An Array of Dielectric Resonator Antenna for wireless application

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***Abstract* —** This project describes a design on array dielectric resonator antenna using disk shape. The dielectric resonator antenna (DRA) consists of high dielectric constant materials, high quality factors and mounted on a grounded dielectric substrate of lower permittivity. DRA is fabricated from low-loss and high relative dielectric constant material of various shapes whose resonant frequencies are functions of the size, shape and permittivity of the material. Two dielectric resonators is introducing as an array. The selected dielectric disks are operating at frequency of 2.4 GHz with dielectric constant of 34.73. The miscrostrip transmission line has been used as a feeding line for the resonator. The microstrip line is quarter wavelength where the frequency that applied from the input can get same with the output and divider was introduced in this layout. The simulation process was done using Computer Simulation Technology (CST) Microwave Studio. The antenna has been fabricated on the FR-4 microstrip board using the wet etching technique. The DRA is operating at the frequency bands used for IEEE 802.11b/g Wireless LANs.

Keywords— An Array DRA, DR, Transmission line feed, Microstrip line.

1. INTRODUCTION

Dielectric Resonator Antenna (DRA) is fabricated from low-loss and high relative dielectric constant material of various shapes whose resonant frequencies are functions of the size, shape and permittivity of the material. DRA can be in a few geometries including cylindrical, rectangular, spherical, half-split cylindrical, disk, and hemispherical shaped. The fact that dielectric resonators radiate energy was proven by Richmyer in 1939 however practical application did not take place until the 1960's when suitable dielectric compounds became available [1]. Dielectric resonators were first popular as filter elements devices in microwave circuits with the first reported use as a radiating element not until the early 1980's when the smaller size potential and higher frequency applications boosted the research into the dielectric resonator antenna. The DRA has some interesting characteristics, like the small size, ease of fabrication; high radiation efficiency, increased bandwidth and low production cost, and DRA are very promising for application in wireless communications.

DRAs offer several attractive features including:

- High dielectric constant $\varepsilon_r = 20 – 100$
- High radiation efficiency (≈ 95%) due to the absence of conductor or surface wave losses
- Wide control over size and bandwidth
- Tight ε_r tolerance: ± 1- 5%,
- High quality factor Q: up to 10000 (f = 10GHz)
- Wide frequency range: f = 0.7 - 35GHz
- Wide range of temperature coefficient of resonance frequency: τ_f = (-12…+30) ppm/ °C
- Tolerance τ_f = ± 0.5; ±1.0; ±2.0 ppm/ °C

2. DIELECTRIC RESONATOR ANTENNA DESIGN

The summary of the design for an array DRA is shown in Figure 1. In simulation, two methods have been introduced such as layout design which is called Method of Moments (MoM).

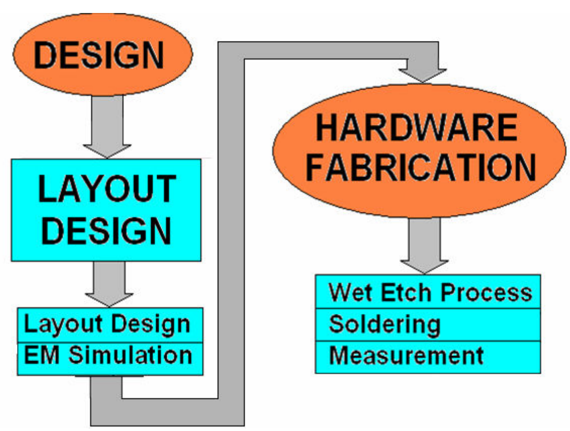

Figure 1: The Design and fabrication Workflow

For MoM, the design was done using CST Microwave studio software. Analysis on simulation results have been made to get optimum results before proceeds to the fabrication process. The fabrication process was done on the FR-4 microstrip board with a dielectric constant (ε_r = 4.5), the thickness of substrate (h = 1.6 mm) and loss tangent (tan δ =0.019) using the wet etching technique.

Figure 2 shows the prototype of array DRA. The DRA is located on top of microstrip line. This method is attractive due to the low cost and eases of fabrication, since there is no requirement to etch both sides of the substrate, as required in the aperture coupling technique. The amount of coupling is depending on the permittivity of the dielectric, the higher the permittivity the higher the coupling. However, the higher permittivity of the dielectric material yields the lower bandwidth. The specification of the dielectric resonator is shown in Table 1.

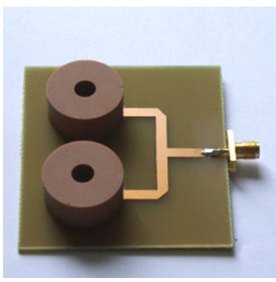

Figure 2: The disk shape of Dielectric Resonator antenna

Table 1: Data of the Dielectric Resonator

Parameters	Values
Part Name	C8371-0945-438-262 Ceramic batch #QC1266470
Outer Diameter	24 mm
Inner Diameter	6.6 mm
Height	11.1 mm
Dielectric Constant	34.73
Frequency Approx.	2.415 GHz

An important parameter for DRA is its resonant frequency. The resonant frequency of the DRA is given by [7]:

$$f_r \approx \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{2\left(\frac{\pi}{a}\right)^2+\left(\frac{\pi}{2b}\right)^2} \qquad (1)$$

Where:

- f_r : resonant frequency of TE_{mnp}- mode
- a : diameter of the dielectric resonator
- b : height of the dielectric resonator
- ε_r : permittivity of the dielectric
- c : velocity of light ($\approx 3 \times 10^8$ m/s)

From equation (1) the resonance frequency of a dielectric resonator depends on the dimensions of the resonator and its dielectric constant. Therefore, the DRA size decreases as the dielectric constant increases.

Wavelength of the dielectric resonator is important because from this wavelength the dimensions of microstrip circuit can be designed. The equation of the wavelength is given by:

$$\lambda = \frac{c}{f_r\sqrt{\varepsilon_r}} \qquad (2)$$

The guided wave length has been calculated at frequency 2.4 GHz. The length is selected to ensure that the dielectric resonator will resonate upon excitation by a magnetic field. For simplification the frequency that has been applied from the input will resonate at the desired frequency. The length of microstrip line obtained from the calculation is 3 mm for the width and 14 mm for the length of the microstrip line.

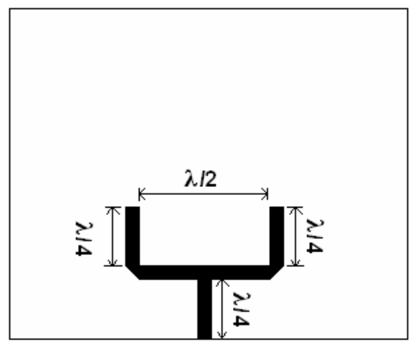

Figure 3: the size of an array DRA

The design of an array DRA as shown in Figure 3. From the Figure 3, the microstrip line for array is quarter wavelength (λ/4) from the wavelength calculated (λ) so that to yield the desired frequency that is 2.4 GHz. The concept that the lengths are carefully selected is to ensure that the dielectric resonator will resonate or oscillate upon excitation by a magnetic field. That means the frequency that applied from the input will resonate or oscillate at the desired frequency.

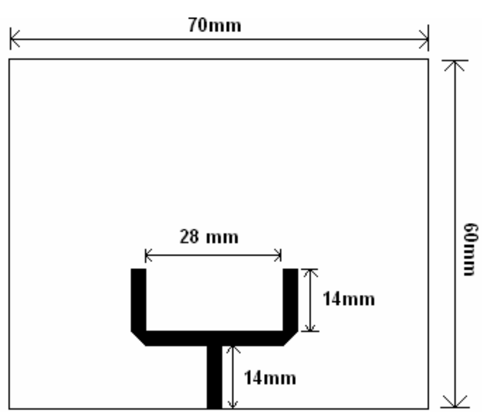

Figure 4: The actual size of an array DRA

Figure 4 is the actual size of an array DRA. The optimum distance between DR and microstrip line are determined by simulation and measurement. This is base on the trial and error approached. From the experimental work, the best distance obtained between DR and microstrip line is 4 mm as shown in Figure 5.

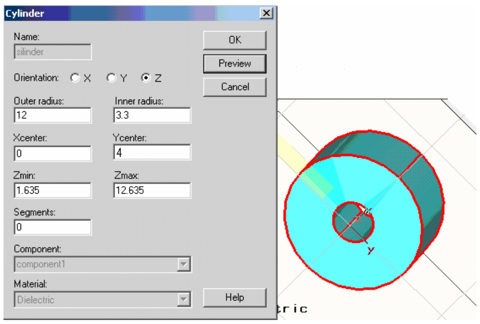

Figure 5: The distance between DR and microstrip line using CST software

RESULT AND DISCUSSION

Figure 6 shows the comparison between simulation and measurement result. It shows that the simulation and measurement give the comparable result. The return loss for simulation is -16.71 dB at frequency 2.3238 GHz. The measurement result gives the return loss of -15.82 dB at frequency 2.34 GHz. The bandwidth for simulation and measurement is 109 MHz and 134.34 MHz respectively. The frequency has been from measurement and simulation to the lower range of frequency. This will be explained in the end of the discussion.

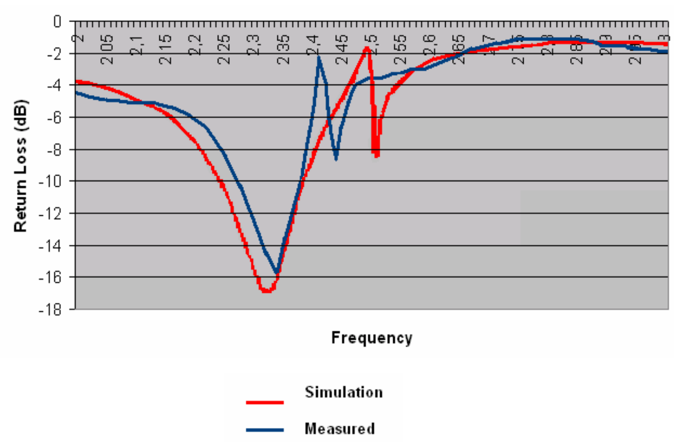

Figure 6: The graph between the simulation and measurement results.

Table 2: Simulated and Measured Return Loss and Bandwidth for array DRA

Parameter \ Method	Simulation	Measurement
Frequency Resonant	2. 3238 GHz	2.34 GHz
Return Loss	-16.71 dB	-15.82 dB
Bandwidth	134.34 MHz	109 MHz
Percentage Bandwidth	5.81 %	4.688 %

Table 2 shows the simulation and measurement results for return loss and bandwidth of DRA. The desired frequency resonant is at 2.4 GHz and the tolerance is between ± 0.2%. The simulation, measurement and calculation using the formula given in equation (1) are within the range of frequency resonant. A good antenna should indicate a return loss of less than -10 dB, which indicates that the antenna absorbs more than 90% of the fed power. The designated DRA is suitable for Wireless LAN IEEE 802.11b/g of Wireless LAN application since its bandwidth is within the range of the application.

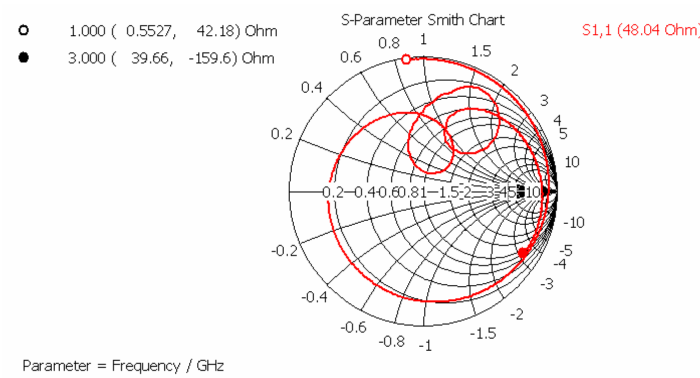

Figure 7: The input impedance of the DRA in S-Parameter Smith Chart

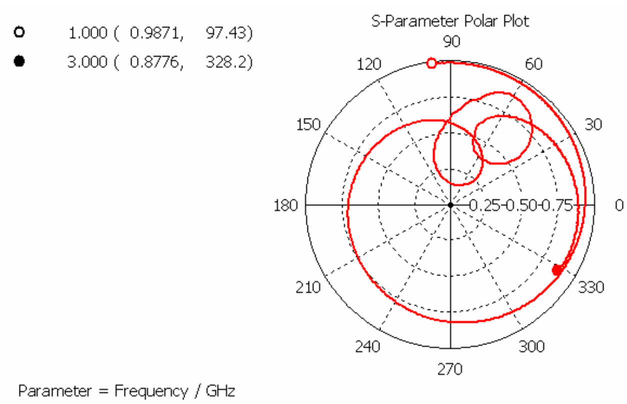

Figure 8: The input impedance of array DRA in S-Parameter Polar Plot

Figure 7 and Figure 8 is the input impedance of the DRA at 2.3238 GHz in polar plot and smith chart respectively. This input impedance is important to matching the impedance.

From polar plot as shown in Figure 7, the magnitude at 1 GHz frequency is 0.9871 and degree is about 97.43^0. At 3 GHz the magnitude is 0.8776 and degree is 328.2^0. From the smith chart as shown in Figure 8, the input impedance is 48.04 Ω approximately is 50Ω. At 1 GHz frequency the input impedance is 0.5527- j42.18 Ω that means the real part of the impedance is about 0.5527 and an imaginary part, with a value of 42.18 as shown in Figure 5.24. For 3 GHz the input impedance is 39.66 – j159.6 Ω.

It can be obtained that the measurement of the resonance frequency has been shifted to the lower frequency compared to the simulation. There are a few factors contribute to this effects. This is listed as below:

3.1. Adhesives for Dielectric Resonator

Adhesives will pull the DR frequency. It's possible for the frequency to go up or down, depending upon the mode, the adhesives' dielectric constant, and how the adhesive interacts with the E fields. The adhesive will behave as a thin spacer, with bond line that must be process-controlled, between the resonator and the support. This space is filled with a dielectric constant lower than the ceramic, and that effect must be verified experimentally.

3.2. Environment

Environment for the place that the measurement taken is one of the main factors effect the frequency shifted. Suppose the around the environment should be in vacuum so the better results because human, another equipment, win, and another environment fact can effect for the measurement results.

3.3. Equipment

Equipment used for measurement purpose should be in a good condition. All procedure for using the equipment must be followed and supervised by a person who expert in using the equipment or experience technician. The calibration must be done before started to use the equipment.

3.4. Fabrication process

Accuracy is vital in this stage, any minor mistake make an impact on the results. Proper fabrication must be considered while preparing the layout of DRA, etching process and cleanliness.

3.5 Design discussion

There is three general design rules can be apply to any DRA. In this paper, each will be individually addressed and applied to the design of DRAs such as given:

3.5.1 Rule 1

The first rule is the relative permittivity of the material gets higher, both the resonant frequency and the bandwidth go down. The opposite is true, as the relative permittivity gets lower. The single DRA has one resonance; the two- DRA has two resonances as shown in the result.

3.5.2 Rule 2

The second rule is that most of the power radiates through the top surface of the DRA.

3.5.3 Rule 3

The third rule is the DRAs radiate like a cavity because a dielectric-air interface behaves like a perfectly conducting magnetic wall when the relative permittivity of the dielectric is very high. The higher it is, the better the approximation becomes. If the dielectric constant is very low, the antenna pattern can change significantly and the DRA will not function as well as most DRAs do.

4. CONCLUSION

The ring disk DRA was successfully implemented. The desired frequency of interest is at 2.4 GHz, which is suitable for WLAN application. Although the fabricated antennas have shown small percentage of frequency shifted from the desired frequency, radiation performances of DRA are acceptable.

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