FINITE ELEMENT ANALYSIS & EXPERIMENTAL STUDIES OF MICROSTRIP-SLOT COUPLED RECTANGULAR DIELECTRIC RESONATOR ANTENNA

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ABSTRACT: A Microstrip-Slot Coupled Rectangular Dielectric Resonator Antenna (RDRA) operated at fundamental mode of operation TE^{y}_{111} is investigated numerically and experimentally. The effect of slot size on the radiation characteristics of the RDRA is studied. The antenna structure is simulated using the Finite Element based software package. A few experimental set-ups were implemented and the antenna parameters were measured. The simulated results are presented and compared with those obtained by experiments. It is shown that the size of the slot can significantly affect the radiation properties of the RDRA and there are good agreements between numerical and experimental results.

Keywords: Dielectric Resonator, Antennas, Finite Element Method, Microstrip-Slot Coupling

1. Introduction

Advanced dielectric materials made of low loss and high dielectric constant, are useful as Dielectric Resonators (DRs) for microwave applications. They are small in size, low in weight, low cost and are alternative to metallic resonant cavities where they have the advantage of size reduction without reduction in performance. With appropriate feed arrangement, DRs can also be used as antennas [1]. The low loss property of dielectric materials lead to high radiation efficient antennas, which is of great interest for portable and mobile communication units. It has been reported that cylindrical [2], rectangular [3], hemispherical [4], half-split cylindrical [5] and cylindrical ring [6] shaped dielectric resonator, could operate as antennas and provide efficient radiation. They can be fed using different feed arrangements including an axial probe, microstrip transmission line, microstrip-slot and co-planner waveguide.

The slot coupling scheme was fist introduced by Pozar [7] for microstrip antennas. Then, it was used by Martin [8] for a cylindrical DRA. In 1994 Shum [9] numerically analysed a slot coupled RDRA using Finite Difference Time Domain (FD-TD) and return loss was calculated. Theoretical analysis of a microstrip-slot coupled RDRA based on the modal expansions and the spectral domain approach was developed by Antar [10].

In this paper, a microstrip-slot coupled RDRA operating at fundamental TE^{y}_{111} mode is investigated numerically using the Finite Element Method (FEM) and the results are compared with those obtained by experiments.

2. Antenna Structure

The structure of the RDRA under investigation is shown in Figure 1. It consists of a dielectric resonator with dimensions $19\times19\times9.5mm^3$ and ε_r=38 which is located on the ground plane of a microstrip line and feed through a non-resonant narrow slot. The slot of length L_a and width W_a is etched on the ground plane of the microstrip line. The open stub at the end of the line is L_s=22mm long, which is nearly $\lambda_g/4$ where the magnetic field is maximum, from the centre of the slot. The feed line is etched on the bottom side of a piece of RT / Duriod 5880 with dimensions 90mm (length), 80mm (width), 0.787mm (thickness), relative dielectric constant of 2.2 and copper thickness of 35µm. The line is 63mm long and 2.45mm wide giving a characteristic impedance of 50Ω.

3. Antenna Simulation

The antenna structure is simulated using the HP85180A High Frequency Structure Simulator (HFSS), which is a software package to calculate S-parameters of the high frequency structure such as transmission lines and antennas.

The simulation technique is based on the FEM calculate the full 3-D electromagnetic fields inside and outside (far field) of the structure. In general, in the HFSS the geometric model is automatically divided into a large number of elements, called thetrahedra, and all these elements together are refereed to the finite element mesh. The fields in each element are represented by a local function. The value of a vector field quantity, E- or H-field, at a point inside the element is obtained using interpolation based on the value at the vertices of the each element. Antenna structures can be analysed using the HFSS by defining a surface, which totally surrounds the structure as an absorber boundary. This surface represents as an open space and is allowed to radiate the waves instead of being contained within [11].

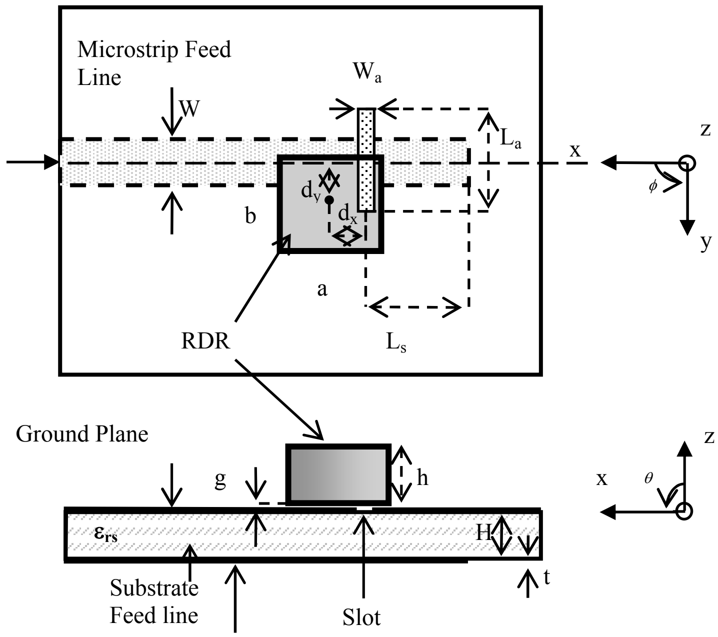

Figure 1: The microstrip-slot coupled RDRA structure

4. Results

The effect of the slot size on the radiation performance of the antenna is studied first. The resonator is placed on a non-resonant coupling slot where d_x=d_y=0, which makes a symmetrical coupling between the resonator and the slot. The slot length L_a is varied from 6mm to 14mm and its width W_a is varied between 0.2mm to 1.8mm. The simulated results for reflection coefficient S_{11} and the resonance frequency versus slot length for different values of W_a are shown in Figure 2. It can be observed for each slot width, there is an optimum length for critical coupling. The optimum slot length decreases as the slot width is increased. For the considered range of slot size, the reflection coefficient varies between ~ –0.5dB and ~–32dB. For slot width $W_a \geq 1$mm, the maximum coupling occurs at the slot length of 9mm. Therefore, the optimum coupling can be obtained by adjusting the slot size. It can be seen that increasing the slot width or length result in the resonance frequency to decrease.

Figure 3 shows the variation of the measured return loss and resonance frequency of the RDRA versus slot length and different value of the sloth width. It can be seen there is an optimum slot length for best coupling for each value of width. The measured radiation patterns are shown in Figure 5 and which shows that patterns are not sensitive to the slot area. The experimental results together with the predicted values in case of best matching point at W_a=1.4mm, L_a=9mm are summarized in Table 1. The resonance frequency differs by only ~7%, which is believed to be due to fabrication imperfection such as gap due to surface roughness in antenna structure. The measured radiation patterns are also plotted in Figure 4 which shows that the patterns are not affected by the size of slot.

5. Discussion and Conclusions

The microstrip-slot coupled RDRA was analyzed using FEM. Result indicates that the slot area is a good parameter to obtain impedance matching in RDRA. However, there is an error in the simulated resonance frequency and bandwidth of the RDRA in compare to the measurement. This is believed to be due to fabrication imperfection such as air gap between the slot and resonator in the antenna structures that is needed to be taken into consideration in numerical modeling to produce more accurate prediction which needs more investigation. Also, the radiation patterns are not affected by the size of the slot.

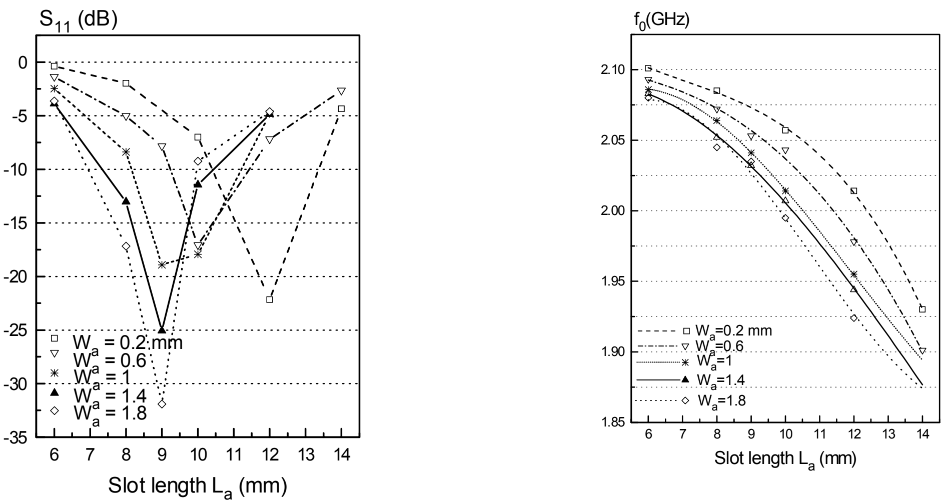

Figure 2: Simulated reflection coefficient and resonance frequency of the microstrip-slot coupled RDRA versus slot length and different values of width.

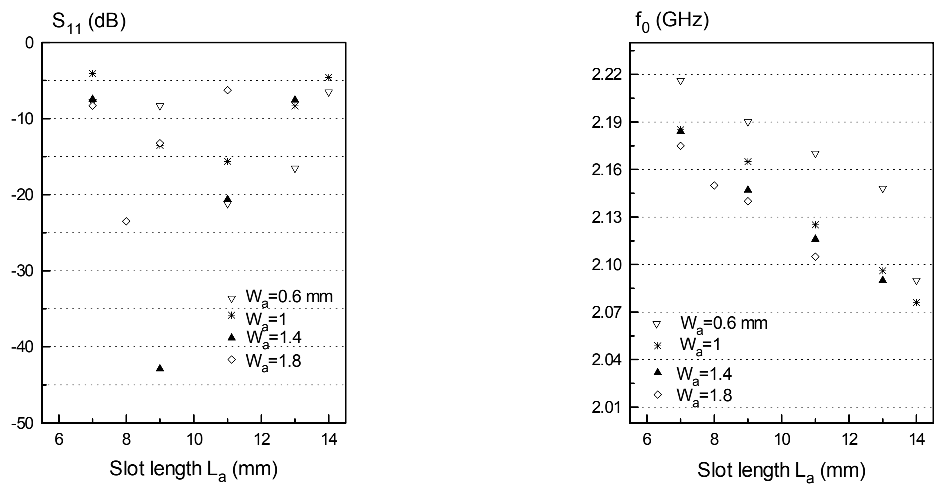

Figure 3: The measured resonance frequency and reflection coefficient of the microstrip-slot coupled RDRA versus slot length and different values of width.

Table 1. The simulated and measured results of the microstrip-slot coupled RDRA at the best coupling condition for W_a=1.4mm, L_a=9mm.

	Simulation	**Measurement**
$\mathbf{f_0}$ (GHz)	2.032	2.147
Return loss (dB)	25.064	42.877
BW (%) VSWR≤2.6	2.25	2.7
Directivity, Gain	3.54	3.02
Input Resistance (ohm)	51.723	48.67
Input Reactance (ohm)	-j0.02	-j0.02

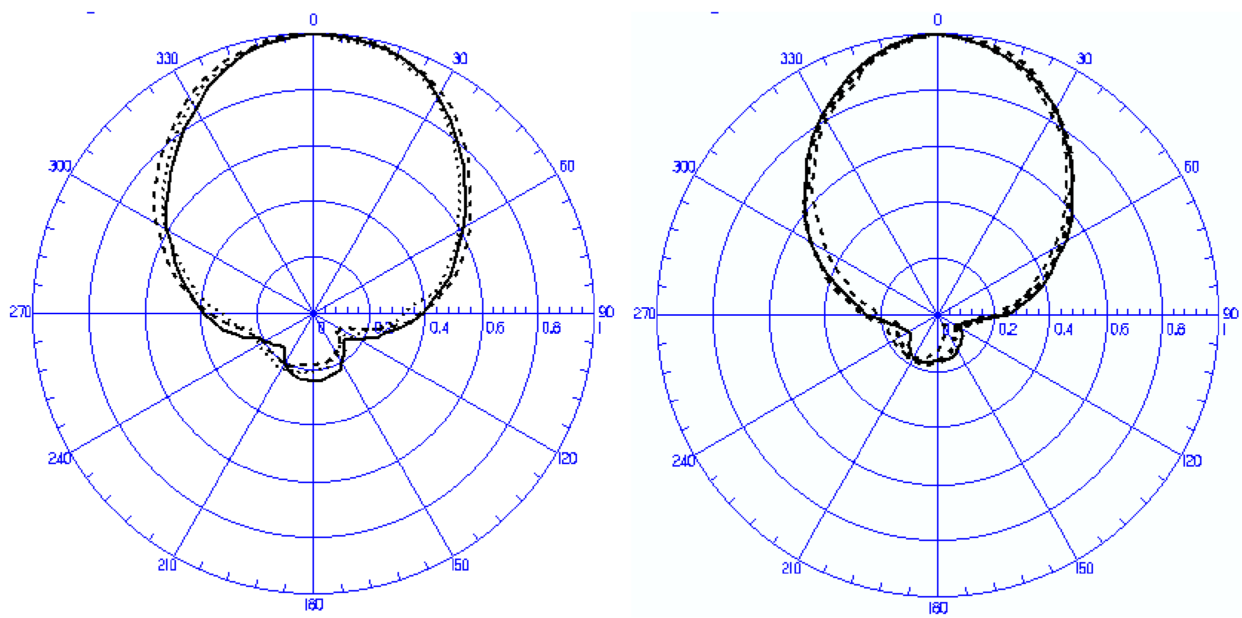

Figure 4: The measured radiation patterns of the microstrip slot-coupled RDRA for W_a=1.4 mm and different slot length. (L_a=7 mm ·················· L_a=9 mm ———— L_a=11 mm - - - - - -)

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