Directive Array Based Pattern Reconfigurable Antenna

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***Abstract*—In this paper, a high-gain pattern reconfigurable antenna system is presented. It consists of one driven monopole antenna at the centre, which is surrounded by six parasitic elements. Each parasitic element made up of metallic strip, loaded with switch and backed by dielectric layer. Parasitic elements will behave like transparent and opaque surface to a vertically polarized incident wave for OFF and ON states of switch respectively. Therefore entire assembly becomes reconfigurable and beam steering is achieved. Proposed antenna offers a high and uniform gain of ~ 8 dBi with beam steering along the entire azimuth plane. The simulation has been carried out for ISM band (fr=2.45 GHz) using CST Microwave studio software.**

***Index Terms*—Beam switching, directive array, pattern diversity, pattern reconfigurable, impedance loading.**

I. Introduction

To enhance the communication link performance, reconfigurable antennas are often applied. They have the capability to alter their characteristics i. e frequency, polarization and pattern on demand. Various approaches for achieving reconfigurability in antenna have been discussed in [1]. As per requirement, antenna can be made frequency, polarization or pattern reconfigurable. Pattern reconfigurable antennas are most versatile candidates of this reconfigurable domain. A great efforts have been made for achieving pattern reconfigurability in last few years. Concept of directive array [2] is one of the widely accepted arrangements of beam scanning. In the vicinity of driven monopole/dipole antenna parasitic elements are placed to introduce directivity in the inherent omni-directional pattern of antenna. Impedance loading at different ports [3] is a backbone of this beam steering phenomena. Four beams are generated with moderate gain in [4]. Beam scanning with relatively low gain is achieved by reconfigurable frequency selective reflector (RFSR) fed by a single antenna [5-7].

A new reconfigurable antenna based on impedance loading of the ports [3], is presented. Proposed structure used the well known concept of directive array [2] for achieving reconfigurability in radiation pattern. This antenna comprises a cylindrical monopole antenna (driven element) in the center, surrounded by six parasitic elements (with switch) backed by rectangular dielectric plates. Former elements are mounted on a finite square ground plane. The radiation characteristics of a 7-port antenna system (1 driven element & 6 parasitic) can be controlled by the ON/OFF state of

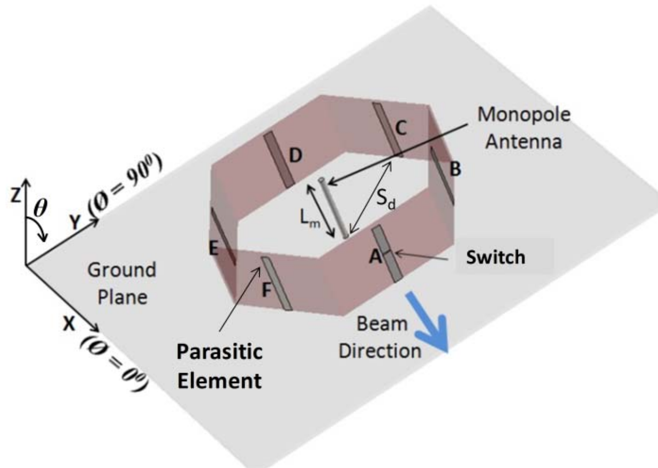

Fig.1. Layout of pattern reconfigurable antenna (L_m=29 mm, S_d=48 mm)

switch. At the resonating frequency of 2.45 GHz, the six outer parasitic elements shows resonance & out of-resonance behavior for ON & OFF state of switch respectively. These two different states (ON/OFF) of switch in parasitic element makes these surface reflective (switch ON) / transparent (switch OFF) to incident field. Impedance matching networks of this antenna are hidden beneath the ground plane to avoid the undesired electromagnetic coupling.

II. Antenna Configuration

The proposed 60^0 corner reflector antenna, as shown in Fig.1, comprises feeding driven monopole antenna of length "L_m" ($\lambda_0/4$ ~ 29.0 mm at f_0 = 2.45 GHz) in the centre, six parasitic elements of directive array with switches (A, B, C, D, E & F) and the ground plane (on which parasitic directive array of six surfaces are located). The dimension of ground plane is 206×206 mm^2. Parasitic elements are placed at a distance of S_d = 48 mm from monopole antenna. The ON and OFF states of switch are realized by metallic strip (perfect short) and slot (perfect open) respectively. Fig. 2 shows layout of the one element of directive array. The total length of parasitic directive element (L_1+L_2+L_s = 29.0 mm) is equal to the quarter of the free space wavelength ($\lambda_0/4$) at the operating frequency of 2.45 GHz.

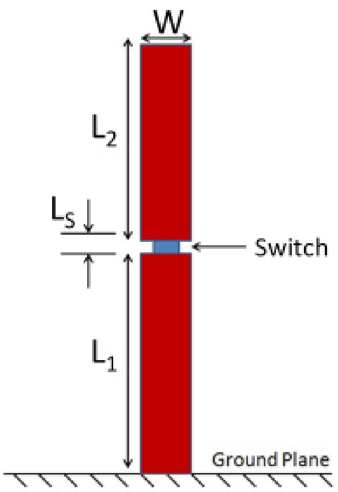

Fig.2. Element of directive array with parameters (L_1=15, L_2=13.5, L_s=0.5, W=4 in mm)

This element consists of one switch at a height of L_1 from ground plane. In ON state of switch parasitic element resonates at the operating frequency of f_0=2.45 GHz and behaves as a reflecting surface. Parasitic element will become transparent to incident field of driven monopole antenna for the OFF state of switch. Therefore only six switches are enough for configuring the reflection / transmission states of the six side walls of the proposed 60^0 corner reflector antenna. With various combinations of the switching states, beam scanning can be achieved. In simulation, FR4 (ϵ_r = 4.3, loss tangent = 0.02, thickness = 2 mm) is used as a dielectric material for ground plane. Low loss material Rogers RT-5880 (ϵ_r = 2.2, loss tangent = 0.0009, thickness = 0.787 mm) is considered as a substrate for parasitic elements to maintain the efficiency of system.

III. Results and Discussion

Fig. 3 shows surface current distribution for centre fed monopole antenna and parasitic directive array for two different states of switch. Fig. 3, (a) and (b) shows the similar current distribution for monopole antenna and directive element (with ON state of switch) at the resonating frequency of 2.45 GHz. By changing the state of switch (ON to OFF) in parasitic element, current distribution of directive element alter (Fig. 3(c)) and thus it shifts resonance at higher frequency, depending on the location L_1 of the slot (switch) in Fig.2.

ON state of switch makes electrical length of both parasitic element and driven monopole antenna equal. The strong induced current on the parasitic element (which is vertical to horizontal ground plane) re-radiates the electromagnetic field which in turn cancel or re-directed incident field of centre fed monopole antenna. Thus element with ON state of switch will act as a reflector for incident

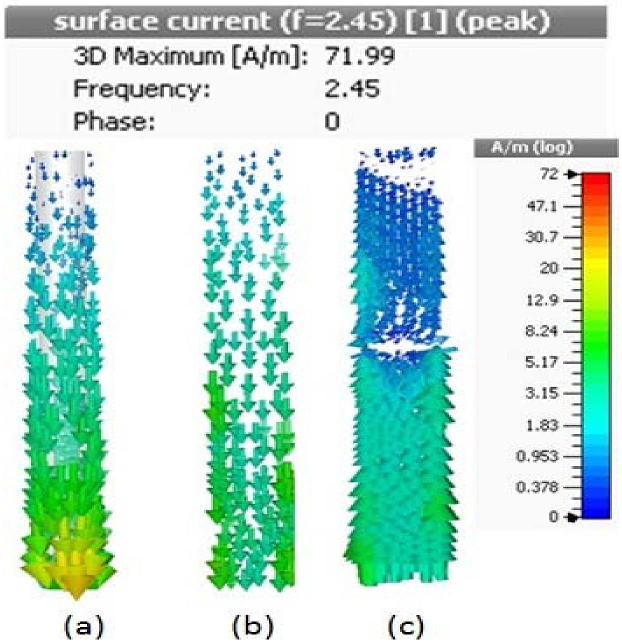

Fig.3. Simulated induced current density distribution at f_0=2.45 GHz for (a). Centre fed monopole antenna (b). Directive element with ON state of switch (c). Directive element with OFF state of switch

field. On the other hand, when switch is OFF, parasitic element comes out of resonance. Under this condition, parasitic element will behave as a transparent surface for incident field.

Fig. 4 shows the H-plane (beam directions $\emptyset$ = 0^0) directivity patterns for different location of switch in parasitic elements. Location of switch (L_1 in Fig. 2) can be varied from 0 mm to 20 mm, after which the resonance of parasitic element (associated with OFF state of switch) comes closer to monopole antenna and it starts reflecting. For the location of switch L_1=25 mm, corresponding element reflect the signal even though the switch remain in OFF state. Therefore switch can be placed at any location ($L_1 \leq 20$ mm) in parasitic element.

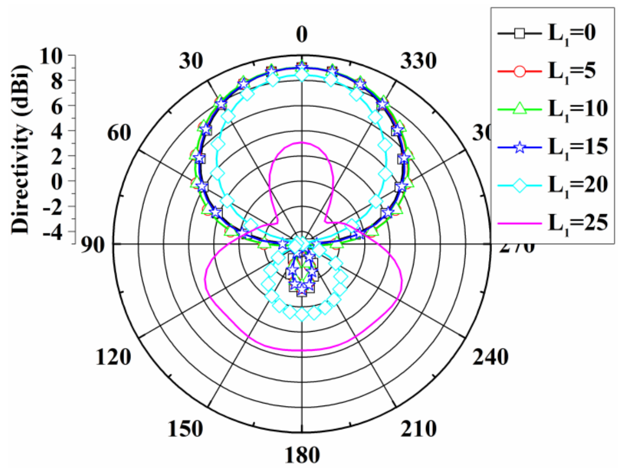

Fig.4. Simulated H-plane (θ = 50^0) directivities in Case 1 (main beam directions $\emptyset$ = 0^0) for different location of switch at f_0=2.45 GHz

In proposed structure, switches are placed at a location of L_1=15 mm in parasitic elements for verifying the aforementioned illustrated concept.

By reconfiguring the states of the switch (A to F), of proposed structure (Fig.1) switched beam steering can be achieved over the entire azimuth plane (Fig. 5, Cases 1-6). For better understanding and clarity of beam scanning in horizonatal plane, only co-polarized patterns are shown in Fig.5. Direction of maximum radiation with peak gain for different cases are listed in Table I, which shows maximum gain of tilted beams (θ ~50^0) for different cases varies from 8 to 8.5 dBi. Tilt of beam can be explained due to effect of ground plane.

Simulated E-plane radiation patterns (co and cross polarization) for different cases are shown in Fig.6 to Fig.8. Patterns are almost similar for all the cases (1 to 6). The average value of simulated H-plane and E-Plane radiation parameters i.e. beam-width, cross-polarization level, front-to-back ratio (FTBR) and side lobe level (SLL) are listed in Table II. FTBR and SLL are defined in H-Plane and E-Plane respectively. Low cross-polarization level is noticed for all beam directions. Outcomes of antenna shows satisfactory results in all directions.

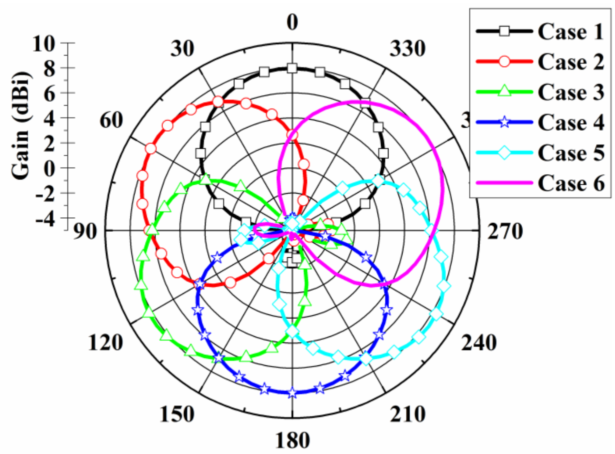

Fig.5. Simulated co-polarization patterns for azimuth cut (constant θ =50^0, Table I) for different cases

TABLE I FUNDAMENTAL CASES

Case	OFF Switch	Peak Gain (dBi)	Direction of Peak Gain (Deg.)
1	A	7.96	$\emptyset=0^0$
2	B	8.11	$\emptyset=60^0$
3	C	8.26	$\emptyset=120^0$
4	D	7.98	$\emptyset=180^0$
5	E	8.35	$\emptyset=240^0$
6	F	8.10	$\emptyset=300^0$

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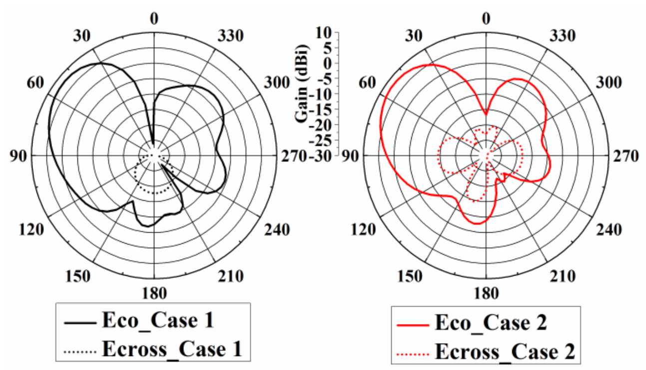

Fig.6. Simulated E-Plane gain pattern at f_0=2.45 GHz for the main beam directions $\emptyset = 0^0$ (Case 1) and $\emptyset = 60^0$ (Case 2)

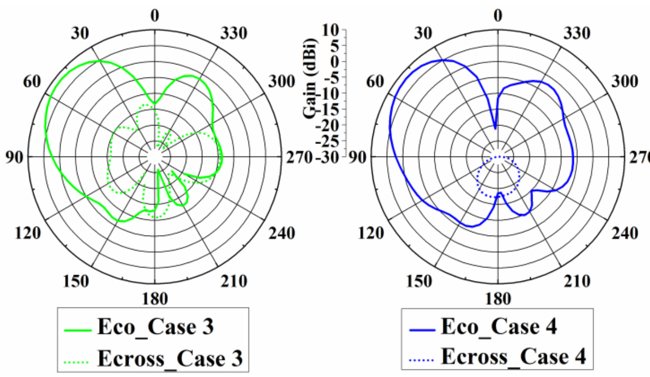

Fig.7. Simulated E-Plane gain pattern at f_0=2.45 GHz for the main beam directions $\emptyset = 120^0$ (Case 3) and $\emptyset = 180^0$ (Case 4)

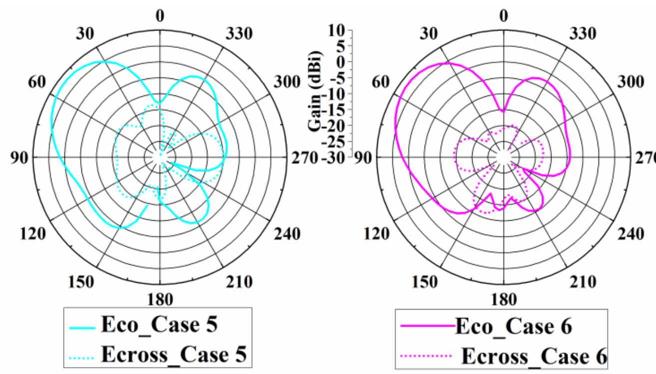

Fig.8. Simulated E-Plane gain pattern at f_0=2.45 GHz for the main beam directions $\emptyset = 240^0$ (Case 5) and $\emptyset = 300^0$ (Case 6)

TABLE II RADIATION PARAMETERS

Plane	Beam-width	FTBR (H-Plane) SLL (E-Plane)	Cross-pol. level
H-Plane (θ ~50^0)	90^0	10 dB	-43 dB
E-Plane	48.0^0	-11.0 dB	-42 dB

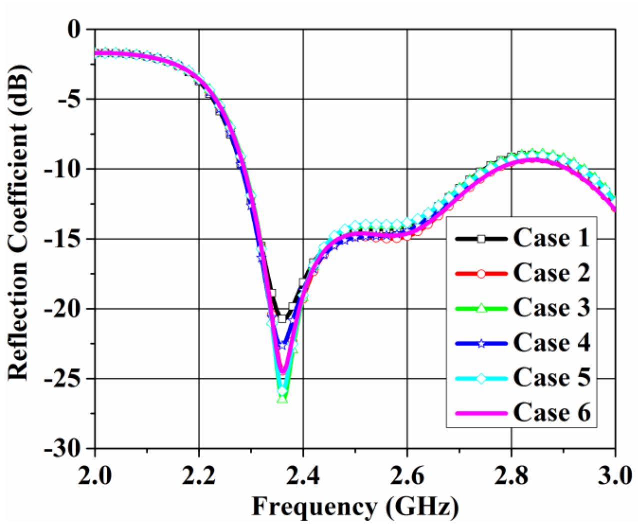

Fig.9 Reflection coefficients for different beam directions

Matching is the crucial parameter for pattern reconfigurable antennas. It should not be changed with different beam directions. Variation in reflection coefficient with frequency for different cases are shown in Fig.9. Due to symmetry, -10 dB impedance bandwidth of 470 MHz is obtained in all cases.

IV. Conclusion

The proposed seven port structure is the extension of reactive loading of ports [3]. To give a high directive radiation pattern in the desired direction, port current are resonated by different loading of ports (ON/OFF state of switch). System shows the capability to scan the beam over each of the 60^0 scan angle in the entire azimuth plane by controlling the states of switches in directive array. This structure gives high gain with tilt of ($\theta \sim 50^0$) 40^0 from ground plane. Proposed structure shows high potential as a pattern reconfigurable antenna. As a future work, structure can be implemented with real switches (PIN diode) and appropriate biasing networks.

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