Design and Performance Analysis of Reconfigurable Microstrip Patch Array Antenna

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Abstract : The objective of this paper is to design and fabricate a 4-element reconfigurable microstrip patch array antenna. In this paper, initially we designed single patch microstrip antenna and developed reconfigurability in it and after evaluating the outcomes of antenna features like operation frequency, radiation patterns, return loss, directivity and antenna gain, we transformed it to a 1X2 array and then finally 1X4 array to increase directivity, gain and to get better radiation patterns. The simulation has been performed by CST software and the desired antenna provides a gain of 6.389dBi and directivity of 9.989dBi at 5.128 GHz by using FR4 dielectric substrate with dielectric constant as 4.4 and thickness, h= 1.6mm. The side lobe is maintained lower than the main lobe. Since the resonant frequencies of these antennas are in the range of 4.2- 5.2 GHz, so these are suitable for C – band applications and can be used in WLAN communication systems, Satellite communication systems and weather radar systems.

IndexTerms **- Array Antenna, Directivity, Gain, Reconfigurable Antenna, Reconfigurable Microstrip Patch Array Antenna, Satellite Communication, WLAN**

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I. INTRODUCTION

Wireless communication has become an integral part for modern world. Microstrip patch antenna consists of a dielectric substrate with a ground plane on other side. A reconfigurable microstrip patch array antenna which is simple, low cost and high gain has been demonstrated in this paper with suitable feeding technique and dielectric substrate for GHz frequency range applications. Single microstrip patch antenna comes up with many advantages like low cost, low weight, low profile and conformal etc. But it has certain limitations as well like low gain, low directivity, low efficiency and narrow bandwidth. To overcome these limitations, implementation of multiple patches has been proposed in the array configuration. Because of the advancement of technology in the present scenario, there is a need of antenna which can satisfy changing operating requirements. The reconfiguration capability of reconfigurable antennas is used to maximize the antenna performance in a changing scenario. So, in this paper we have designed array of microstrip patch antenna and developed reconfigurability in it, so that we can get all benefits in together like low profile, low weight, low cost, high gain, high directivity and different operating capability. PIN diodes are used to achieve reconfigurability. Diodes basically changes the path of current flow and thereby achieve reconfigurability. This antenna can be widely used in Satellite Communication, WLAN communication as WiFi and weather Radar systems.

II. ARRAY DESIGN

2.1 Design of 1X1 array:

The geometrical structure of the antenna and the radiating element including dimensions is shown in Fig.1. The antenna is based on a 60mm × 60mm FR4-epoxy substrate with a dielectric constant of 4.4, loss tangent 0.02 and a thickness of 1.6 mm. The patch, which is square shaped, is fed using a 3mm wide microstrip feed line. The width of feed is chosen according to best impedance matching. Antenna is printed on non-grounded part of substrate. The antenna inhabits an area of 40mm x 40mm. Reconfigurability is achieved by using a PIN diode. Simulated design of antenna when diode is OFF and when diode is ON is shown in Fig.1 andnFig.2 resp.

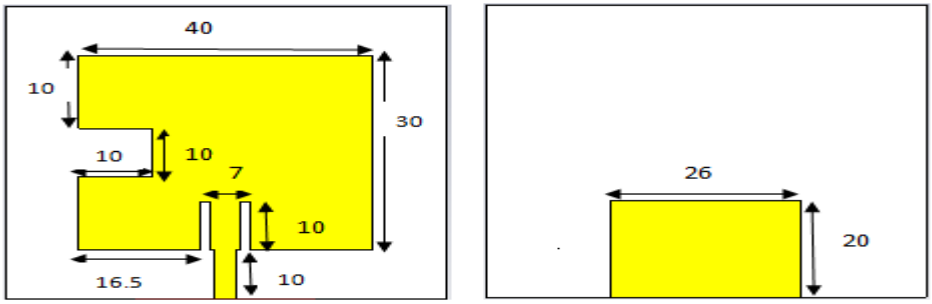


Fig. 1. Simulated Design of 1X1 reconfigurable Antenna for WLAN Communication when the diode is OFF (Front View and Back View) with dimensions

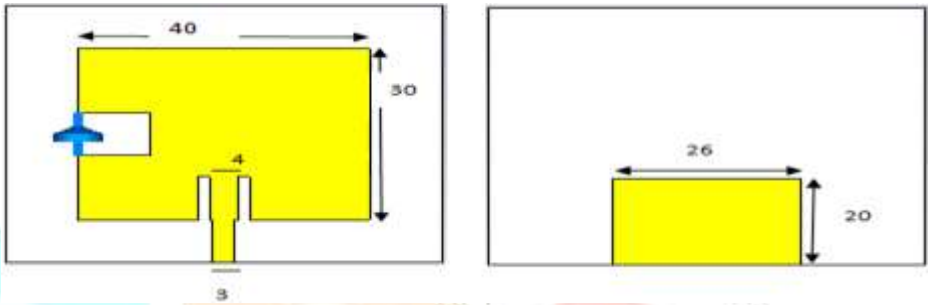
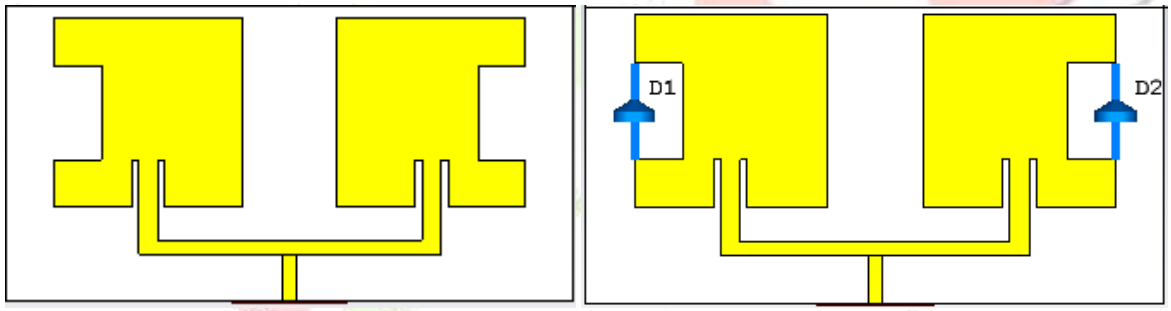


Fig. 2. Simulated design of 1X1 reconfigurable Antenna for WLAN Communication when the diode is ON (Front View and Back View) with dimensions

2.2 Design of 1X2 array:

Here 1X2 reconfigurable array antenna has been designed with above said dimensions. In this design, as shown in Fig.3, two patches are joined together with a common feed. PIN diodes are used to achieve reconfigurability.

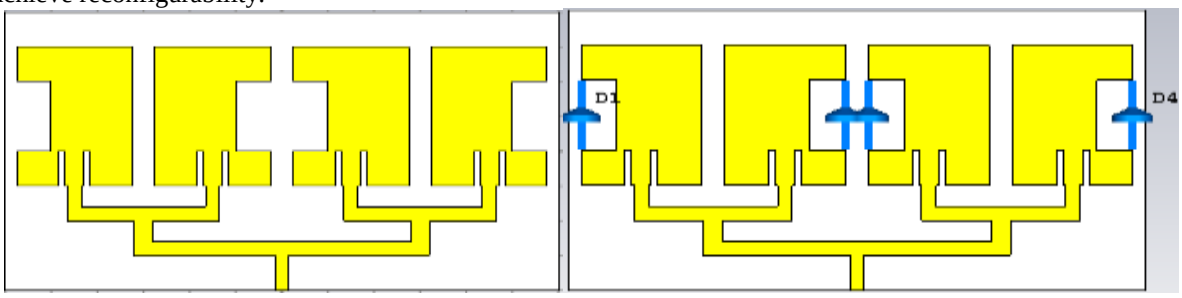


i) When diode is OFF ii) When diode is ON

Fig. 3. Simulated design of 1X2 array reconfigurable Antenna for WLAN Communication

2.3 Design of 1X4 array:

Here 1X4 reconfigurable array antenna has been designed with above said dimensions. In this design, as shown in Fig.4, two 1X2 reconfigurable array antennas are joined together which is sharing a common feed. In this configuration as well, PIN diodes are used to achieve reconfigurability.



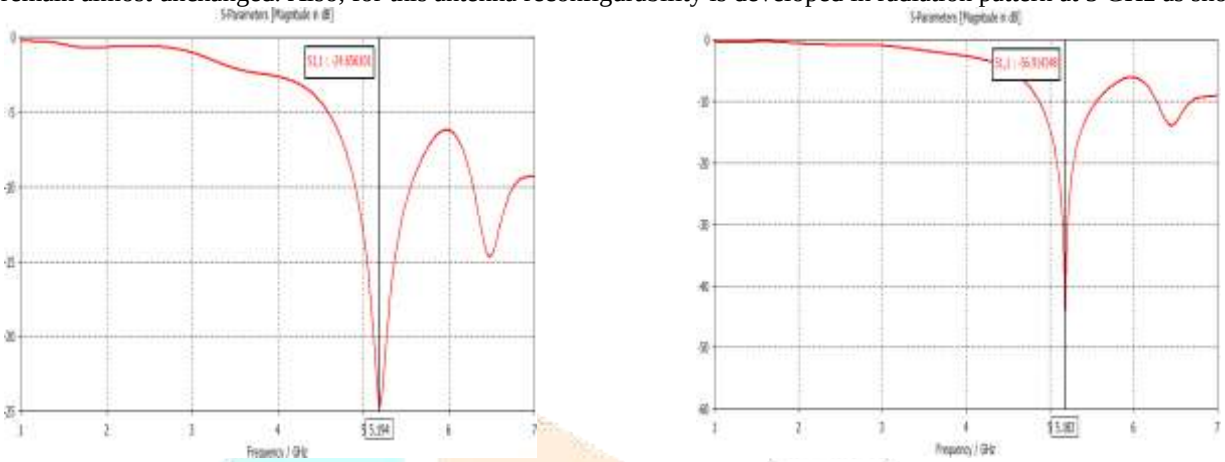
i) When diode is OFF ii) When diode is ON

Fig. 4. Simulated design of 1X4 array reconfigurable Antenna for WLAN Communication

III. Simulation and Study Results

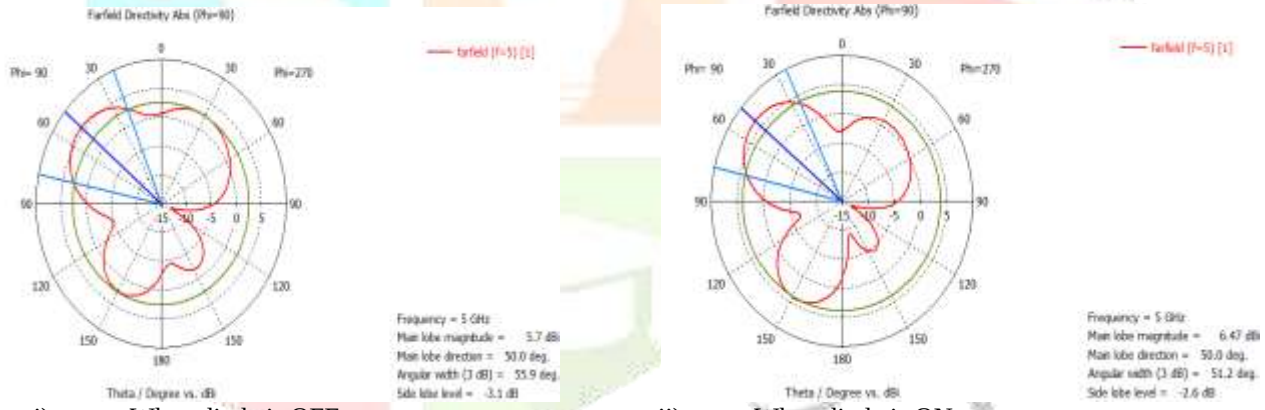
3.1 Simulation and Results of 1X1 antenna:

Return loss and Radiation pattern characteristics of 1X1 antenna is displayed in the Fig.5 and Fig.6 respectively. When diode is in OFF state, then it radiates on frequency 5.194 GHz and when diode is in ON state, it radiates on frequency 5.182GHz. Radiation pattern reconfigurability is the modification in the spherical distribution of radiation pattern while resonant frequency and polarization remain almost unchanged. Also, for this antenna reconfigurability is developed in radiation pattern at 5 GHz as shown in Fig.6.



i) When diode is OFF ii) When diode is ON

Fig. 5. Return loss of 1X1 antenna in OFF and ON condition of diode



i) When diode is OFF ii) When diode is ON

Fig. 6. Radiation pattern of 1X1 antenna in OFF and ON condition of diode

3.2 Simulation and Results of 1X2 array:

Return loss and Radiation pattern characteristics of 1X2 array antenna is displayed in the Fig.7 and Fig.8 respectively. When diode is in OFF state, then it radiates on frequency 4.288 GHz and when diode is in ON state, it radiates on frequency 4.366 GHz. Also, for this antenna reconfigurability is developed in radiation pattern at 4.5 GHz as shown in Fig.8.

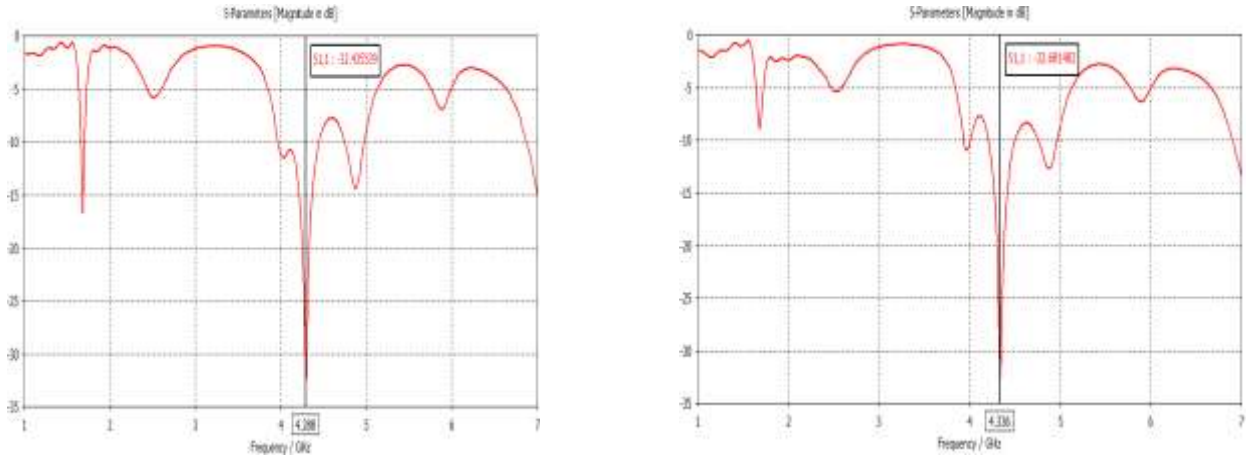


Fig. 7. Return loss of 1X2 array antenna in OFF and ON condition of diode resp.

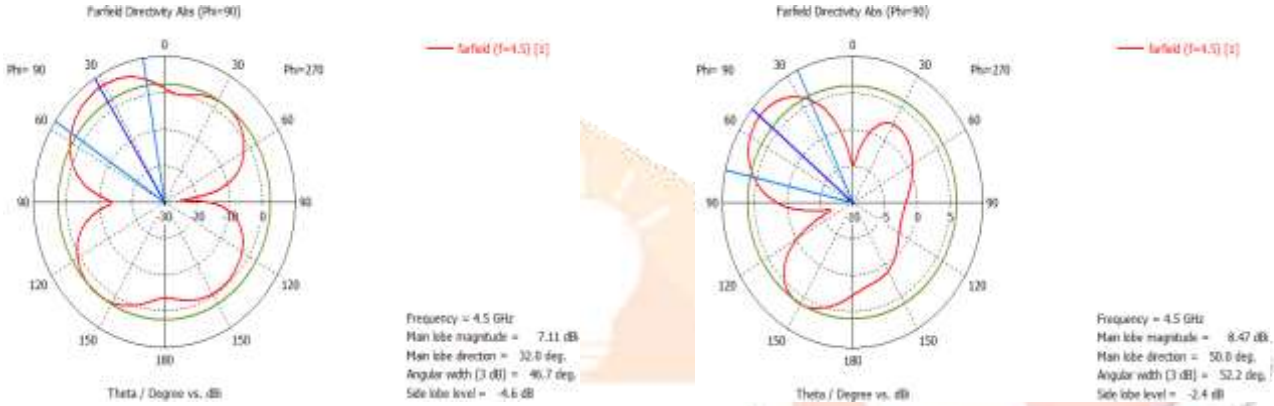


Fig. 8. Radiation pattern of 1X2 array antenna in OFF and ON condition of diode resp.

3.3 Simulation and Results of 1X4 array:

Return loss and Radiation pattern characteristics of 1X4 array antenna is displayed in the Fig.9 and Fig.10 respectively. When diode is in OFF state, then it radiates on frequency 5.092 GHz and when diode is in ON state, it radiates on frequency 5.128 GHz. Also, for this antenna reconfigurability is developed in radiation pattern at 5 GHz as shown in Fig.10.

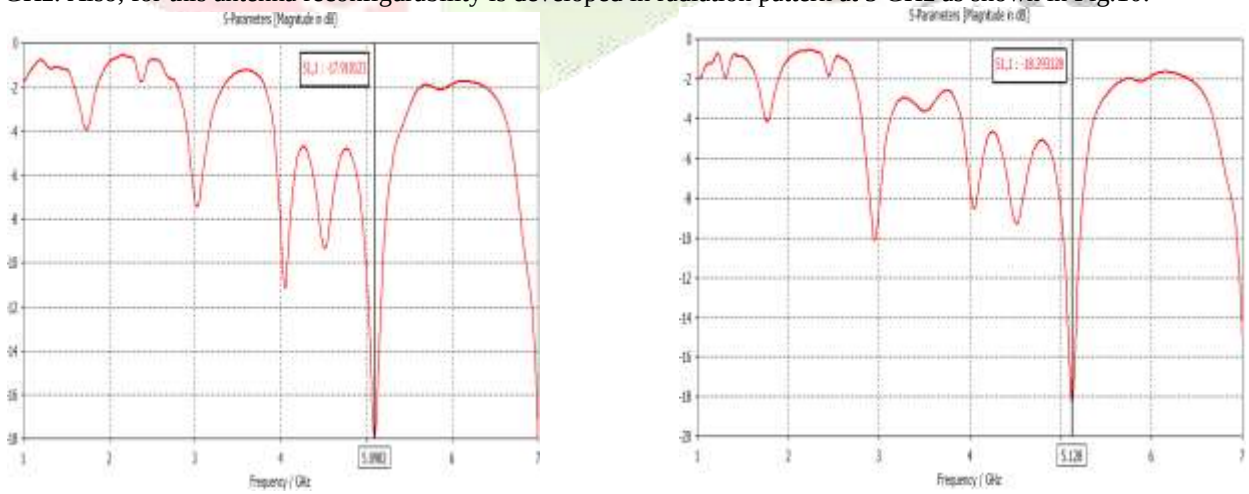


Fig. 9. Return loss of 1X4 array antenna in OFF and ON condition of diode resp.

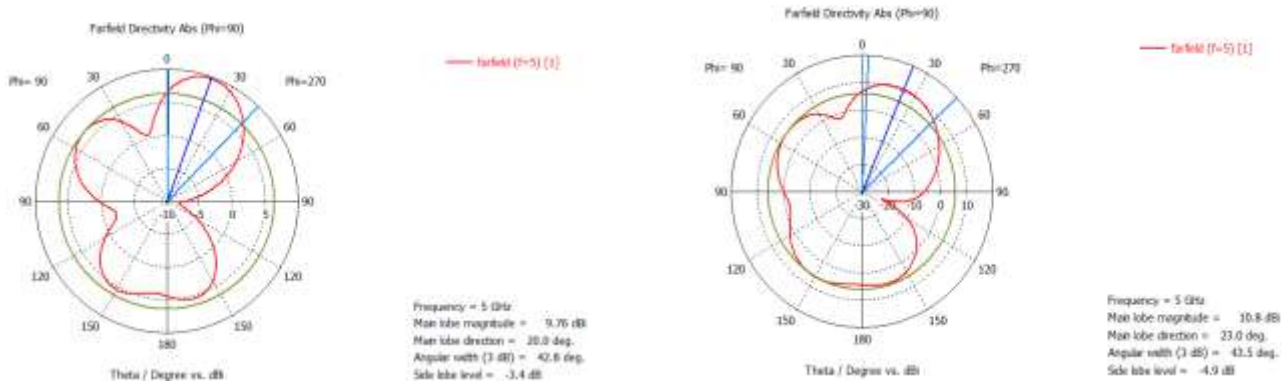


Fig. 10. Radiation pattern of 1X4 array antenna in OFF and ON condition of diode resp.

IV. Comparative Study of All the Designs

As we can see in below Table 1, when there is single Patch Antenna with no diodes, then it radiates on frequency 5.194 GHz, with Gain as 3.979dBi and Directivity as 5.914dBi. On applying diode, radiation frequency slightly changed to 5.182 GHz, with Gain and Directivity increased as 4.258dBi as 6.261dBi resp. Similarly, we can clearly see from Table 1, as numbers of patches in the array are increased, Gain and Directivity are also getting increased. In this paper, we have designed up to 4 patches in the array and obtained maximum gain and directivity as 6.389dBi and 9.989dBi resp.

Table 1. Operating frequency, and return loss, Gain and Directivity of the antenna for each condition

Design	Frequency	S-Parameter	VSWR	Gain	Directivity
1X1	5.194	-24.656	1.124	3.979	5.914
1X1 with diodes	5.182	-56.914	1.002	4.258	6.261
1X2 array	4.288	-32.435	1.048	4.761	7.773
1X2 array with diodes	4.366	-32.681	1.047	5.084	8.236
1X4 array	5.096	-17.913	1.291	6.026	9.608
1X4 array with diodes	5.128	-18.293	1.277	6.389	9.989

1V. Conclusion

In this paper, we have proposed 1X1, 1X2 and 1X4 array antennas and developed reconfigurability for all the three proposed structures. In this design, we have used PIN diodes to achieve reconfigurability, which acts as a switch. From above, it is clear that with the increase of the no. of elements, antenna parameters like gain and directivity are getting improved. As a future work, we can simulate 1X4 microstrip array antenna with different diode configurations to achieve better radiation characteristics like more gain, directivity and bandwidth and reduced return loss. The operating frequency of all our designed antennas ranges from 4.288GHz to 5.194GHz, which is suitable for C-band applications, WLAN applications and Satellite applications.

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