H-shaped slot coupled Dual-Polarized Dielectric Resonator Antenna for C-Band applications

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***Abstract*— In this paper, a cylindrical dielectric resonator antenna (DRA) excited by two orthogonally placed H-shaped aperture slot is presented with high isolation exceeding 32 dB in C-band. For dual linear polarization, the DRA in its TM_{110} (HEM_{11}) mode is excited to yield broadside radiation pattern. To confine the slots to the central area of cylindrical DR for TM_{110} mode, the rectangular shaped slots are molded to H-shaped slots. The co-polarization level in both planes is found to be nearly 30 dB higher than the cross-polarization in broad-side direction. The proposed feed for cylindrical (DRA) has been achieved -10 dB impedance bandwidth of 4.8% for 6.1 to 6.4 GHz. The broadside radiation patterns with nearly same pattern shapes are found to be stable with the gain of 5.2 dB for both ports.**

Keywords—dual polarization; dielectric resonator; cross-polarization; C-band

I. INTRODUCTION

The polarization-diversity antennas have been an important subject for antenna designers. There have been significant works on different feeding methods, different shapes of DRA with linearly polarized or circularly polarized radiation patterns [1]. The number of designs of dual polarized DRA are however very less in currently available open literature. The study of DRA has been increasing in the last decade for their inherent merits of small size, low cost and no conductor loss as an efficient radiator [2]. In general the dual-polarized radiation has practical applications in wireless communication systems. With the capability of dual polarization, the antenna can combat the multipath effects and optimize the system performance with increased information rate [3]. This technique combines two feed ports with mutually orthogonal polarization directions and works in the duplex model of transmitting and receiving signals in the meantime.

For better isolation the two feed-ports are kept in two different exciting modes. In this paper a slot coupled fed cylindrical DRA with dual H-shaped slots is demonstrated to obtain two orthogonally polarized fields. The aperture coupled technique has been taken for this design because it is suitable at high frequency operation as well as in MMIC application [4-5]. The DR element studied has a cylindrical shape with permittivity ε_r=9.8, with two slots kept under it. The level of coupling can be adjusted by the position of the slots with respect to DR. The antenna is designed and optimized using CST Microwave Studio suite™ 12, based on the three-dimensional finite integration time-domain (FITD) method.

II. ANTENNA DESIGN AND GEOMETRY

The proposed antenna geometry of the dual linear polarized DRA with slot coupling technique is shown in Fig.1.

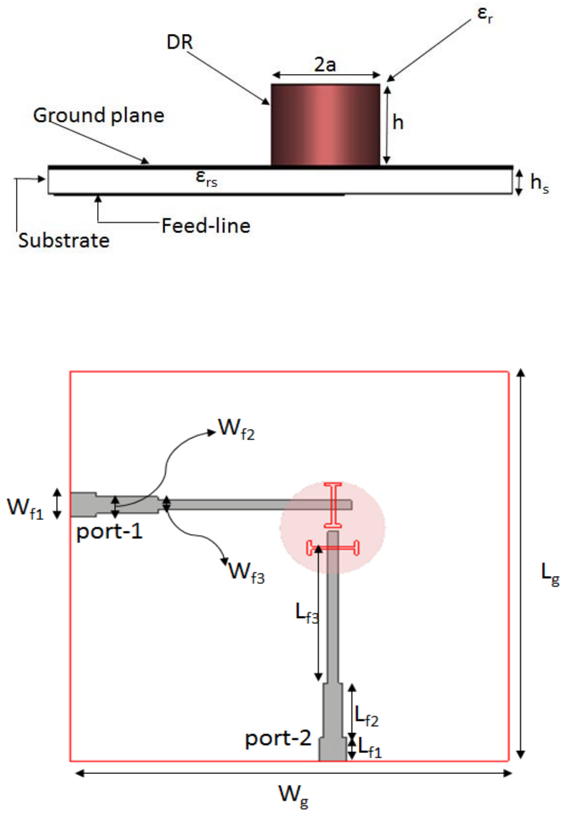


Fig. 1. Geometry of the dual-polarized Dielectric Resonator Antenna.

In this proposed antenna, the cylindrical DR is placed unsymmetrically above a substrate FR4 of 1.6 mm thickness with permittivity of ε_{rs}=4.3.

For cylindrical DRA of radius ‘a’ and height ‘h’ the field distribution can be described in terms of Bessel functions as(1):

$$\text{TM: } E_z^{npm} = J_n\langle (X_{np}^{TM} r) | a \rangle \{sin(n\Phi)\} cos[(2m+1)\pi z \,/\, 2h] \tag{1}$$

$$n = 1,2,3 \ldots;\ p = 1,2,3 \ldots; m = 0,1,2 \ldots;$$

Where J_n is the nth order Bessel function of the first kind. While X_{np}^{TM} is the root that satisfies the corresponding characteristic equation(2):

$$J_n(X_{np}^{TM}) = 0 \tag{2}$$

The simplified mathematical expression for the resonant mode frequencies is given by equation (3):

$$f_{npm} = \frac{c}{2\pi a\sqrt{\varepsilon_r}} \sqrt{\{X_{np}^{TM^2}\} + \left[\frac{\pi a}{2d}(2m+1)\right]^2} \tag{3}$$

Employing the corresponding mode, for instance TM_{110} mode the expression (3) reduces to:

$$f_{TM110} = \frac{c}{2\pi a\sqrt{\varepsilon_r}} \sqrt{\{X_{np}^{TM^2}\} + \left[\frac{\pi a}{2d}\right]^2} \tag{4}$$

$$\text{Where } \{X_{np}^{TM^2}\} = (1.841)^2$$

The mathematical expression used to find out the radius and height of the DR element, for resonant mode frequency is given by (4).

Two microstrip feed lines are etched on the bottom side of the substrate. Two H-shaped slots are designed on the topside ground plane to enable inductive coupling energy transfer as shown in Fig. 2.

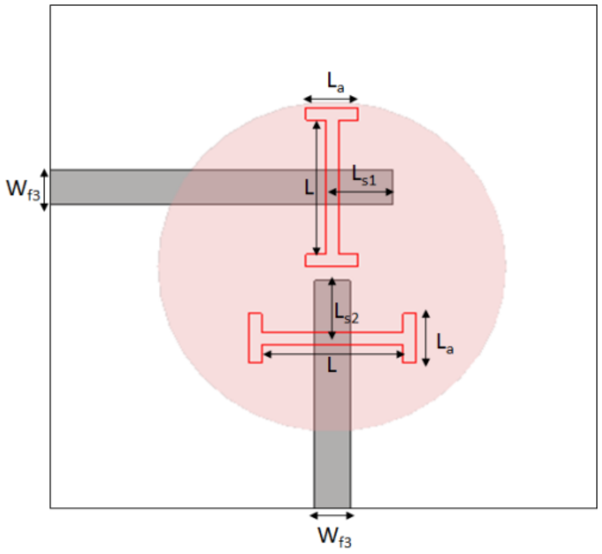


Fig. 2. Enlarged view of an orthogonally H-shaped slot.

Ground plane and substrate dimensions are fixed to W_g= L_g=50 *mm*. The excitation of TM_{110} mode to achieve dual linear polarization strictly requires that these slots be confined to the central portion of the radiating element, and at the same time to offer good level of isolation between the ports. As a result this avoids radiation pattern degradation and resonance frequency shift. To resolve this issue, the two rectangular shaped apertures are changed to orthogonally placed H-shaped slots.

The resulting optimal design parameters of the proposed antenna are summarized as follows: W_{f1}=3.1mm, W_{f2}=2.15mm, W_{f3}=1.24mm, L_{f1}=3mm, L_{f2}=7mm, L_{f3}=17.4mm, L_{s1}=1.8mm, L_{s2}=2.1 mm, L=4.9mm, L_a=1.8mm, W_s=0.45mm, h=5mm, h_s=1.6mm, 2a=12mm. This approach makes the slot not only confined to the smaller central region of the DRA but also supports to manipulate the stub lengths and feed line positions in order to improve the port isolation to 32 dB.

III. RESULTS AND DISCUSSIONS

A. Reflection co-efficients and Isolation

The design was started taking the good starting dimensions of the DR and slots using (4). The simulated reflection co-efficients (s_{11} and s_{22}) and isolation (s_{12}) are shown in Fig. 3. There is an excellent performance for common impedance bandwidth for port-1 and port-2, starting from 6.1GHz to 6.4GHz. The slight dissimilarity appears after 7GHz. Fig. 3 shows, at the frequency of operation 6.3 GHz the impedance bandwidth is 4.8%. The isolation between the ports is found to be more than 32dB at the frequency of operation. This behavior is due to the H-shaped slots; with an addition to the isolation it is giving the required radiation modes for dual polarization.

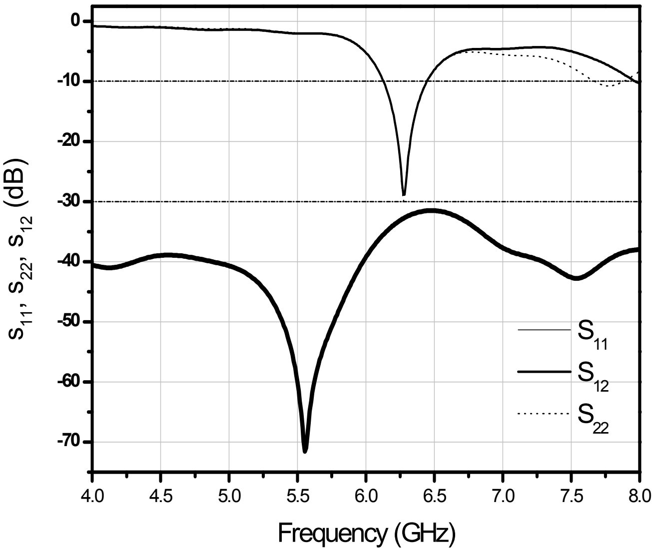


Fig. 3. Simulated reflection co-efficients and isolation versus frequency for design.

B. Parametric analysis of stub lengths

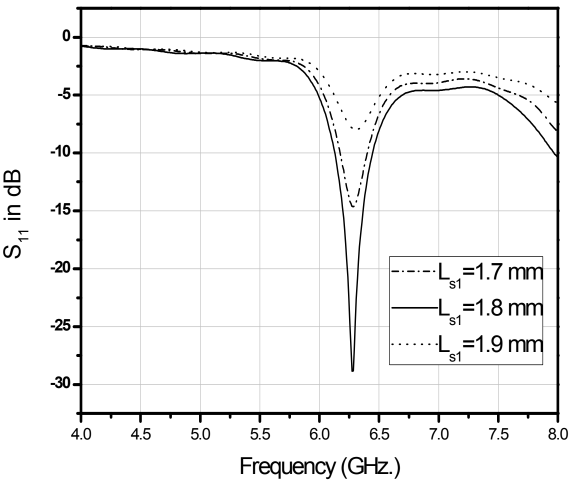


Fig. 4. Set of reflection coefficient curves for different values of stub lengths L_{s1}.

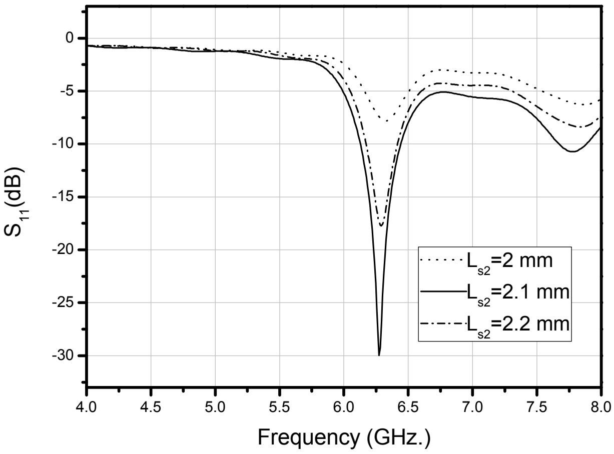
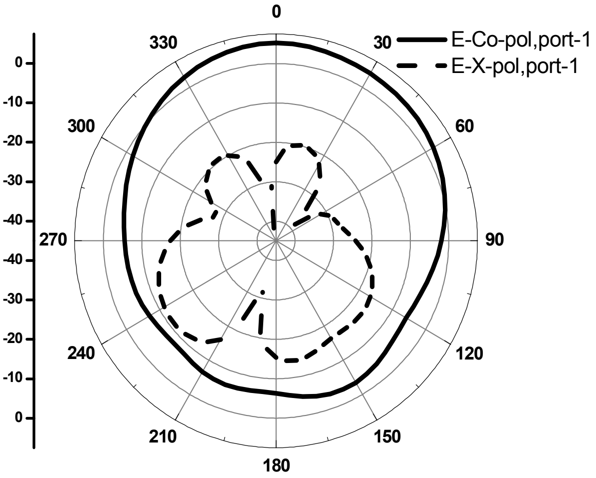


Fig. 5. Set of reflection coefficient curves for different values of stub lengths L_{s2}.

The parametric analysis for varioust values of stub lengths of port-1 and port-2 has been carried out as shown in Fig. 4 and Fig. 5 respectively. The stub lengths are closely approximating quarter wave length ($\lambda_g/4$) plays a significant role in improving the coupling mechanism when its reactance cancels to the reactance of the aperture slot. So choosing the slot lengths as 1.8 and widths 0.45, stub lengths are varied for port-1 and port-2. It is observed from Fig.4 that for stub length of L_{s1}=1.8 mm the reflection coefficient, S11< -28dB is found which is much better as compared to L_{s1}=1.7mm and L_{s1}=1.9 mm respectively. Similarly from Fig. 5 for stub length L_{s2}=2.1mm, the S_{11}< -30dB has been found. So from this analysis L_{s1}=1.9 mm and L_{s2}=2.1mm has been considered for the design.

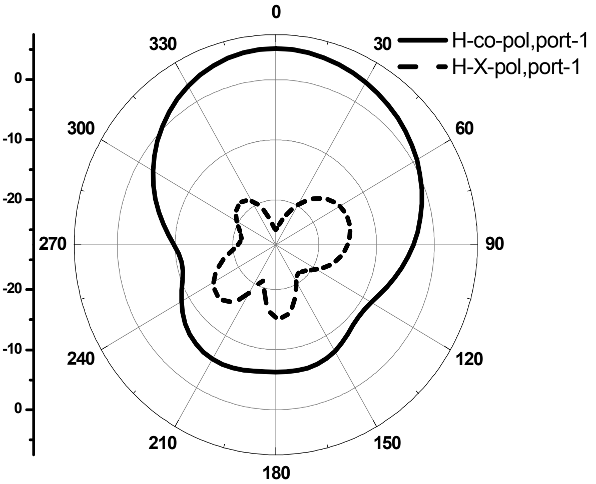
C. Radiation pattern characteristics

The E and H plane far-field radiation patterns with co and cross polarizations, for port-1 are shown in Fig. 6.



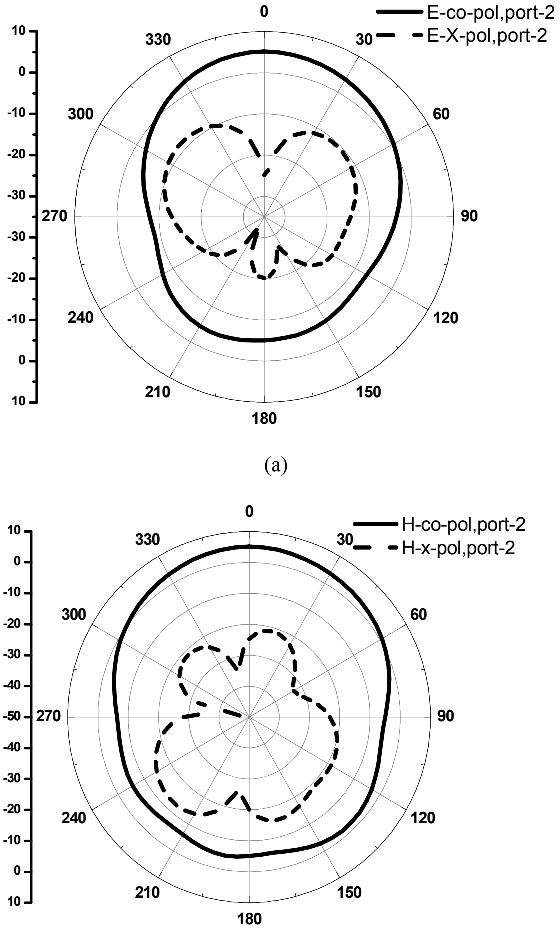
(a)

For both planes the co polarization level is 30dB higher than the cross-polarization level in the broadside direction. Both the planes are more or less found to be symmetric. For individual excitation of port-1, the 3-dB beam widths are found to be 96° and 66° in E- and H- planes respectively.



(b)

Fig. 6. E-plane (a), and H-plane (b) Radiation patterns of the proposed antenna at 6.3 GHz for port-1.



(a)

(b)

Fig. 7. E-plane (a), and H-plane (b) Radiation patterns of the proposed antenna at 6.3 GHz for port-2.

The E-plane and H-plane radiation patterns with the co-polarization and cross-polarization levels are shown in Fig.7 for port-2.

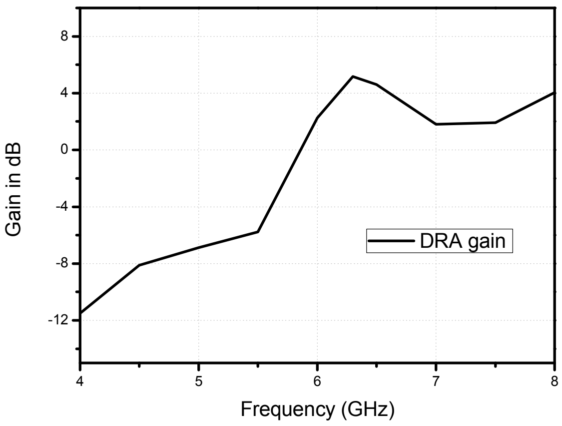


Fig. 8. Simulated gain of proposed antenna.

With the individual excitation of port-2 the 3-dB beam widths 61.9º, for E-plane and H-plane patterns has been achieved. The wider beam width for E-plane pattern at port-1 is due to the effect of the slight shift of positioning the slots under the DR center.

D. Gain Characteristics

Fig. 8. Plots the simulated gain versus frequency of the proposed antenna, where the gain is 5.2 dB at the center frequency of 6.3GHz.

IV. CONCLUSIONS

A dual-polarized DR antenna design has been presented. The design is sharing the common impedance bandwidth of 6.1 GHz to 6.4 GHz perfectly by port-1 and port-2 respectively. For the two input ports, input isolation exceeds -32dB among them makes this antenna a good candidate for wireless applications in avoiding multipath effects. It is found that the proposed design has much lower cross-polarization level (-30dB) as compared to co-polarization level. The simulated results demonstrate that the proposed DRA achieves an impedance bandwidth of 4.8% for 6.1 to 6.4 GHz, with simulated gain of 5.2 dB at the center frequency of 6.3GHz. The structure can be easily integrated with planar circuitry. It seeks promising applications in the satellite and radar communication systems operating in C-band.

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