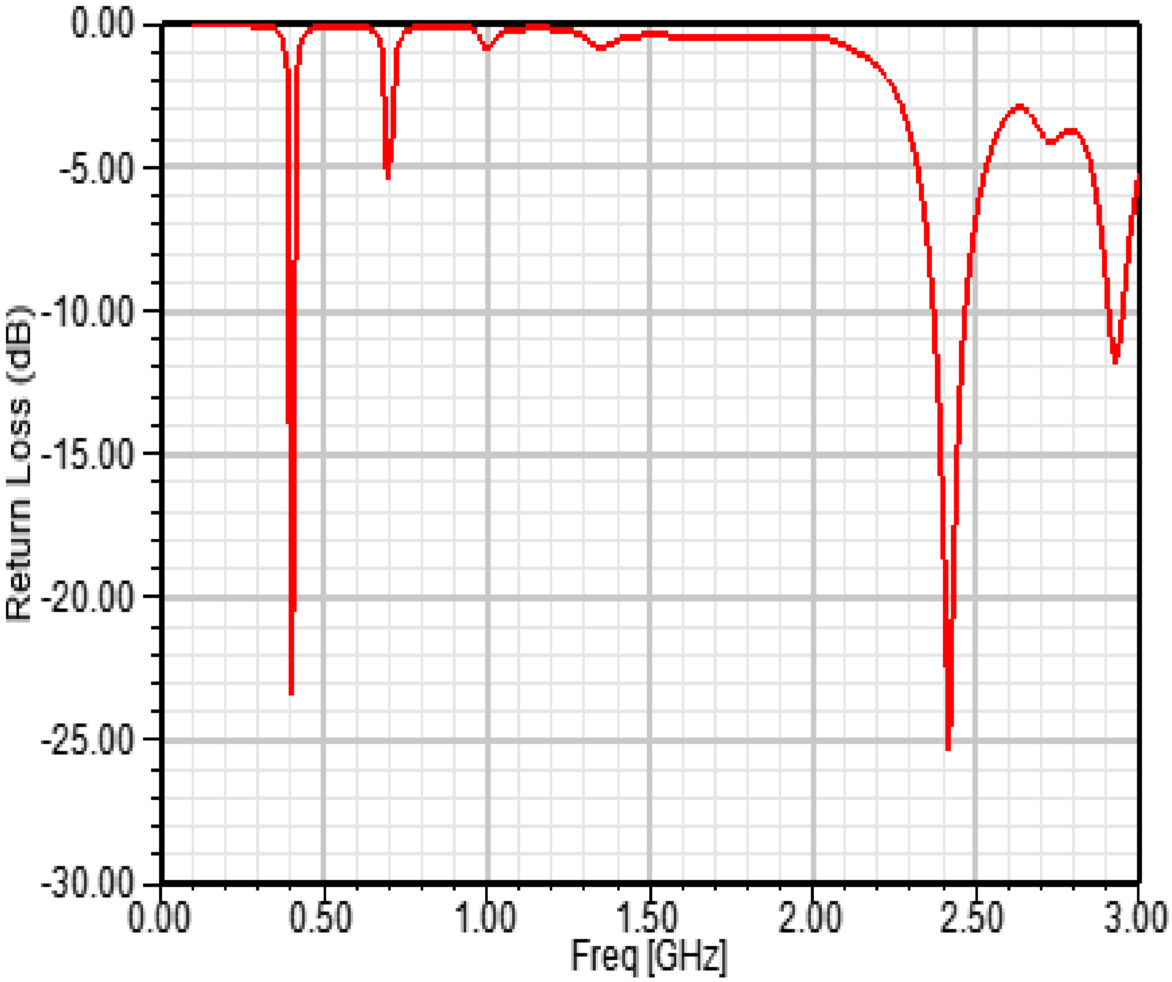
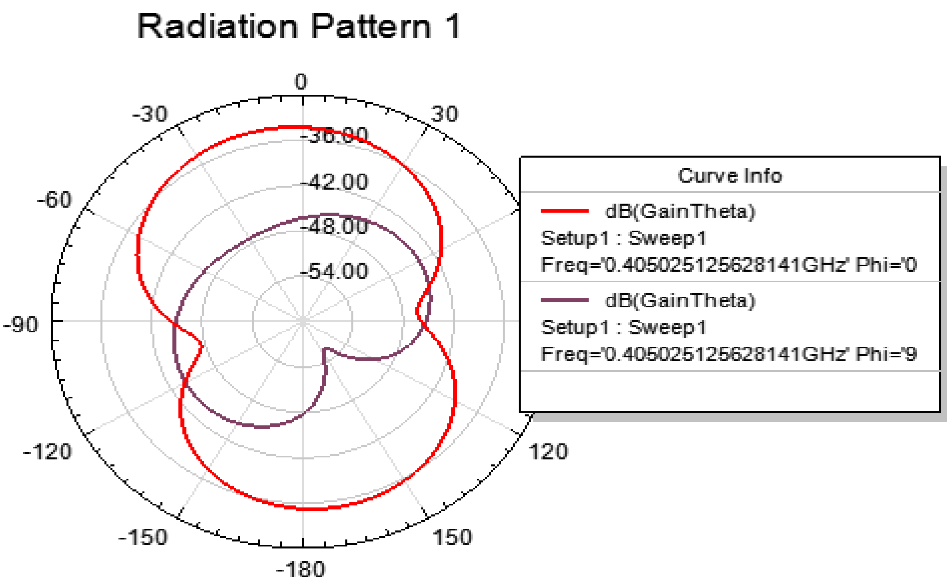


Figure 2: Simulated return loss at MICS and ISM band

The radiation waves of the simulated antenna structure at 403 MHz and 2.4 GHz with phi=0 (deg) and phi = 90 (degree) are shown in Figure 3. The proposed antenna radiates a maximum in the broadside direction at 2.4 GHz and parasitic - opening slot resonator is radiating the waves in bidirectional at 403 MHz. The radiation patterns of an antenna provide the information that describes how the antenna directs the energy it radiates. All antennas, if 100% efficient radiate the same total energy for equal input power regardless of pattern shape. Radiation patterns are generally presented on a relative power dB scale. It can be show in polar plot 360 degree. Example of radiation pattern is shown in Figure 1.1. In many cases, the convention of an E-plane and H-plane pattern is used in the presentation of antenna pattern data. The E- plane is the plane that contains the antenna's radiated electric field potential while the H-plane is the plane that contains the antenna's radiated magnetic field potential.



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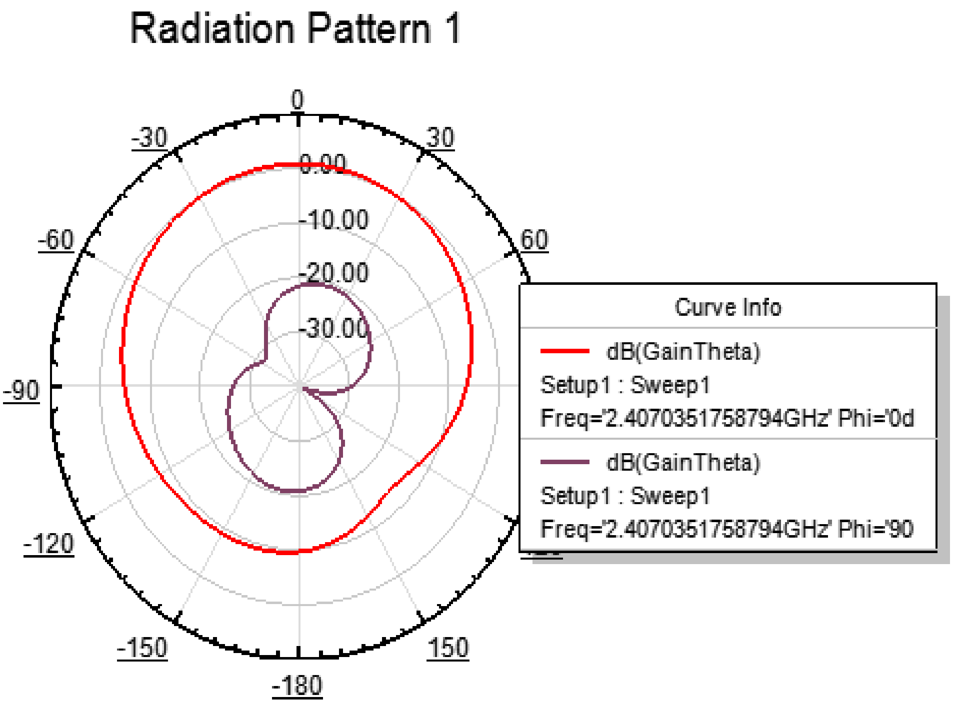

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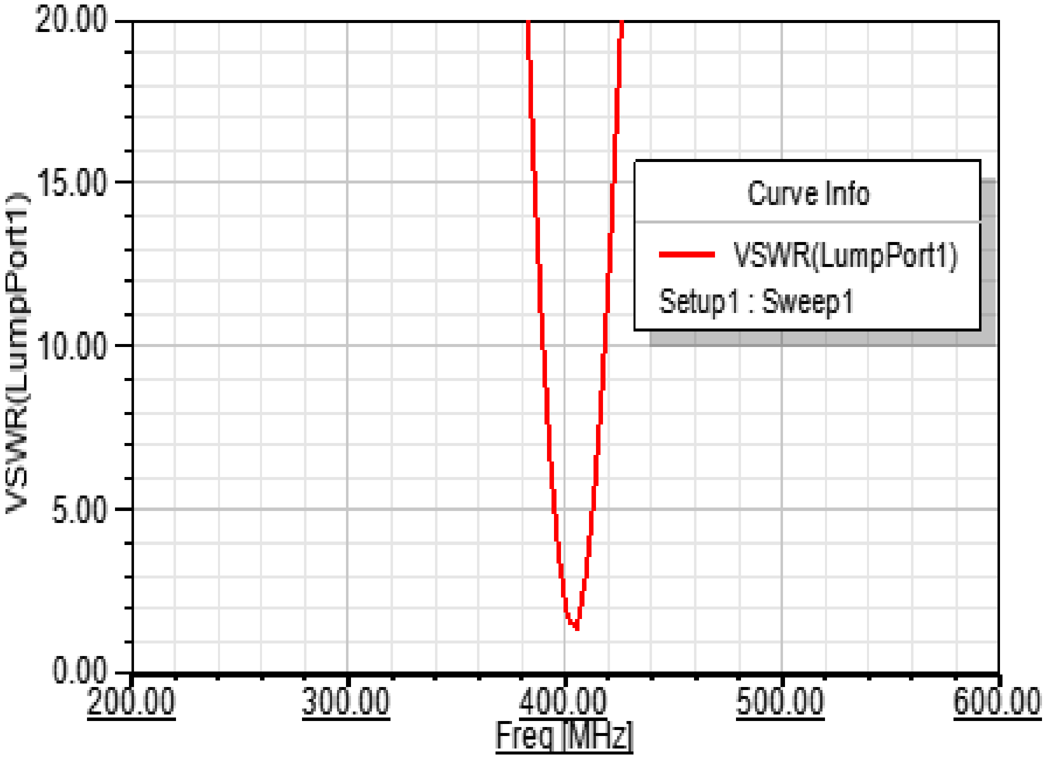
Figure 3: Simulated radiation patterns at: (a) MICS; (b) ISM

The voltage standing wave ratio (VSWR) of the proposed configuration is as shown in Figure 4.It is gives as analysis of the mismatch between the load and the transmission line. For ideal case value of VSWR is 1 and for good impedance matching. The VSWR of intended antenna is 1.5 at 0.403 GHZ and 1.2 at 2.4 GHZ.



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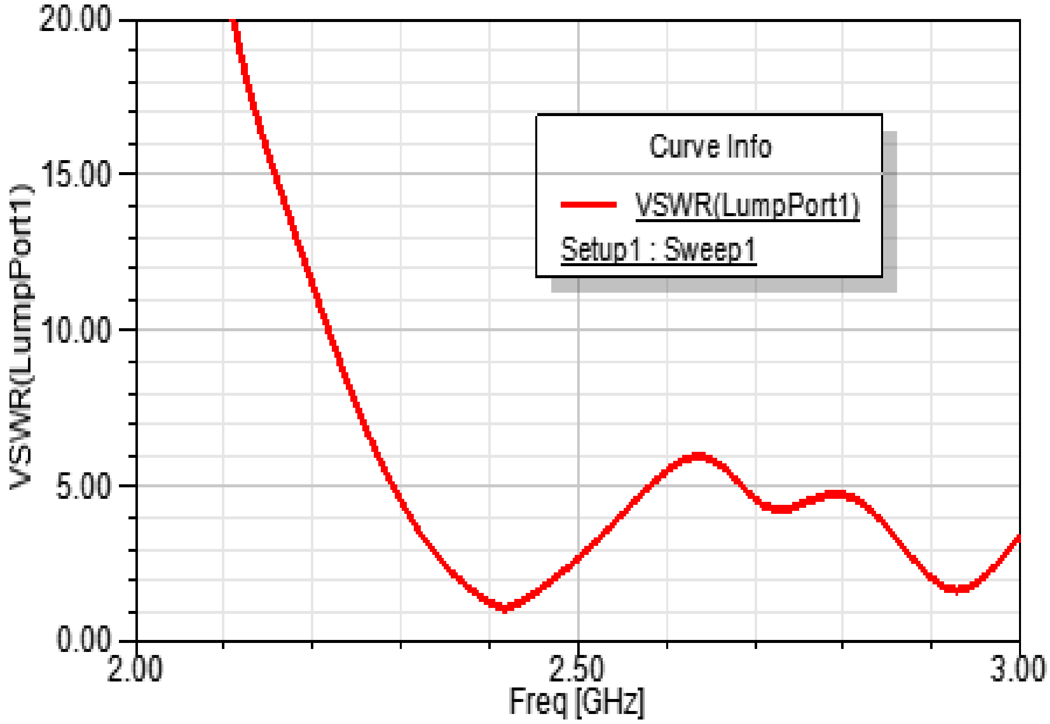

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Figure 4: Simulated VSWR at MICS and ISM

The VSWR indicate that how closely or efficiently an antenna's terminal input impedance is matched to the characteristic impedance of the transmission line. The large number of VSWR, the greater the mismatch between the antenna and the transmission line.

IV. CONCLUSION

A dual band rectangular dielectric resonator antenna with parasitic opening sustained by microstrip line is intended to attain dual frequency operation. The investigated rectangular patch and parasitic - space resonators are operates at the primary band (2.4 GHz) and secondary band (403 MHz) respectively. The antenna structure has been simulated and it is noticed that return loss of -24 dB, -26 dB at the resonant frequencies of 403 MHz and 2.4 GHz subsequently. The bandwidths of the proposed antenna were wide enough to cover the MICS (402–405 MHz) and ISM bands (2380–2485 MHz). The radiation pattern of the antenna is advantageous for communication with implant devices in the MICS band and external devices in the ISM band. The arranged antenna configuration has small in size, less weight, reduced cost, acceptable isolation and sufficient operational bandwidth, with the end goal that it is suitable for WBAN applications.

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