Dielectric Resonator Based Pattern Reconfigurable Antenna

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***Abstract*- In this paper, pattern diversity scheme based on Dielectric resonator antenna (DRA) and parasitic directive array is presented. Antenna is centrally fed through DRA and by reconfiguring the states of switches in the parasitic elements pattern diversity is achieved. DRA is excited in $EH_{11\delta}$ mode and thus provides omni-directional radiation pattern. Parasitic elements behave like transparent and opaque surface to a vertically polarized incident wave for the ON and OFF states of switch respectively. Proposed antenna offers uniform gain of ~ 4.8 dBi with beam steering along the entire azimuth plane. The simulation has been carried out for the operating frequency of 6.32 GHz using ANSYS HFSS & CST Microwave studio software.**

***Index Terms* — Pattern diversity, beam switching, dual beams, directive array, dielectric resonator antenna (DRA).**

I. INTRODUCTION

Pattern reconfigurable antennas are the key components of wireless communication system. They have the capability to direct the beam in the direction of user and creating a null towards interfering sources. A great efforts have been devoted in the past decade to design pattern diversity antennas. The direction of main beam can be altered in the horizontal or vertical plane. For steering the main beam in the horizontal plane, one monopole antenna is used as a driven element and it is surrounded by parasitic elements. By reconfiguring the reflecting/transmitting property of parasitic elements, pattern diversity is achieved [1-2]. The concept of reactively controlled directive array is introduced by Harrington [3], in which impedance loading at each of the port can be varied to generate desired radiation pattern. In [4] the concept of parasitic monopole is introduced. The parasitic monopole act as a transparent or reflecting surface depends on the condition of associated switch. On the basis of this concept, pattern diversity is achieved in [5] by circular array of two states reactive loads, which comprised 25 wire monopole elements. Structure with one driven and four parasitic elements is proposed [6] to scan the entire horizontal plane over each of the 90^0 scan angle. In all the aforementioned structures monopole antenna is act as an driven element.

Dielectric resonator antennas are considered to be the alternative of metallic antennas at high frequency because of numerous advantages such as light weight, compact, no inherent conductor loss, high radiation efficiency etc. [7].

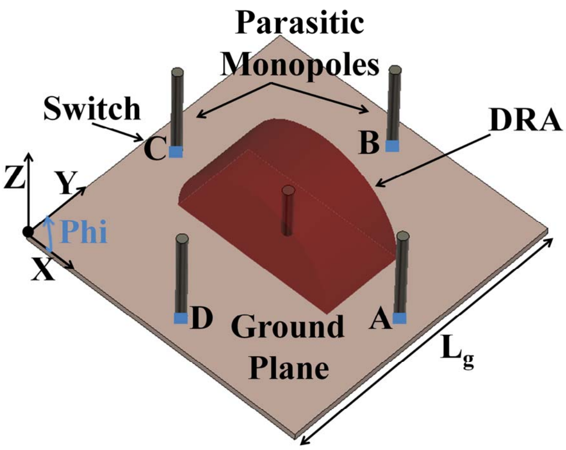

Figure 1. Layout of pattern diversity antenna (L_g=36 mm).

In this paper, an integrated system of half split cylindrical DRA and parasitic directive array for pattern diversity is proposed. Here, the DRA is used as an driven element and is fed centrally by a coaxial probe. This excites $EH_{11\delta}$ mode which radiates like electric monopole antenna [8]. The half split cylindrical DRA is loaded with parasitic quarter wave monopoles to exhibits directivity in the inherent omnidirectional pattern of DRA. The assembly of DRA and parasitics are mounted on the finite square ground plane. DRA is excited through co-axial feed, field of which impinged on parasitic surfaces. Each parasitic is connected to the ground plane through switches. ON state of switch makes parasitic surface electrically equal to monopole antenna and therefore it re-radiates due to induced current. In ON state of switch, associated parasitic behaves as a reflective surface for the incident field. On the other hand, in the OFF state of switch, parasitic is just a hanging wire above a ground plane and exhibits property of dipole antenna [4] with higher resonating frequency. Therefore parasitic act as a transparent surface at the design frequency in the OFF state of switch. By reconfiguring (ON/OFF) the states of switches, beam scanning in entire horizontal plane is achieved. Same structure with different topology of switching states can be used for bi-directional radiation pattern. Loading effect of parasitic altered the effective input impedance of DRA and thus degrade the matching characteristics. For mitigating this loading effect, impedance matching network is designed and placed beneath

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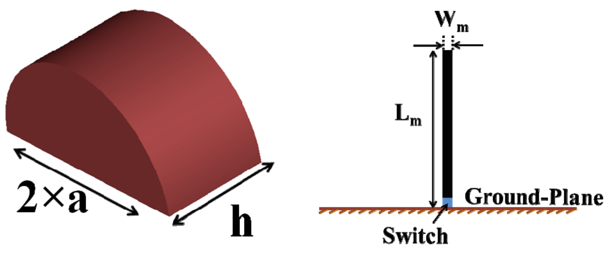


(a) (b)

Figure 2. (a) Geometry of DRA (a = 10, h = 10 in mm).
(b) Element of directive array (Lm =11.86, Wm= 1.2. in mm).

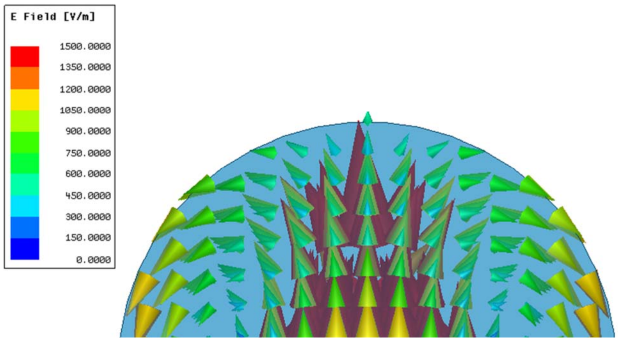


Figure 3. E-field distribution in DRA at f_0 = 6.32 GHz.

the ground plane to avoid the undesired electromagnetic coupling.

II. ANTENNA-CONFIGURATION

The proposed antenna, as shown in Fig. 1, comprises centre-fed half split cylindrical DRA surrounded by four parasitic cylindrical monopole antennas. Assembly of DRA and parasitics are mounted on the square ground plane of length L_g = 36 mm. Switches (A,B,C,D) are used to connect four parasitics to ground plane. Layout of DRA and parasitic monopole are illustrated in Fig. 2. The dimensions of DRA are : radius 'a' and height 'h' and is designed using RT Duroid 6010 (ε_r=10.2). The length of parasitic directive element 'L_m' is equal to the quarter of the free space wavelength ($\lambda_0/4$) at the operating frequency of 6.32 GHz. At the bottom side of each parasitic monopole switches are inserted. The ON and OFF states of switch forced corresponding element to behave as a reflective and transparent surface for the vertically polarized incident electromagnetic (EM) wave.

As per the previous findings, the reconfigurable behavior (Reflective/transparent) of monopole parasitics are apparently shows only for vertically polarized EM wave. Therefore, DRA is excited coaxial probe placed at the center which generates $EH_{11\delta}$ mode. The electric field distribution at f_0=6.32 GHz shown in Figure. 3 confirms the excitation of the above said mode. The electric fields are vertically polarized and generates electric monopole like radiation. Field generated by DRA impinged on the parasitic elements and hence current is induced. In the ON state of switch, parasitic behaves as a quarter wave monopole antenna at the operating frequency (f_0) and thus reflects the incoming waves. On the other hand, in the OFF state of switch, associated parasitic element act as a dipole antenna with the same physical length and thus resonates at the higher frequency (2× f_0). The induced surface current density on the parasitics for the ON and OFF states of switches are shown in Fig. 4. The beam is directed towards transparent surface, which is associated with OFF state of switch and act as a dipole antenna. At the same time beam is reflected from the parasitics associated with ON state of switches and behave as a monopole antenna. Beam steering is achieved over each of the 90^0 scan angle by reconfigure the

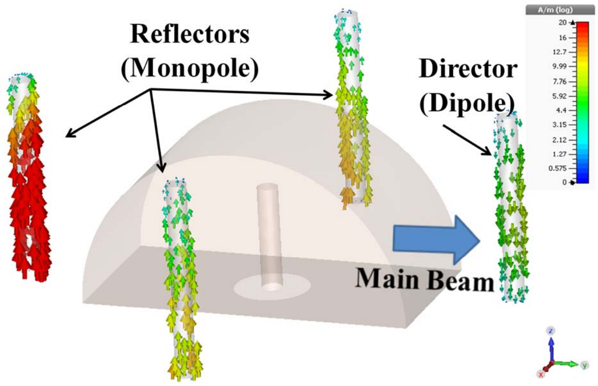


Figure 4. Simulated induced current density in parasitics at f_0 = 6.32 GHz.

switching states of various switches. The proposed structure can be used to generate bi-directional radiation pattern with different topology of switches as discuss in section III. To support the structure, Rogers RT-5880 (εr = 2.2, loss tangent = 0.0009, thickness= 0.787 mm) is used as a dielectric substrate for ground plane. The simulation has been carried out for the operating frequency of 6.32 GHz using ANSYS HFSS & CST Microwave studio software.

III. RESULTS AND DISCUSSION

Variation of reflection coefficient with frequency has been shown in Fig.5. The -10 dB impedance bandwidth of DRA is 19.14 % centered at the design frequency of 6.32 GHz. Radiation pattern of DRA has been shown in Fig. 6. Pattern is isotropic in H-Plane and having two nulls in the direction of $\theta = 0^0$ and $\theta = 180^0$ in E-plane. Gain of DRA at the design frequency of 6.32 GHz is 4.23 dBi. Adequate cross-polarization level is achieved in H-Plane, whereas it is significantly improved in E-plane. For achieving directionality in the omni-directional pattern of DRA, four parasitics associated with four switches (A,B,C,D) are placed in the vicinity of DRA. Due to loading effects of these parasitics, impedance matching is deteriorated and therefore matching network is designed at the beneath of the ground plane. Proposed structure can scan the beam in horizontal plane over each of 90^0 scan angle. Same structure with different states of

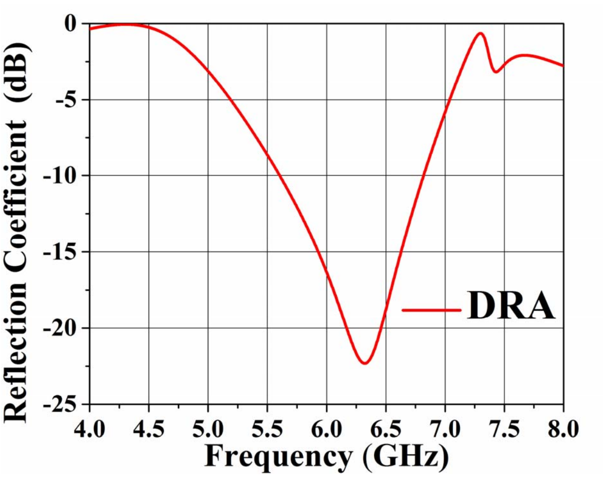
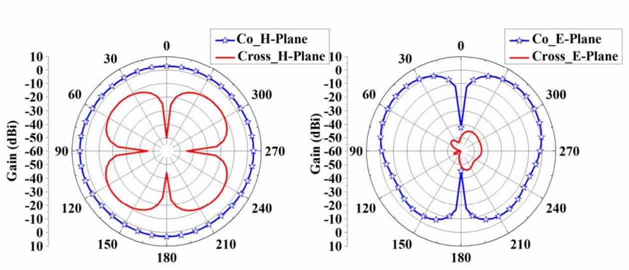


Figure 5. Variations of reflections coefficient for DRA.



(a) (b)

Figure 6. Radiation pattern of DRA (a). H-Plane (b). E-Plane (Phi=0^0).

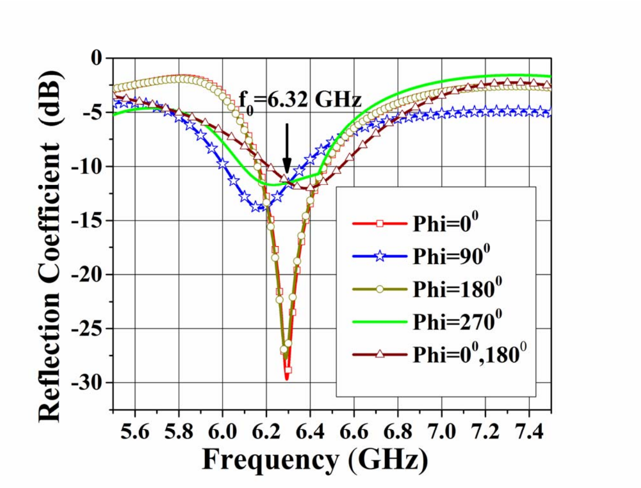


Figure 7. Variations of S-parameter for different beam directions.

switches can be used for generating bi-directional radiation pattern. The gain and corresponding beam directions for different cases (I-V) are given in Table. I.

Variation of reflection coefficient for different beam directions is shown in Fig. 7. Perfect matching is obtained for the beams directions of Phi = 0^0 and Phi = 180^0. Whereas performance is degraded for remaining three cases.

TABLE I
FUNDAMENTAL CASES

Case	OFF Switch	Peak Gain (dBi)	Direction of Peak Gain (Deg.)
I	A	4.69	Phi=0^0
II	B	4.99	Phi=90^0
III	C	4.85	Phi=180^0
IV	D	4.82	Phi=270^0
V	A & C	4.01	Phi=0^0 & 180^0

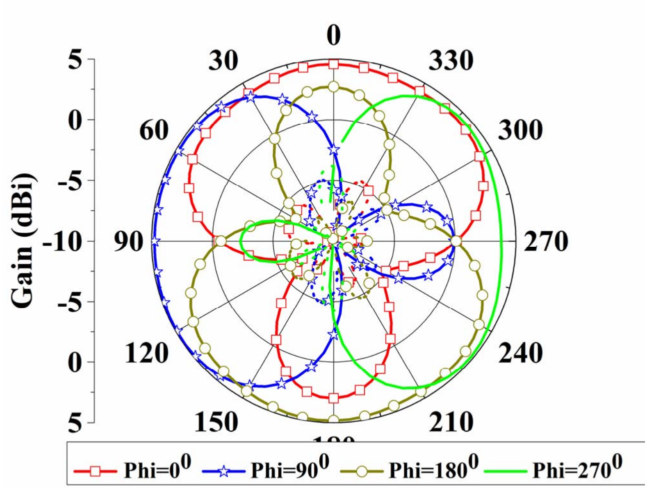


Figure 8. Simulated H-plane radiation patterns for different beam directions (Table I) .

Fortunately, matching is achieved at the design frequency of 6.32 GHz for all the aforementioned cases. Beam scanning in H-plane over each of 90^0 scan angle is illustrated in Fig. 8. Gain and directions of four beams, corresponding to four different states of switches are given in Table I. Patterns have Half-power beamwidth (HPBW) in the order of ~155^0 with good cross-polarization level are achieved. The E-Plane co-polarization patterns for the beam directions of Phi=0^0 and Phi=90^0 are shown in Fig. 9. 56.2^0 and 45.0^0 HPBW are obtained in E-plane for the beam direction of Phi=0^0 and Phi=90^0 respectively. Fig. 10 shows the E-plane co-polarized radiation pattern for the beam direction of Phi=180^0 and Phi=270^0. HPBW of 57.5^0 in E-plane for the beam direction of Phi=180^0 is somewhat similar to previous case, whereas HPWB of 107.5^0 is obtained for the beam direction of Phi=270^0. The variations in HPBW for different beam directions is perhaps due to slight non-uniformity of DRA radiation pattern in H-plane. Due to high cross-polarization level, cross-polarized patterns are omitted in above discussed E-plane radiation patterns. Bi-directional radiation pattern (Case V), where main beams are directed towards Phi=0^0 and phi=180^0 are shown in Fig. 11. Cross-polarization level is below the satisfactory level. Aforementioned antenna is highly flexible in terms of beam scanning and generation of bi-

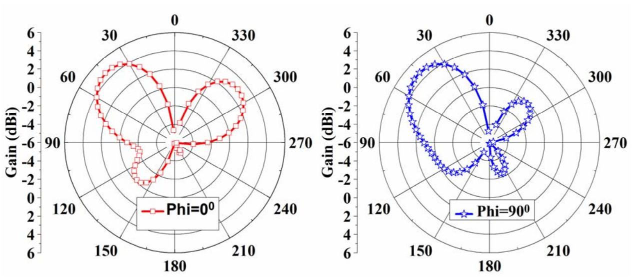


Figure 9. Simulated Co-polarized E-plane patterns for two different beam directions (Phi=0^0 and Phi=90^0).

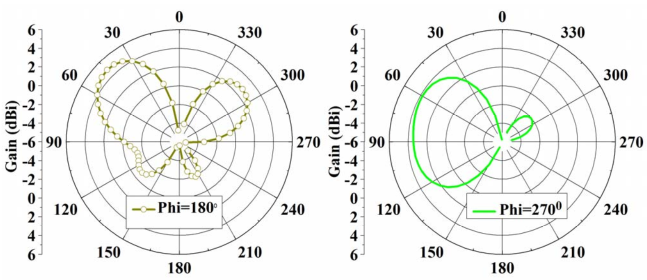


Figure 10. Simulated Co-polarized E-plane patterns for two different beam directions (Phi=180^0 and Phi=270^0).

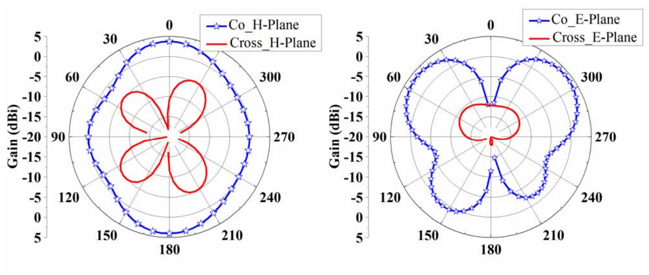


Figure 11. Simulated radiation pattern for dual beams at Phi = 0^0 and Phi = 180^0.

directional radiation pattern. High side lobe level is a main constraint of all aforementioned topology.

IV. CONCLUSION

Proposed integrated structure has the capability to scan the entire azimuth plane over each of the 90^0 scan angle. By different combination of switches, dual beam patterns is also obtained. Due to the effects of ground plane, beams are tilted by ~ 45^0 from ground plane. PIN diode with proper biasing network can be used as a switch in aforementioned structure. In the future, by using some advance techniques like phase correcting surfaces and reconfigurable matching network high gain with improved bandwidth and SLL can be achieved.

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