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Design and Analysis of Frequency Reconfigurable Microstrip Patch antenna for Multi Band Operations using PIN Diodes

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Abstract*: Multiband reconfigurable patch antenna plays a vital role in wireless communication applications. By changing the current path on the patch a multiband reconfigurable antenna can be achieved. A simple multiband frequency reconfigurable microstrip patch antenna is presented in this paper. The proposed antenna structure is simulated in CST microwave studio. This antenna operates between 1.3 to 5.6 GHz with more than fifteen different frequencies. The antenna is analyzed for four different configurations. The designed antenna is resonating at five different frequencies (1.45 GHz, 2.36 GHz, 3.09 GHz, 3.6 GHz and 5.45 GHz) when both PIN diodes are ON. When PIN diode D1 is ON and D2 is OFF the antenna is resonating at 1.4 GHz, 2.22 GHz, 2.5 GHz, 3.08 GHz and 3.59 GHz. When D1 is OFF and D2 is ON the antenna is resonating at 2.34 GHz, 3.2 GHz, 3.62 GHz and 5.38 GHz frequencies. The slotted antenna or when both PIN diodes are in OFF condition antenna is resonating at 2.22 GHz, 2.49 GHz, 3.21 GHz, 3.6 GHz and 5.42 GHz. For each configuration the antenna parameters like gain, VSWR, directivity and radiation patterns are analyzed.

***Keywords*: Multiband, PIN Diodes, Frequency Reconfigurable antenna, CST MWS**

I. INTRODUCTION

The disadvantages of conventional antenna can be overcome by using reconfigurable antenna where we can dynamically alter the antenna parameters like radiation pattern, operating frequency, polarization or combination of these parameters which is not possible with the conventional antenna [1] [12]. Day by day the demand for wide band, multiband reconfigurable antenna is increasing which satisfy wireless communication applications. For satellite and wireless communication applications the reconfigurability feature has become an essential component of modern, radio-frequency (RF) systems [3] [5].

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The cost of communication systems, size and complexity can be significantly reduced by using reconfigurable antenna technique. Switching devices like PIN diodes, varactor diodes or MEMS switches are used to change the current paths on the antenna thereby we can achieve multi frequency function [2] [6]. The designed antenna contains two slots, one slot on patch and other one on ground surface. PIN diode is placed in patch slot as well as ground slot. The effect of switching effects, gain, directivity, VSWR and radiation patterns are discussed.

II. ANTENNA GEOMETRY

CST microwave studio is used to design and simulate the proposed antenna. The structure of the antenna is shown in fig.1 (front view) and fig. 2 (back view). FR-4 lossy (with dielectric constant of 4.3) is used as the substrate material and the height is 1.6 mm. The dimension of the patch is 46.07 mm X 35.85 mm. Frequency reconfigurability is achieved by using two PIN diodes (BAP50_02). Following formulae [7], [12] were used to design the antenna:

Width of the patch can be calculated by,

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad ----(1)$$

Length of the patch can be calculated by,

$$L = L_{eff} - 2\Delta L \quad ----(2)$$

Where

$$\Delta L = 0.412h\left[\frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)}\right] \quad ----(3)$$

$$\varepsilon_{reff} = \left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right)\left[1 + 12(\frac{h}{W})\right]^{-0.5} \quad ------(4)$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\frac{2}{\varepsilon_{reff} + 1}}} \quad ------(5)$$

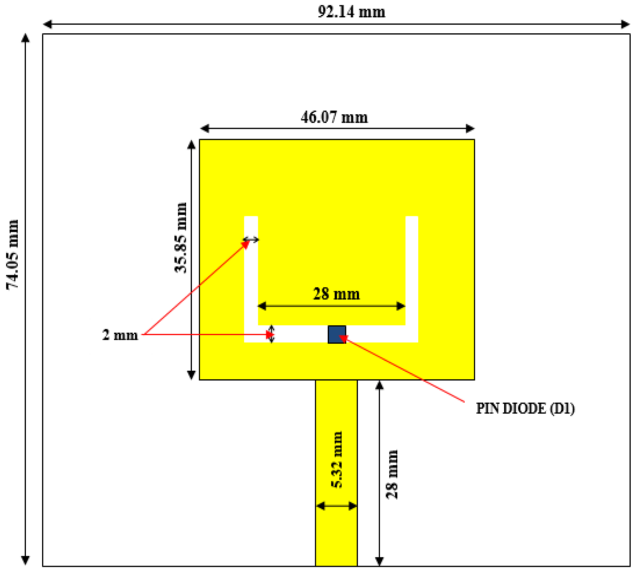


Fig.1: Front view of proposed antenna

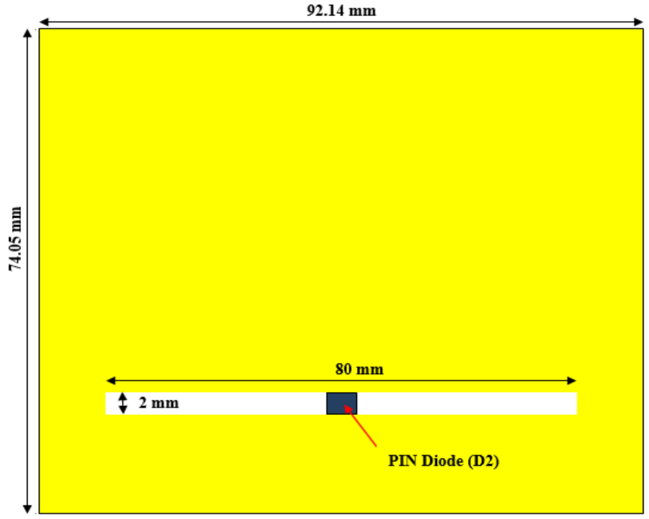


Fig. 2: Back view of proposed antenna.

III. RESULTS AND DISCUSSIONS

A. Effect of Slots (When D1 and D2 are OFF)

One slot is cut on the patch and the other one on the ground surfaces as shown in fig. 1 and fig. 2 respectively. Fig. 3 shows the return loss graph for slotted antenna.

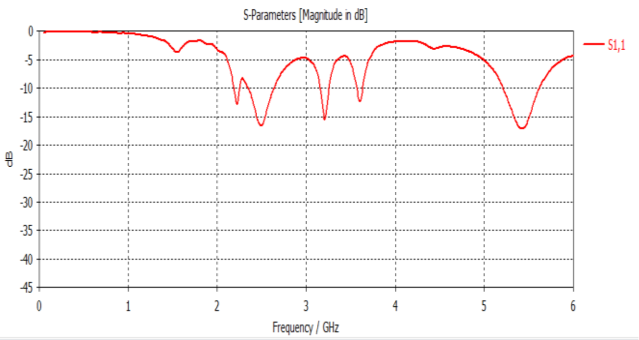


Fig. 3: Return Loss graph of Slotted antenna

Simulated results of slotted antenna are presented in Table-I.

Table-I: Simulated results of slotted antenna

Frequency (GHz)	Return Loss (dB)	Bandwidth (GHz)	VSWR	Gain (in dB)	Directivity (in dBi)
2.22	-12.93	0.07	1.94	4.10	6.46
2.49	-16.65	0.29	1.70	5.38	6.59
3.21	-15.47	0.09	1.99	5.68	6.04
3.6	-12.28	0.08	1.7	0.05	6.68
5.42	-17.14	0.4	1.41	2.15	4.91

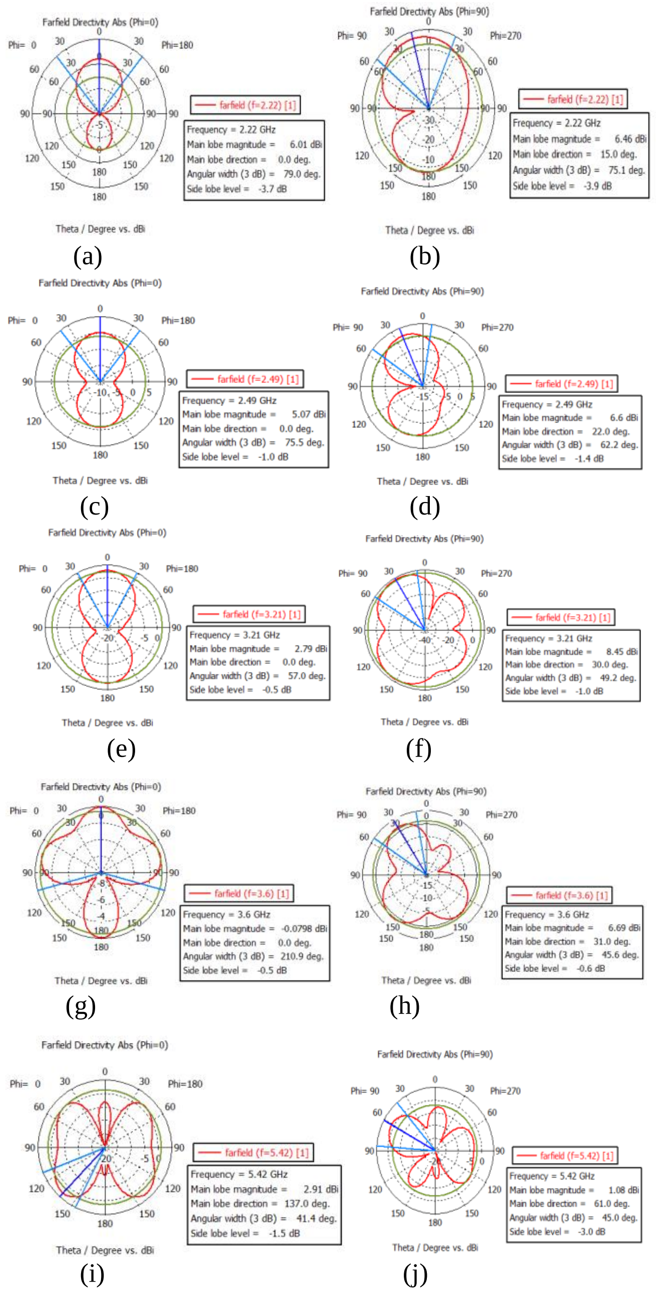


Fig. 4: Radiation patterns for slotted antenna. [(a), (c), (e), (g) and (i) represent E-plane] and [(b), (d), (f), (h) and (j) represent H-plane]

In fig. 4 the simulated radiation patterns for slotted antenna are shown. Some of the E-plane patterns are omnidirectional and remaining (H-plane also) are like shaped beam pattern.

The slotted antenna can be used for Mobile Satellite Service, Broadband Radio Service, TV Broadcast Auxiliary Service, Amateur Radio Service, the Fixed Satellite Service, Radiolocation Service and Long-distance radio telecommunications.

B. B. Effect of PIN Diode

i. Case-I: Both PIN diodes (D1 and D2) are ON:

To achieve the frequency reconfigurability one PIN Diode is placed in the patch slot as shown in the fig. 1 and other is placed in the ground slot as shown in fig. 2. Table-II presents the simulated results of the proposed antenna when PIN diode D1 and PIN diode D2 are in ON condition. The antenna radiates at 1.4 to 5.5 GHz as shown in fig. 5.

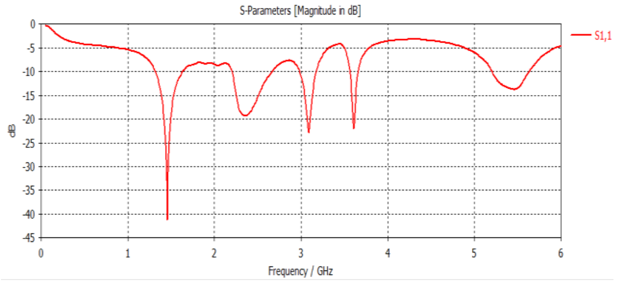
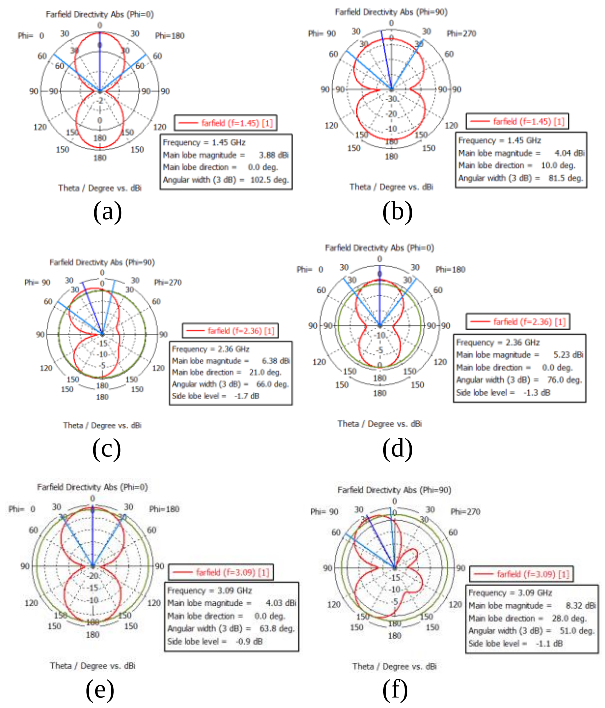


Fig. 5. Return Loss graph for proposed antenna (Case-I)

Table-II: Simulated results for Case-I

Frequency (GHz)	Return Loss (dB)	Bandwidth (GHz)	VSWR	Gain (in dB)	Directivity (in dBi)
1.45	-40.8	0.313	1.27	2.41	4.04
2.36	-19.27	0.458	1.67	5.15	6.36
3.09	-22.85	0.203	1.72	5.78	8.31
3.6	-21.95	0.09	1.70	0.05	6.68
5.45	-13.79	0.43	1.45	2.31	5

The simulated radiation patterns are presented in fig. 6.



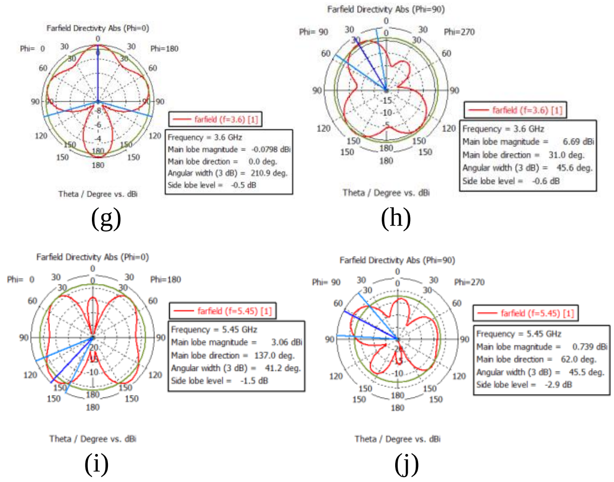


Fig. 6: Radiation patterns for Case-I. [(a), (c), (e), (g) and (i) represent E-plane] and [(b), (d), (f), (h) and (j) represent H-plane].

This antenna configuration can be used for Aviation Service, Maritime Service, Radiolocation Service, Fixed Satellite Service and long-distance radio telecommunications.

ii. Case-II: D1 ON and D2 OFF:

For case-II the configuration is PIN diode D1 is ON and D2 is OFF. For this configuration antenna radiates at 1.4 to 3.59 GHz, which is shown in fig.7. Table-III presents the simulated results for case-ii configuration and radiation patterns are shown in fig. 8.

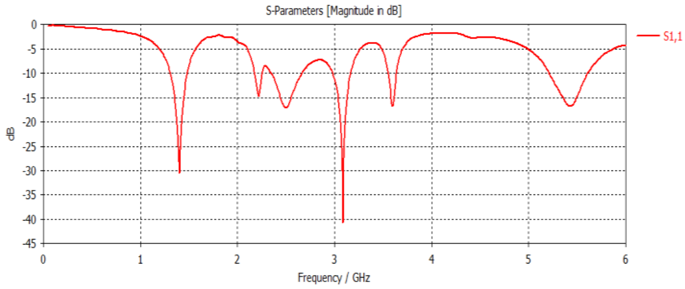
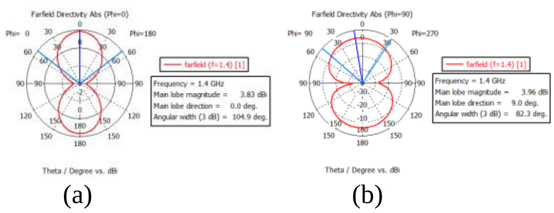


Fig. 7. Return Loss graph for proposed antenna (Case-II)

Table-III: Simulated results for Case-II

Frequency (GHz)	Return Loss (dB)	Bandwidth (GHz)	VSWR	Gain (in dB)	Directivity (in dBi)
1.4	-30.33	0.18	1.3	2.25	3.96
2.22	-14.48	0.09	1.94	4.10	6.46
2.5	-17.08	0.29	1.71	5.41	6.61
3.08	-40.70	0.18	1.70	5.78	8.28
3.59	-16.82	0.08	1.84	-0.25	6.57



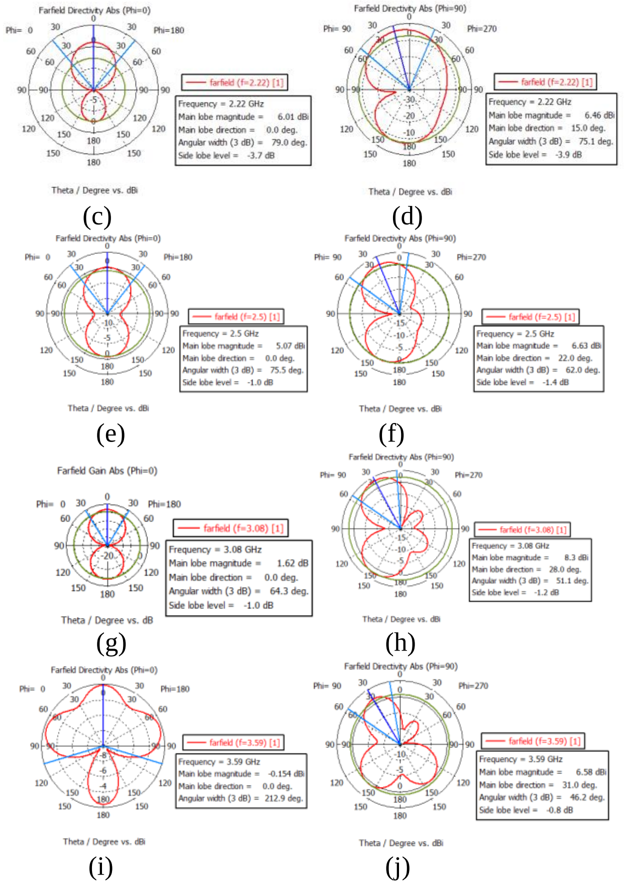


Fig. 8: Radiation patterns for Case-II. [(a), (c), (e), (g) and (i) represent E-plane] and [(b), (d), (f), (h) and (j) represent H-plane].

This antenna configuration can be used for Earth Exploration-Satellite, Radio Astronomy, and Space Research Services, Broadband Radio Service, Mobile Satellite Service, TV Broadcast Auxiliary, Maritime Service, Fixed Satellite Service and the Radiolocation Service.

iii. Case-III: D1 OFF and D2 ON:

When PIN diode D1 is OFF and PIN diode D2 is ON the antenna radiates at 2.34 GHz to 5.38 GHz as shown in fig.9. Table-IV presents the simulated results of Case-III and radiation patterns are shown in fig. 10.

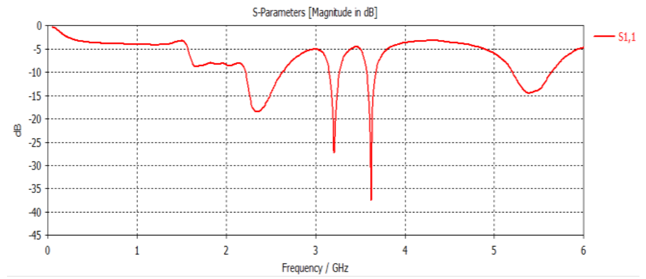


Fig. 9. Return Loss Graph for Case-III.

Table-IV: Simulated results for Case-III

Frequency (GHz)	Return Loss (dB)	Bandwidth (GHz)	VSWR	Gain (in dB)	Directivity (in dBi)
2.34	-18.52	0.41	1.66	5.06	6.18
3.2	-27.22	0.10	2.02	5.71	6.04
3.62	-37.21	0.10	1.49	0.83	6.98
5.38	-14.48	0.44	1.38	1.78	4.09

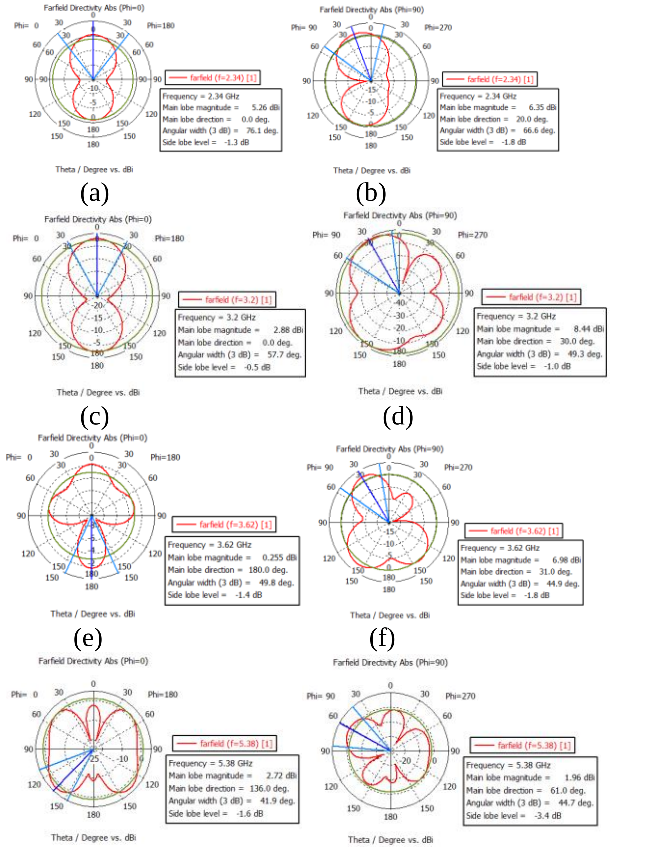


Fig. 10: Radiation patterns when D1 is ON and D2 is OFF. [(a), (c), (e) and (g) represent E-plane] and [(b), (d), (f) and (h) represent H-plane].

This antenna configuration can be used for Aviation Service and the Wireless Communications Service, Amateur Radio Service, the Fixed Satellite Service, Radiolocation Service and long-distance radio telecommunications.

iv. Case-III: Both D1 and D2 OFF:

When both the PIN diodes are off the antenna configuration is similar to the slotted antenna which is discussed in section III A.

A comparison between proposed antenna with different antenna models available in literature is presented in Table-V.

Table-V: Comparison results

Reference	No. of PIN diodes used	Patch Area (WxL) mm^2	Resonant Frequencies (GHz)
Reconfigurable Single and Dual Band Microstrip Patch Antenna for Satellite communications [8]	4	17.4x12.48	3.46, 3.99, and 4.64
Design frequency reconfigurable Microstrip patch antenna for s-band Applications [9]	3	35x21.5	2.07,2.23,2.55, 2.76, 2.78, 2.83, 3, and 3.12

Design of Reconfigurable Fractal Antenna using Pin Diode Switch for Wireless Applications [10]	6	30x30	2.47, 3.58, 3.62, 5.55, 5.88, 5.93, 6, 6.07,8.63, 8.67 and 8.72
Frequency Reconfigurable Rectangular Antenna with TSlotted Feed Line [11]	2	98.5x72	1.8, 2.3 and 2.4
Proposed	2	46.07X35.85	1.4, 1.45, 2.22, 2.34, 2.36, 2.49, 2.5, 3.08, 3.09, 3.2, 3.21, 3.59, 3.6, 3.62, 5.38, 5.42, and 5.49

IV. CONCLUSION

CST MWS tool is used to design and analysis of multiband frequency reconfigurable antenna. Only two PIN diodes have been used to configure the antenna as multiband frequency reconfigurable antenna. Four different configurations are presented for the proposed antenna. This antenna operates between 1.3 to 5.6 GHz with more than fifteen different frequencies. A comparison results of proposed antenna were discussed. The antenna is compact, low cost, has high gain and directivity, low power and it will be well suited for L band, S band, and C-band wireless applications.

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