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Geometry Perturbation of Dielectric Resonator for Same Frequency Operation as Radiator and Filter

Taomia T. Pramiti*(1), Mohamed A. Moharram(1), and Ahmed A. Kishk(1)
(1) Electrical and Computer Engineering Department, Concordia University, Montréal, Québec, Canada

Abstract

A single dielectric resonator is used for a dual functional application using the geometry perturbation method at the desired frequency. The high Q $TE_{01\delta}$ mode for a filter operation and the low Q $TM_{01\delta}$ mode for radiation at the same frequency. To operate both modes at the same frequency a circular metallic disk is used to control the energy concentrations of the modes inside the dielectric resonator. In addition,a metal disk is used to provide partial shielding for the $TE_{01\delta}$ mode and allow the $TM_{01\delta}$ mode radiation and at the same time enhance the insertion loss and matching. The design is made for Wi-Fi applications at 2.45 GHz.

1 Introduction

Dielectric Resonators (DRs) are being used tremendously for several decades in various applications due to their combination of properties, such as the low machining cost as well as small size [1]. In addition, the associated quality factors (Q) with their modes make it suitable for the applications ranging from antennas to filters. Using the high Q modes of the dielectric resonators for microwave filters (bandpass and bandstop filters) enabled developing several designs for satellite and radio link applications [2]. However, the low Q modes of the DR are also being used as antennas of different radiation patterns[3].

Modern communication systems require compact size multifunctional devices under restricted operating conditions such as the frequency band, interference, traffic patterns [10]. DRs can serve the purpose as multi-functional devices by using its different modes simultaneously for different functions. Several applications can be found that investigated the ability of dielectric resonator for multi-functions operations, such as a dual polarized antenna, filter-antenna, Diplexer [4, 7]. Several research groups explored various techniques to perturb the resonant frequencies of different modes of the dielectric resonators to operate at the same frequency [8, 9]. Different methods were implemented for frequency tuning such as using screws, irises, corner cuts ..etc. Therefore, the dielectric resonator has become an intriguing subject for several applications.

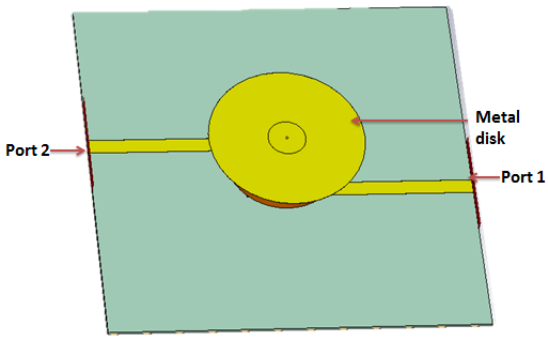
The proposed design consists of a dielectric resonator that acts as a filter using the $TE_{01\delta}$ mode and as a a radiator using the $TM_{01\delta}$ mode that provide omnidirectional radiation pattern at 2.45GHz. However, having the DR sits on a ground plane suppress the $TE_{01\delta}$ mode. Therefore, it has to be lifted up using the dielectric substrate. On the other hand the resonance frequency of $TE_{01\delta}$ mode and $TM_{01\delta}$ mode are different. Therefore, geometry perturbation is used to tune the resonance frequency of both modes to operate within their bandwidths. In addition, a metallic disk is placed on the top of the resonator to provide partial shielding for the $TE_{01\delta}$ mode to enhance its Q-factor. In the design, the metallic disc is also used to improve the filter insertion loss without significant effect on the radiating $TM_{01\delta}$ mode. The proposed antenna can be used for the indoor 2.45 GHz Wi-Fi applications where the antenna can be used to transmit or receive signals besides the filter function to reduce the noise effect.

2 Design

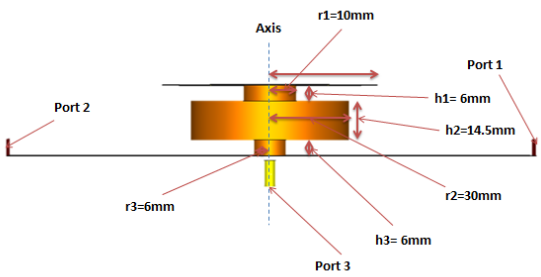
First the resonator shape and dimension is chosen depending on desired resonance frequencies, energy concentration inside DR and also in terms of a high Q factor [11]. The initial value of the cylindrical dielectric resonator has the radius and height of 19.76mm ($\lambda_g/2$ at 2.45 GHz) of Rogers 6010 (ε_r =10.2) dielectric resonator over an RT5880 substrate with 1.575 mm thickness (ε_r =2.2) as shown in Fig. 1.

The design is simulated using the CST Microwave Studio [12] Eigenmode solver to check the frequency of the resonant modes $TE_{01\delta}$ and $TM_{01\delta}$. In the unperturbed dielectric resonator, the different modes do not coincide at the same frequency. Based on the field distribution of each mode and their resonant frequencies, geometry perturbation is used to significantly affect the resonance frequency of the $TE_{01\delta}$ mode with little effect on the resonance frequency of the $TM_{01\delta}$ mode. The perturbation is made by removing annular rings of the dielectric materials from the bottom and top parts, as shown in Fig.

To excite the $TE_{01\delta}$ filter mode, two parallel microstrip lines are used (port 1 and 2 in the Fig. 1). The distance between the resonator and microstrip line has to be exact so that the lines operate like a reaction cavity and reflects the RF energy at the resonant frequency. Despite the distance and the length of mictrostrip lines are sensibly cho-



(a)



(b)

Figure 1. The geometry of the proposed design. (a) Top view. (b) Side view.

sen, the impedance matching of the $TE_{01\delta}$ mode is very poor. The reason behind this is the lack of shielding which is improved by using the upper circular metallic disk.

To excite the $TM_{01\delta}$ mode simultaneously with the existing ports for $TE_{01\delta}$ mode, a coaxial probe is used at the center of the resonator (port 3). The probe has to be inserted properly so that it can couple with the strong electric field of the $TM_{01\delta}$ mode which is quite different from the case of the full circular dielectric resonator. From the field distribution of the $TM_{01\delta}$ mode the strongest field is found at the top part of the dielectric resonator. So the probe length is kept long enough to reach that level. Figure 1(b) shows the $TM_{01\delta}$ mode excitation using a coaxial probe.

3 Using metal disk to improve impedance matching

As mentioned early, the impedance matching of $TE_{01\delta}$ mode was not at the acceptable level. To improve this condition a circular metal disk of very small thickness has been placed on top of the resonator, similar to [4]. A parametric study is performed on the distance between the DR and the metal and a better response is found at the required frequency when the disk is directly placed on top of the dielectric resonator. The radius of the metal has a significant effect on improving the insertion loss and impedance matching of $TE_{01\delta}$ mode. The electric field is tangential in $TE_{01\delta}$ mode and placing the metal on top of resonator forces the tangential field to be zero on the boundary. This confines the electric field strictly inside the resonator. In addition, increasing the metal radius improves the insertion loss.

The metal disc has been found to have a small effect on $TM_{01\delta}$ mode . The electric field is normal to the metallic disc surface. Thus, the disc radius is used to as well as the height of the disc be used to improve the impedance matching of the $TM_{01\delta}$ mode.

4 Simulated Results

Fig. 2 shows the reflection coefficient, insertion loss and the coupling coefficient of the designed filter and antenna. After exciting both modes, $TE_{01\delta}$ resonates at 2.44 GHz and $TM_{01\delta}$ resonates within a wide band due to the natural lower Q of the $TM_{01\delta}$ mode. At 2.45 GHz the impedance matching found to be around 18 dB for $TE_{01\delta}$ and 12 dB for $TM_{01\delta}$ modes. The insertion loss of the filter is 1.3 dB and the coupling coefficient between the two modes is 26 dB.The radiation pattern of the omnidirectional antenna mode is shown in Fig. 3. The antenna provides a maximum gain of 3.74 dB.

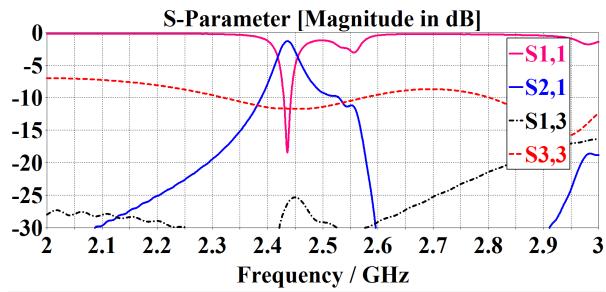


Figure 2. Reflection coefficient, Insertion loss and Coupling coefficients of the 3 ports designed structure.

5 Conclusion

The paper has presented a new design using two modes simultaneously for filter and antenna application. The Geometrical perturbation has been used to tune the resonant frequency of the $TE_{01\delta}$ mode to be at the resonant frequency of the $TM_{01\delta}$ mode. Also improving the insertion loss and matching of the filter by using shielding metallic disc have been described. The proposed concept has been applied to a dual functional antenna/filter for Wi-Fi applications.

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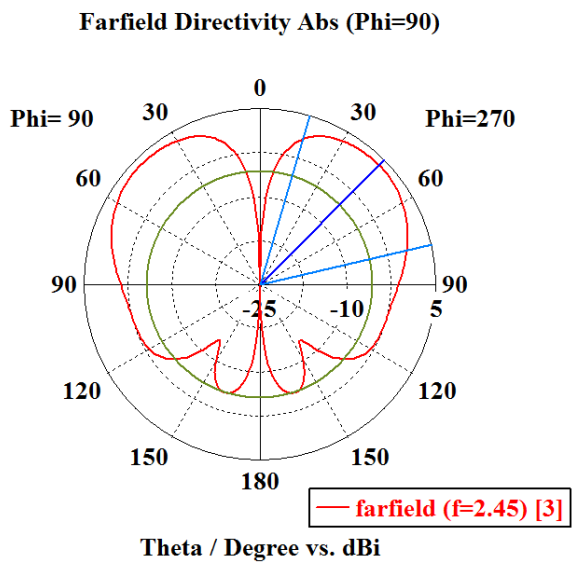

Figure 3. Radiation pattern of the omnidirectional $TM_{01\delta}$ mode.

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