Comparative Investigation of Dielectric Image Line-Slot and Microstrip-Slot Coupled Rectangular Dielectric Resonator Antenna

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Abstract - *Two Dielectric Resonator Antenna (DRA) structures, Dielectric Image Line-slot and Microstrip-slot fed, are numerically investigated using two commercial software, HFSS and CST. Radiation characteristics of both antennas including return loss, radiation patterns and gain variation versus frequency are presented and compared for two DRAs. The effects of ground plane loss and dielectric loss on the radiation performance of the* antennas *are investigated. The results show that DIL-slot fed DRA has lower loss compare to microstrip-slot coupled DRA at 9.9 GHz.*

Keywords - *Dielectric Resonator Antenna, Dielectric Image Line, Microstrip-slot Coupled*

1. INTRODUCTION

Dielectric Resonator (DRs) made of low loss and high dielectric constant materials have been widely used as an energy storage component or tuning element in microwave circuits such as filters and oscillators. DRs are small in size, light in weight and have low cost and high temperature stability [1-2]. They have replaced waveguide cavities especially in MICs and MMICs. Like metallic cavity resonators, DRs can be excited to resonate at different modes. For circuit applications, the mode of operation is usually chosen in such a way that radiation is minimized. So, the resonators are enclosed in metallic shield to prevent radiation and provide a high *Q* factor. However, open DRs can be used as an electromagnet radiator offering high radiation efficiency. Different shape of resenators such as cylindrical, hemispherical, cylindrical rings and rectangular have been reported in literatures. Common methods for fed DRAs are all types of transmission line such as coaxial probe, microstrip line, microstrip-slot coupled and coplanar waveguide [1-3].

Microstrip-slot coupled excitation of DRs is one of the most common method for antenna application due to the printed technology which is easy to fabricate and present a good method of impedance matching [2,6]. But the radiation efficiency of this type is reduced at high frequencies due to skin effect and high conductive of the feed line. Dielectric transmission lines such as Dielectric Image Line (DIL) have lower losses at microwave frequencies compare to conventional transmission line [4,5,8].

In this paper a rectangular DRA fed using two methods; DIL-slot and microstrip-slot fed through a narrow slot on ground plane is numerically investigated. Both of antenna structures is studied based on the Finite Element Method (FEM) using High Frequency Structure Simulation (HFSS) and Integral Equation Time Domain using CST microwave studio package. The radiation performance of both structures are presented and compared.

2. ANTENNA STRUCTURES

The geometry of antenna structure fed by DIL and microstrip line is shown in Fig. 1. A rectangular DRA of length a, width b and height c with relative permittivity of ε_r is placed on metallic ground plane. In Fig. 1-a Dielectric Image Line as a transmission media, consist of a rectangular dielectric slab of relative permittivity ε_{rd} placed under the ground plane. A narrow slot of length L and width W is etched at the center of the ground plane is used to excite the DR at the dominant mode of operation.

The second antenna, microstrip-slot coupled DRA is shown in Fig. 1-b. A 50 Ω feed line is etched on the bottom side of a substrate with relative permittivity $\varepsilon_{rs.}$ The coupling slot same as the first antenna is etched at the center of the metal plane. The ground plane size for DIL-slot and microstrip-slot antenna is 134.2 mm×140 mm and 50 mm×50 mm respectively with a metal thickness of 35 μm. All dimensions of two structures are summarized in Table 1.

The most important feature of both structures is placing the feed network of the antenna at the backside of the ground plane, isolating the radiating parts from spurious radiation provides by DIL or microstrip line especially at high frequencies[1-2].

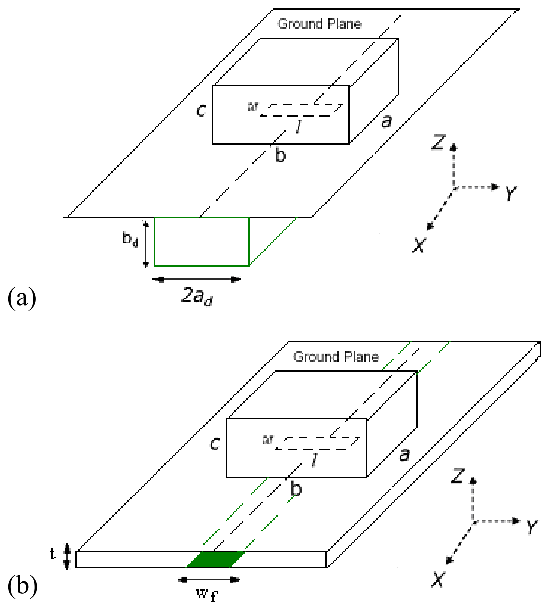


Fig. 1. The geometry of the DRA fed by a) DIL, b) microstrip line through a narrow slot

Table 1. Antenna Dimensions

DR		**DIL**		**Microstrip**	
		a_d	4.25 mm	W_f	2.45 mm
a	6.2 mm	b_d	4.03 mm	h	0.787 mm
b	6 mm	ε_{rd}	10.2	ε_{rs}	2.2
c	6.1 mm	L	4 mm	L	4 mm
ε_{rd}	10.2	W	0.15 mm	W	0.15 mm

3. ANTEENA SIMULATION

The RDRA structures are numerically investigated using HFSS [7]. To verify the accuracy of the obtained results, both structures are also investigated using CST software. Simulated technique in HFSS is based on the Finite Element Method (FEM), while CST it is based on the Integral Equation Time Domain. Both software calculate the full 3-D electromagnetic fields inside and outside (far field) of the structures.

Fig. 2-a shows the detailed structure of the first antenna defined in simulations. A standard metal waveguide is used to excite the DIL, at the input and output of the transmission media [8,9]. 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. The dimension of the DIL is chosen in such a way that only the principal mode of operation, TM^{z}_{11} is excited over a considerable range of frequency around 10 GHz.

Fig. 2-b show the microstrip-slot coupled DRA. 50 Ω terminated to a matched load is used as the transmission media. Both structures include two ports. Port one is defined as the input to excite the feed line, while the second port at the output is terminated to matched load. As a result, a travelling wave is propagated in DIL and microstrip line which efficiently excites the RDRA at the resonance frequency thorough the non-resonate narrow slot

The slot on the ground plane upon which the RDRA is located, determines the amount of power coupled from the DIL and microstrip line 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 [1-2]. To achieve strong coupling to the RDRA the slot is located in center of RDRA.

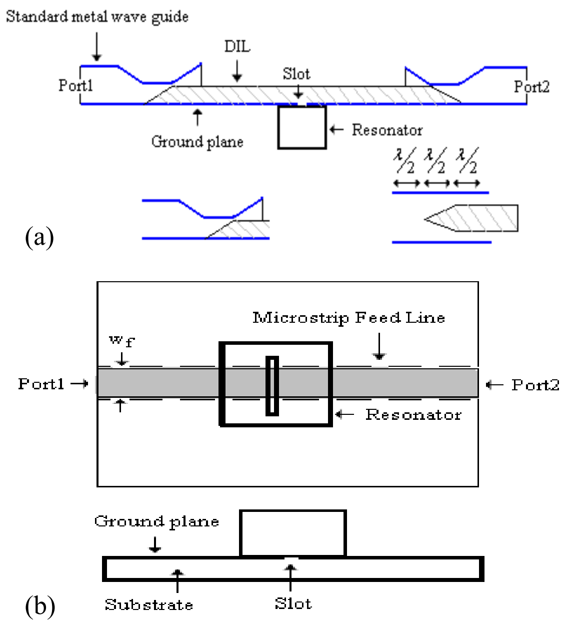


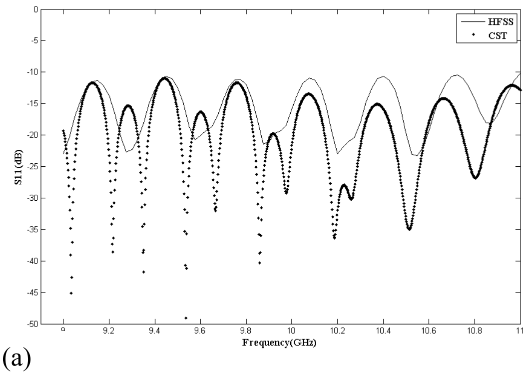
Fig. 2. Detailed feed structure of RDRA in simulation: a) DIL, b) microstrip line

4. RESULTS AND DISCUSSION

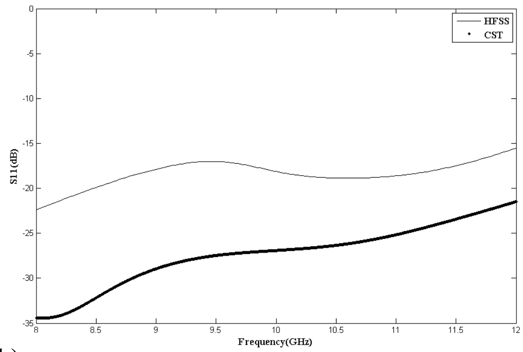
Return loss of the simulated antennas fed by DIL and microstrip line through a slot are shown in Fig. 3-a and Fig. 3-b respectively. It can be seen that a good matching is obtained at input port for both feed lines. In the first structure, there is ripple in S_{11}, while in the second structure no ripple can be seen. This is due to existence of the DIL in antenna structure [4].

Radiation patterns for two structures are shown in Fig. 4, which are broadside perpendicular to the ground plane for both antennas. The ripples in patterns are due to diffraction from the edge of the ground plane, however, there is more ripple in antenna DIL structure compare to the microstrip line.

Fig. 5 shows the variation of antennas gain versus frequency for two structures in different situations. In ideal situation, the maximum gain of the first structure is 7.46 dB at 9.925 GHz, while for the microstrip-slot fed, gain is 6.5 dB at 10 GHz. Also, it can be seen the DIL-slot fed structure has lower beamwidth than the second one, which is due to the lower size of the ground plane for the second structure.

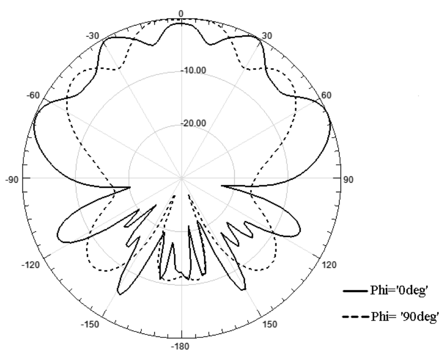


(a)

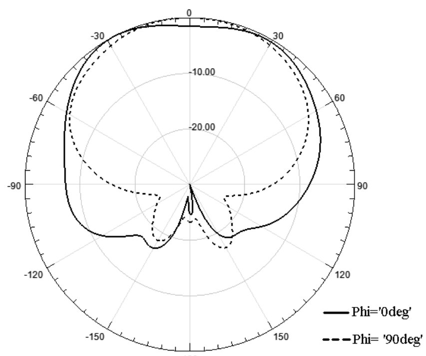


(b)

Fig. 3. Return loss of RDRA: a) DIL, b) microstrip line



(a)



(b)

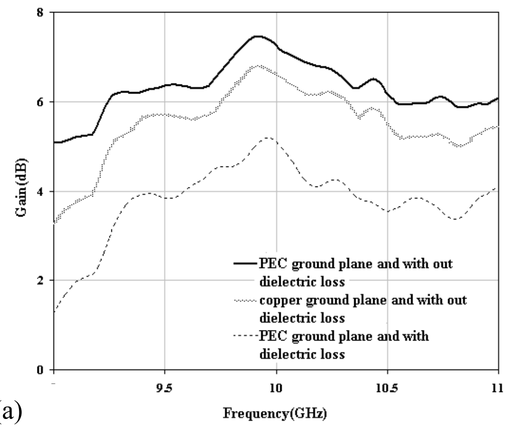
Fig. 4. Radiation pattern of the RDRA: a) DIL, b) microstrip

To take into account the effects of dielectric loss and non-ideal properties of the ground plane, both antennas are simulated considering conductive loss of the ground plane is made of copper. Numerical investigation is carried out using tan δ = 0.0009 for DIL line and substrate of the microstrip board. It can seen that copper ground plane would lower gain, while in microstrip-slot DRA gain is more decreased due to metal loss at 9.9 GHz. Table 2 summarize gain avlues for both structures in case of different situations.

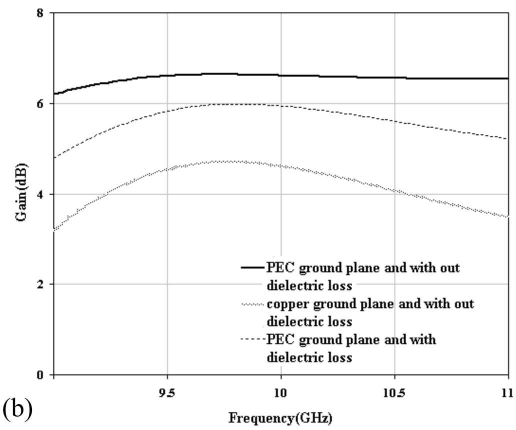
The results considering dielectric loss are also shown in Fig 5-a and 5-b in gain versus frequency variation plots. It can be seen that the DIL-slot coupled structure would present lower gain than the other structure due to bigger size of dielectic material. However, using a lower loss dielectic material as the feed network of the strcture would offer higher gain.

Table 2. Antennas gain (dB) at 9.9 GHz

situations	DIL	Microstrip
ideal (no loss)	7.46	6.5
dielectric loss	5.18	5.97
copper ground	6.8	4.67



(a)



(b)

Fig. 5. Effect of dielectric loss and metal loss on RDRA gain a) DIL, b)microstrip

5. CONCLUSION

In this paper two dielectric resonator antennas (DRAs) fed by DIL-slot and microstrip-slot, was numerically investigated using commercial software packages. Radiation performance of both antennas including return loss, radiation patterns and gain variation versus frequency were presented. Moreover, the effects of no-ideal properties of dielectric and metal parts of structures were also studied. The results show good agreement for individual antennas using HFSS and CST software. Also, metal parts of microstrip-slot DRA would lower gain more than the DIL-slot DRA. Considering same dielectric loss in both structures, dielectric loss is more effective in DIL-slot fed antenna. However, using a lower loss material would increase gain in DIL-slot DRA.

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