Numerical Investigation of Rectangular Dielectric Resonator Antennas (DRAs) Fed by Dielectric Image Line (DIL)

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Abstract— In this paper Rectangular Dielectric Resonator Antennas (RDRA) fed by Dielectric Image Line (DIL) which is excited through a narrow slot on the ground plane is numerically investigated. The antenna structure is studied based on the Finite Element Method (FEM) using High Frequency Structure Simulation (HFSS) package. The effects of the slot size are considered on the radiation performance of the antenna. Results show that the optimum length and width of the slot, for 7 dB gain at 10 GHz, are 3.7 mm and 0.144 mm respectively. The return loss and radiation patterns of the antenna are also provided for a specific DRA.

1. INTRODUCTION

Dielectric Resonators (DRs) made of high dielectric constant and low loss material have been used as a tuning elements in microwave filters and oscillators. DRs are small in size, low in cost and light in weight offering high temperature stability [1, 2]. Due to these specific performances, they have been replaced metal waveguide cavities especially in MICs and MMICs. In recent years, the subject of open DRs as an electromagnetic radiator has been increased in literature because of no inherent conductor loss leading to high radiation efficiency. It has been reported that cylindrical, hemispherical, cylindrical rings and rectangular shaped DRs could operate as an efficient antennas. Another advantage of DRAs is compatibility with all types of transmission line such as coaxial probe, microstrip line, microstrip-slot coupled and coplanar waveguide [1–3].

The radiation efficiency of the communication system is reduced at high frequencies due to skin effect and high conductive loss of microstrip lines. Dielectric transmission lines such as Dielectric Image Line (DIL) have lower losses at microwave frequencies compare to conventional transmission line [1, 3]. Rectangular DRAs fed by DIL can be excited at their resonant frequency through a narrow slot on the ground plane.

In this paper a RDRA fed by DIL which is excited through a narrow slot on the ground plane is numerically investigated. The antenna structure is studied based on the Finite Element Method (FEM) using High Frequency Structure Simulation (HFSS) package. The effects of the slot size on the radiation performance of the antenna are studied. The optimum length and width of the narrow slot, for 7 dB gain at 10 GHz is obtained. Return loss, radiation patterns and the variation of the RDRA gain versus frequency are presented.

2. ANTENNA STRUCTURE

The geometry of the antenna structure is shown in Fig. 1. A rectangular DRA of length a, width b, height c with the relative permittivity of ε_d is placed on the ground plane. A slot of length L and width W is etched at the center of the metal plane to excite the resonator at the dominant mode. DIL, as the transmission media, comprise a rectangular dielectric slab of relative permittivity ε_r with a length of 3λ at 10 GHz placed under the ground plane. The dimensions of the DIL transverse plane are $2a_d$ and b_d shown in Fig. 1 and all dimensions are summarized in Table 1. The most important feature of this structure is placing the feed network of the RDRA at the backside of the ground plane, isolating the radiating parts from spurious radiation provides by the DIL especially at high frequencies [6, 7]. The slot width is chosen smaller than the wavelength of guided wave by the DIL. For a strong coupling between DIL and the RDRA, the slot should be placed in a region of strong magnetic fields [4, 5].

3. ANTENNA SIMULATION

The RDRA structure is numerically investigated using HFSS [8]. To excite the DIL, a standard metal waveguide is used at the input and output of the transmission media. Three sections of waveguide using a proper tapering provide transition from TE_{10} mode of the metal rectangular waveguide to dominant mode of the DIL. Rectangular dielectric waveguides support TM^y_{mn}, TM^z_{mn}

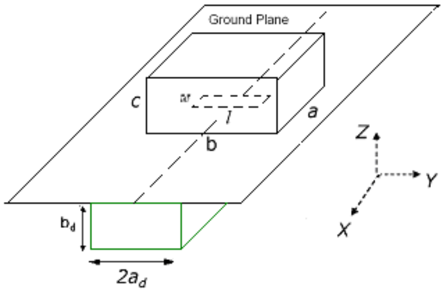


Figure 1: The geometry of the DRA fed by DIL through a narrow slot.

a	6.2 mm
b	6 mm
c	6.1 mm
a_d	4.25 mm
b_d	4.03 mm
ε_d	10.2
ε_r	10.2
DIL Length = 3λ	66.67mm

Table 1: Dimensions of the antenna structure.

modes. The presence of ground plane lead to propagating only TM_{mn}^z mode [5]. The dimension of the DIL is chosen in such a way that only the principal mode of operation, TM_{11}^z is excited over a considerable range of frequency around 10 GHz. This structure has two ports as show in Fig. 2. Port one is defined as the input to excite the TE_{10} mode of metal waveguide. The second port at the output is terminated to a matched load so; a travelling wave is propagated in DIL which efficiently excites the RDRA at the resonance frequency. For simplicity, all simulations are carried out for infinite ground. The slot on the ground plane upon which the RDRA is located determines the amount of power coupled from the DIL to the resonator. The slot operates as a magnetic current in parallel to the resonator length exciting the RDRA at the principal TE_{111} mode of the operation [4, 7].

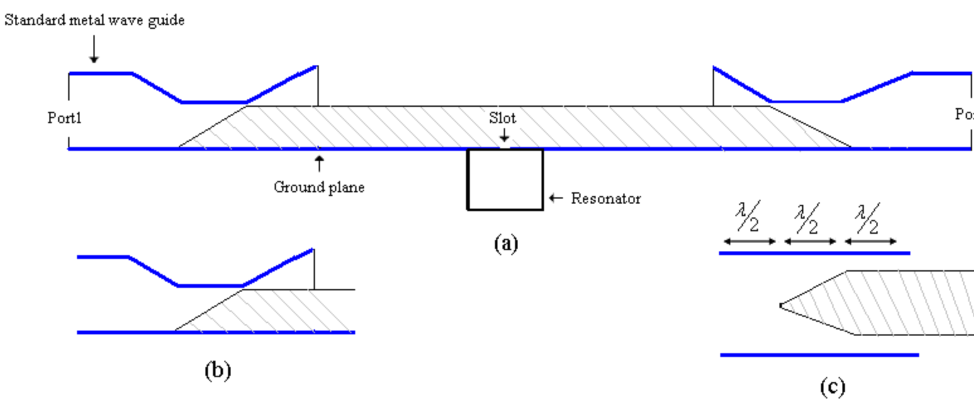


Figure 2: (a) Feed structure of the RDRA, (b) side view of the feed port, (c) top view of the feed port.

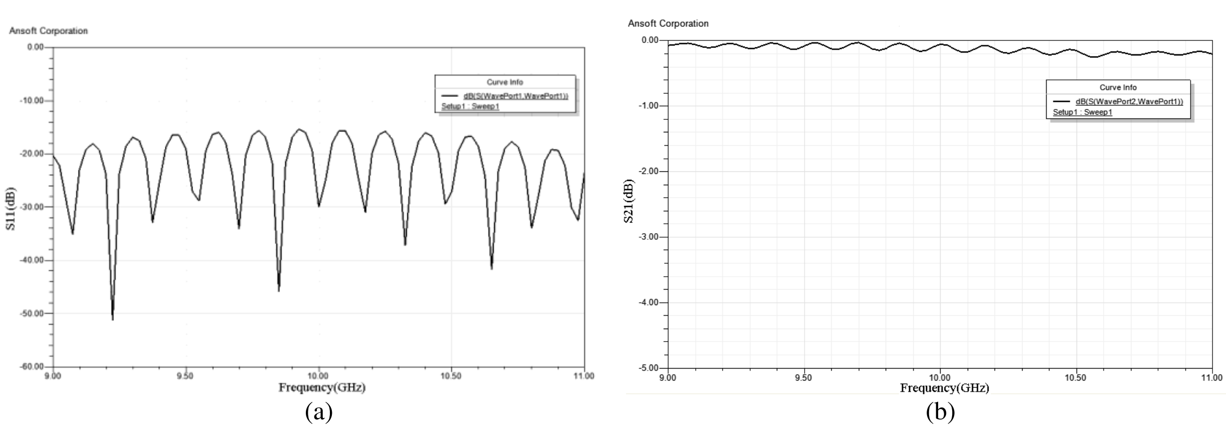


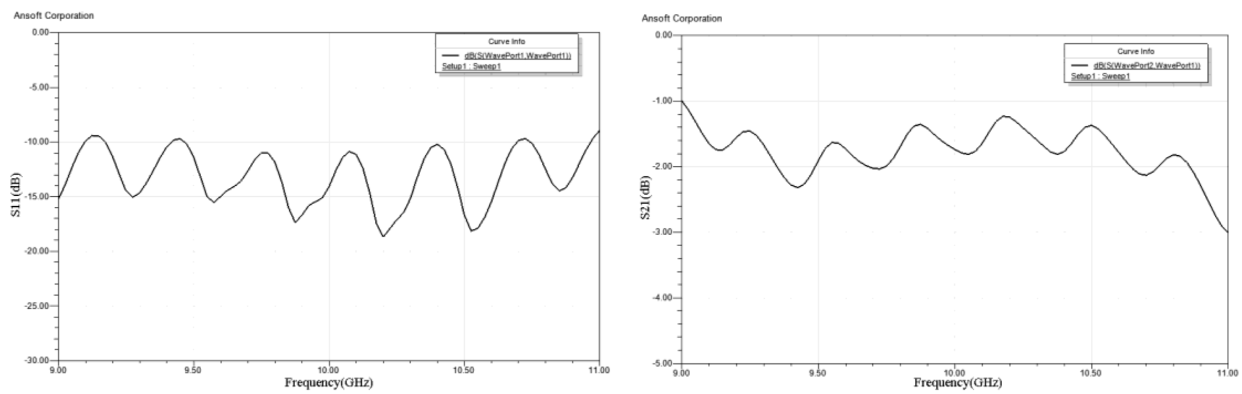
Figure 3: (a) Return loss and (b) transmission coefficient of the antenna structure for only DIL without slot and RDRA.

4. RESULTS

Return loss of the simulated DIL is shown in Fig. 3(a). it can be seen a good matching condition is obtained at input port. Fig. 3(b) shows the transmission coefficient of the DIL, while port 2 is also considered as an exciting port. It can be seen that over the frequency range of 9 GHz to 11 GHz, insertion loss of less than 0.3 dB is obtained that providing well propagation at the operation mode.

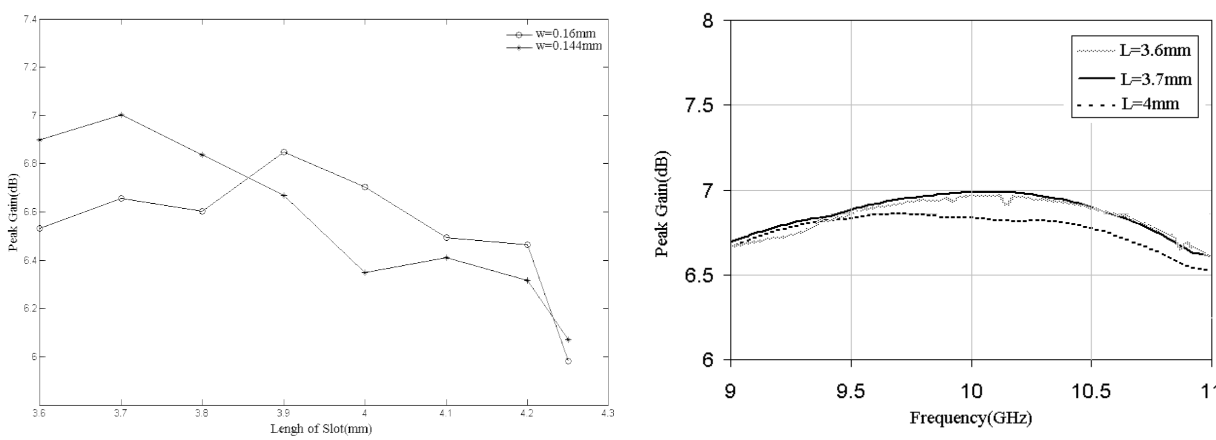
The simulated return loss and transmission coefficient of the whole structure, including DIL, slot and RDRA, is shown in Figs. 4(a) and 4(b). It can be seen that a good matching at input port, while about at 10.1 GHz most of the input power is radiated by RDRA and a part of power is delivered to the matched load.

Figure 5(a) shows the effect of the slot on the antenna gain. Fig. 5(b) shows the antenna gain versus frequency for different slot length and constant slot width of $W = 0.144$ mm. From both figures can be seen that maximum gain of 7 dB is obtained for the optimum slot length and width of $L = 3.7$ mm and $W = 0.144$ mm respectively. In Fig. 6 the return loss is shown for the optimum slot size which is similar to Fig. 3(a). Co polarization and cross polarization radiation patterns of the RDRA for the optimum slot size and infinite ground plane are shown in Fig. 7(a) and Fig. 7(b) respectively. Radiation patterns of the structure are broadside perpendicular to the ground plane. It can be seen that the RDRA radiates a linear polarized wave where the cross polarized level is at least 30 dB lower than the co-polarized in E- and H-Plane patterns.



(a) (b)

Figure 4: (a) Return loss and (b) transmission coefficient of the antenna structure including DIL, slot and RDRA.



(a) (b)

Figure 5: (a) Peak gain of RDRA versus slot length for two values of width, (b) RDRA gain versus frequency for different slot length and constant width of $W = 0.144$ mm.

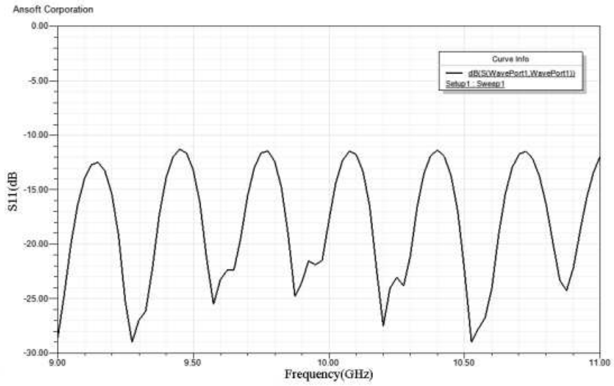


Figure 6: Return loss for optimum slot.

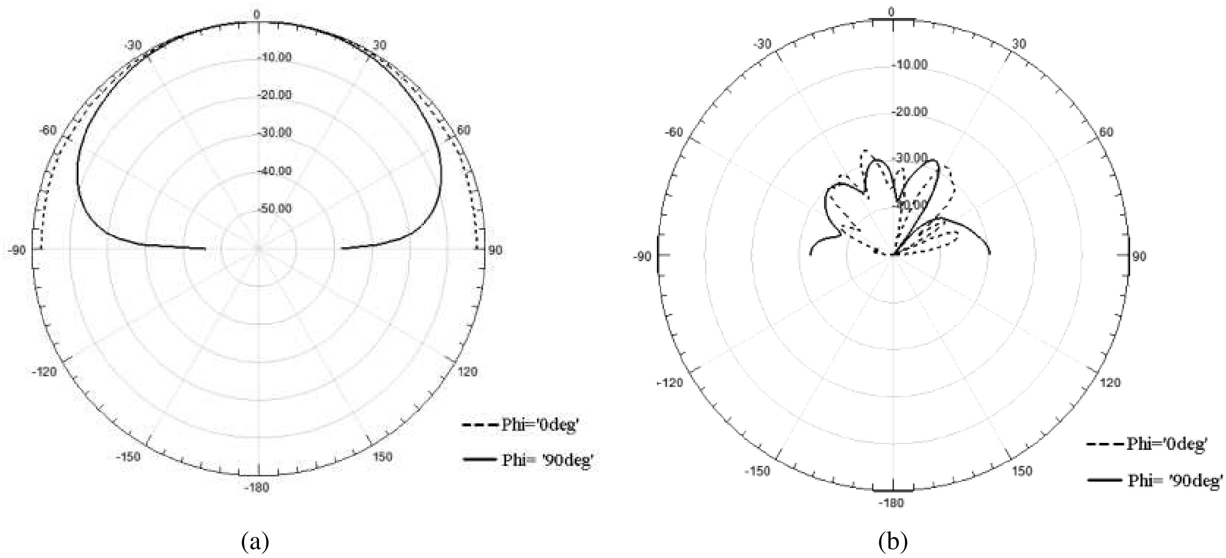


Figure 7: Radiation pattern at optimum dimension of slot for (a) co polarization, (b) cross polarization.

5. CONCLUSION

In this paper the slot coupled RDRA fed by a Dielectric Image Line (DIL) was investigated numerically using HFSS package for an infinite ground plane. For a specific dielectric resonator a parametric study for the slot size was carried out and optimum slot was obtained at the resonance frequency of 10 GHz. A good return loss and a linear polarized broadside radiation patterns was obtained. Results show 7 dB gain at the resonance frequency of the resonator while the cross polarization level is at least 30 dB lower than the co polarization patterns. However, further investigation is needed to consider the effect of finite ground plane on the radiation performance of the antenna structure.

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REFERENCES

1. Luk, K. M. and K. W. Leung, *Dielectric Resonator Antennas*, Research Studies Press Ltd., Baldock, Hertfordshire, England, 2003.
2. Petosa, A., *Dielectric Resonator Antennas Handbook*, Artech House Inc., 2007.
3. Baghaee, R. M., M. H. Neshati, and J. R. Mohassel, "Rigorous analysis of rectangular dielectric resonator antenna with a finite ground plane," *IEEE Transaction on Antenna and Propagation*, Vol. 56, No. 9, 2801–2809, September 2008.

4. Al-Zoubi, A. S., A. A. Kishk, and A. W. Glisson, "Analysis and design of a rectangular dielectric resonator antenna FED by dielectric image line through narrow slots," *Progress In Electromagnetic Research*, PIER 77, 379–390, 2007.
5. Antar, Y. M. M. and Z. Fan, "Theoretical investigation of aperture-coupled rectangular dielectric resonator antenna," *IEE Proc. — Antennas Propag.*, Vol. 143, No. 2, 113–118, April 1996.
6. Kanamaluru, S., M.-Y. Li, and K. Chang "Analysis and design of aperture coupled microstrip patch antennas and arrays fed by dielectric image line," *IEEE Transaction on Antenna and Propagation*, Vol. 44, No. 7, 964–974, July 1996.
7. Bhartia, P. and I. J. Bahl, *Millimeter Wave Engineering and Applications*, John Wiley, New York, 1984.
8. HFSS, High Frequency Structure Simulator Based on Finite Element Method, v.11, Ansoft Corporation.