Multi-Band Rectangular Dielectric Resonator Antenna with Crank-Shape Feed-Line

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Abstract

In this paper, a new method for broadening of impedance bandwidth of rectangular dielectric resonator antenna (DRA) has been demonstrated. In the proposed configuration, two adjacent resonant modes were excited by the additional L-shape feed-line. For the suggested optimum feed network, the impedance bandwidth of over than 11% and 24.5% (for $S_{11}>10dB$) are obtained in two separate frequency bands at 5-8 GHz band.

1. INTRODUCTION

The DRA is a type of resonant antenna, fabricated from low-loss dielectric material. Dielectric structure as an antenna was first proposed in the early 1980's [1].

High radiation efficiency of this structures, due to the deficiency of conductor or surface wave loss (specially in high frequency), and flexibility in design for size decreasing of resonance dimension in antenna structure (with variation of dielectric constant) are two specific advantage of dielectric material personality. In addition, DRAs offer the other advantages of lightweight, low profile, and low cost, making those attractive candidates for wireless applications [2-5].

Coupling from feed-line to antenna structure and consequently impedance bandwidth is one of the main specifications of DRA. Multi-mode operation is used to enhance band coverage of a dielectric structure. Suitable feeding techniques are capable of exciting several modes simultaneously [6]. In pervious work, different configurations for feed-line have been presented to enhance the amount of coupling from the microstrip line to a DRA [7-15].

In this paper, a method for improving impedance matching of rectangular DRA has been demonstrated. For this reason, we introduce the crank-shape microstrip feed-line for rectangular DRA. This improvement offers bandwidth broadening of a DRA. The design methodology and these results of the introduced structure are discussed.

2. THEORY OF THE PROPOSED METHOD

It was found that when the DRA was coupled to a simple microstrip line, as shown in figure 1, both the TE^{x}_{111} and TE^{z}_{111} modes of the DRA were excited. However, the coupling to TE^{x}_{111} mode was much weaker than to the TE^{z}_{111} mode [5].

When the resonant frequencies of these two modes are different from each other, this provides a means of realizing single-feed dual frequency, dual polarization, or circularly polarized antennas.
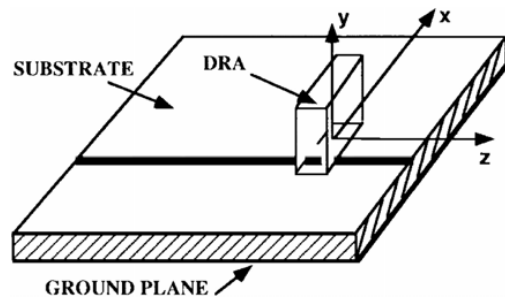

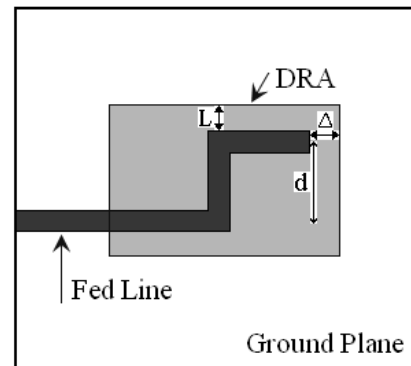Fig. 1: Simple Form Of Microstrip Excitation Of Rectangular DRA

Fig. 2: Geometry Of The DRA On The Proposed Micro-Strip Fed-Line

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The proposed geometry of the rectangular DRA fed with a crank-shape microstrip line is shown in figure 2. In this new structure an L-shape strip section is added to the ordinary feed-line.

In the proposed scheme, with an additional L-shape bend section, similar to the situation where DRA is inclined with respect to the microstrip line, both the TE^x_{111} and TE^z_{111} modes of the DRA are excited (with approximately equal powers).

Through simulations using commercial full wave analysis software package (Ansoft HFSS^{TM} ver. 9.2), we observed that the configuration and size of metallic strip sections under the DRA antenna affects drastically its coupling.

In this microstrip scheme of excitation, the coupling can be controlled by varying the distance between the DRA and the end of microstrip line (Δ). The bend section of feed-line is located in the middle of DRA length. The lateral distances between the feed-line and DRA are equal.

3. SIMULATION RESULTS

The purpose of this section is to investigate the effect of various combinations of parameters of feed-line excitation (Δ, d and L) in order to further enhance the impedance bandwidth of operation.

The initial dimensions of DRA were determined using the equations developed for the dielectric waveguide model (DWM) in free space [5]. Where k_x, k_y, and k_z denote the wave-numbers along the x, y, and directions, respectively, inside the DR. Enforcing the magnetic wall boundary condition at the surfaces of the resonator, the following equations are obtained for the wave-numbers:

$$k_x^2 + k_y^2 + k_z^2 = \varepsilon_r k_0^2 \qquad (1)$$

where

$$k_x = \frac{\pi}{a}, \quad k_y = \frac{\pi}{b}$$

$$k_z \, tag(k_z d / 2) = \sqrt{(\varepsilon_r - 1)k_0^2 - k_z^2} \qquad (2)$$

Then the optimum dimensions of antenna parameters were determined with experimental optimization.

The length, weight and height of the designed DRA are 10.6mm, 6.4mm and 9.4mm, respectively. The dielectric constant of the designed DR is 20. The size of finite ground plane is 5cm × 5cm. The microstrip feed-line was 1mm wide and on a 0.33mm thick substrate with a relative dielectric constant, ε_s=2.2, to give a characteristic impedance of 50Ω.

The designed antenna can be built to have good impedance matching by tuning the feed network parameters and location of the antenna on it. The finest coupling and consequently the maximum bandwidth was achieved for Δ=2mm and L=0.5mm.

A. Input impedance results
The simulated input impedance versus frequency is shown in figure 3 for the designed DRA with optimal fed-line.
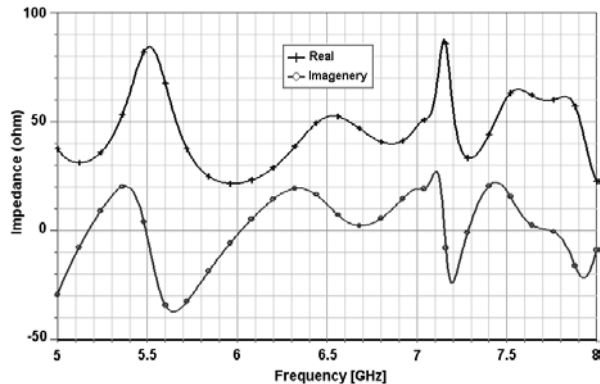

Fig. 3: Input Impedance Curve Of The Simulated Antenna At 5-8 Ghz Frequency Band

The computed return loss versus frequency is shown in figure 4 for the designed antenna structure. The optimum antenna structure achieves a computed return loss of about -14.5dB, -27.5dB and -23.5dB at 3 resonant frequencies of 5.36GHz, 6.63GHz and 7.73GHz, respectively.
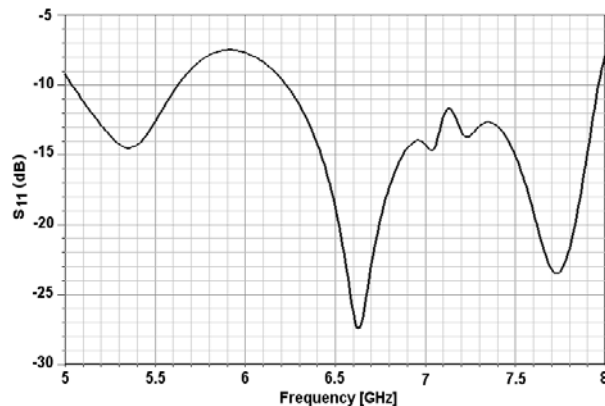

Fig. 4: Return Loss Curve Of The Simulated Antenna At 5-8 Ghz Frequency Band

This structure presents two separate frequency bands at 5.03-5.62GHz and 6.22-7.96GHz and therefore gives two 10 dB return loss bandwidths of over than 11% and 24.5%, respectively.

B. Radiation pattern results
The radiation patterns of the designed antenna at resonant frequencies (5.36, 6.63 and 7.73GHz) are computed. Related results in the φ=0 and 90 deg plane are shown in figures 3 and 4, respectively.
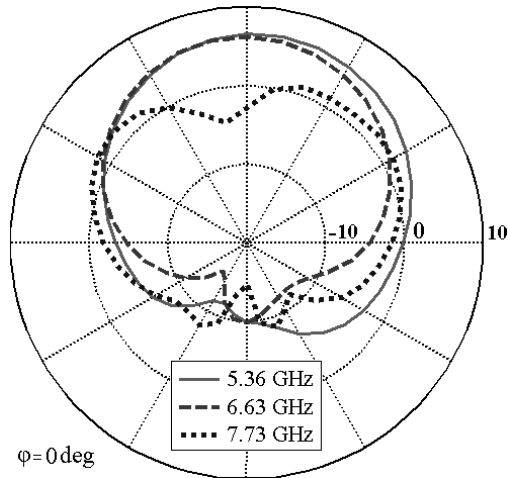
Fig. 5: Radiation Patterns Of The Optimum Design Antenna In The Φ=0 Deg Plane At 5.36 Ghz, 6.63 Ghz, And 7.73 Ghz

As expected, the antenna achieves unlike radiation patterns at 6.63GHz and 7.73GHz due to the use of different mode excitation.
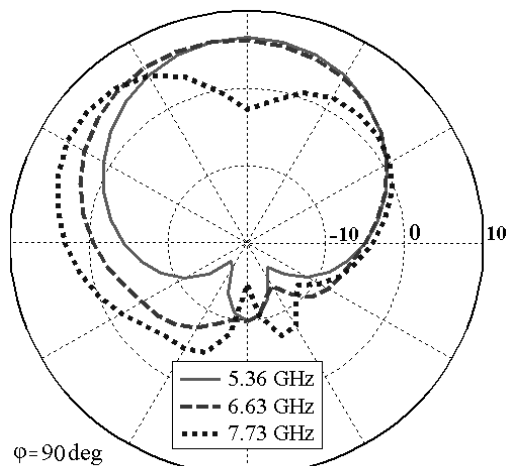

Fig. 6: Radiation Patterns Of The Optimum Design Antenna In The Φ=90 Deg Plane At 5.36 Ghz, 6.63 Ghz, And 7.73 Ghz

The realized gain of the designed DRA on the optimum proposed feed-line is shown in figure 5. The average gain of antenna at 5-6.7GHz frequency band is nearly 6dB, after which the main lobes incline from center of the pattern to the sides. So the antenna gain decreased in this frequency band.
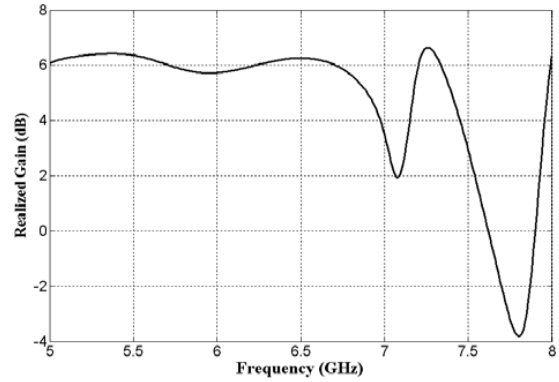

Fig. 7: Realized Gain Curve (Per dB) With Frequency Of The Optimum Design Antenna

4. CONCLUSION

A new method for broadening of impedance bandwidth of rectangular DRA has been demonstrated. In this work, we have investigated the performance of the proposed crank-shape feed-line using numerical software simulations. In the proposed configuration, two adjacent resonant modes were excited by the additional L-shape feed-line.

For the suggested optimum feed network, the impedance bandwidth of over than 11% and 24.5% (for S_{11}>10dB) are obtained in two separate frequency bands at 5.03-5.62GHz and 6.22-7.96GHz.

The next step of our research will be to extend the proposed idea to the meander feed-line scheme for DRA and assess its effect on antenna performance.

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