

# A Frequency Reconfigurable Antenna with Six Switchable Modes for Wireless Application

Rachana Yadav, Sandeep Yadav and Sunita

**Abstract** In this paper, a frequency switchable microstrip patch antenna with defected ground structure is presented. Frequency characteristics of this antenna can be switched between different frequency bands. Reconfigurability is achieved using different slots on ground structure and three PIN diodes loaded onto these slots as switches. By changing the PIN diode states to either ON or OFF, any particular slot on ground structure will be activated, hence making the antenna to be operable in six different modes which serves different frequency bands to be used for different wireless applications. Return loss, VSWR and gain are analyzed for different modes of operation. To design and simulate the proposed antenna CST microwave studio is used.

**Keywords** PIN diode · Reconfigurable antenna · Switching · Wireless applications

## 1 Introduction

In today's communication system, reconfigurable antenna's multifunctional capability plays an advantageous role. Based on reconfigurability of antenna characteristics it is classified into four basic categories—frequency reconfigurable antenna [1], polarization reconfigurable antenna [2], radiation pattern reconfigurable antenna [3], and hybrid (which is the combination of the any of the three other

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categories) [4]. Operating state of antenna can be realized using mechanical or physical alteration, reconfigurable biasing network or using different types of switches (pin diodes, varactor diodes, MEMS etc.) which alter the surface current distribution and change the antenna characteristic [5, 6].

In last few years, many techniques have been used for frequency reconfigurable antenna. PIN diode as a switch is used more frequently because of easy assembly and low cost. MEMS also have been used more often as they have low insertion losses and low power consumption. In wireless communication system, some specific frequency bands are used only for some specific purposes. A frequency reconfigurable antenna with switchable bands provides only one antenna to operate at different wireless standards. In [7], a frequency reconfigurable antenna with narrowband and dual band characteristics is presented. This antenna operates in WLAN (2.4–2.48 GHz) and WiMAX (2.5–2.69 GHz), while the dual-band covers the PCS (1.85–1.99 GHz) and WiMAX (3.4–3.69 GHz). GaAs field effect transistor is used as a switch to achieve reconfigurability. In [8], a reconfigurable antenna with T-slot in patch and E-slot in ground plane is presented. This T-slot divides antenna into three parts. Two PIN diodes are used for reconfigurability antenna works in triple bands (3.9, 8.9 and 11.2 GHz) in one mode and operates in three other bands (4.1, 8.4 and 11.3 GHz) in another mode. In [9], a frequency and pattern reconfigurable antenna is presented. This antenna has three modes of operation, an omnidirectional pattern mode at the lower frequency band of 2.21–2.79 GHz, a unidirectional pattern mode at the higher frequency band of 5.27–5.56 GHz, and both of them working simultaneously.

In this paper, a microstrip patch antenna with defected ground structure is introduced. Antenna is capable to operate in six different modes. To achieve reconfigurability, three PIN diodes are used as switches. These diodes are mounted on the antenna between different slots. By changing the ON/OFF state of diode, different combination of slots are activated at different mode which alter the current distribution of antenna and make it to resonate at different frequencies.

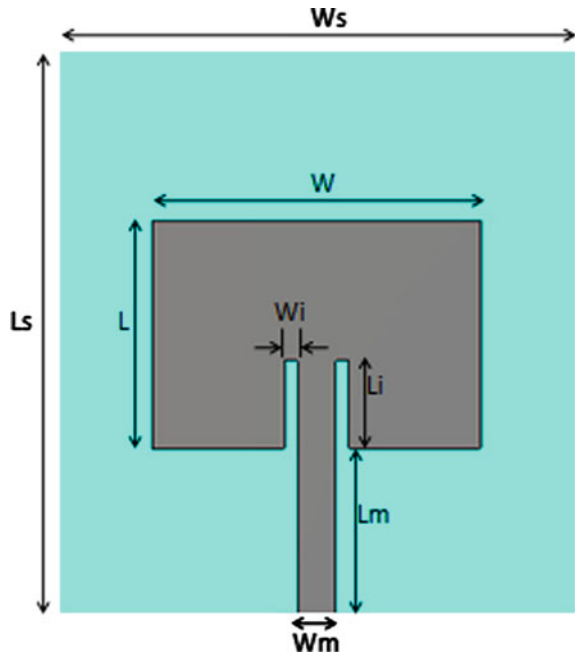
## 2 Antenna Configuration and Design

Front view of proposed antenna is shown in Fig. 1. This is a simple microstrip patch antenna with operating frequency 5.3 GHz. Firstly, antenna is designed using transmission model approach of microstrip antenna. After that, slots have been cut in ground structure of different size and shape.

Antenna has a radiating patch with patch length  $L$  and width  $W$  and FR-4 substrate of dielectric constant 4.4. Length and width of ground and substrate are same for the basic antenna design. Substrate length and height are  $L_s$  and  $W_s$  respectively. Other parameters of antenna are shown in Table 1.

Simulated return loss of base antenna is shown in Fig. 2. A frequency band around 5.31 GHz is achieved.

**Fig. 1** Antenna structure (Front view)



**Table 1** Antenna dimensions of proposed antenna

Parameter	Values (mm)
Width of patch ( $W$ )	17.4
Length of patch ( $L$ )	12.48
Width of substrate ( $W_s$ )	27.48
Length of substrate ( $L_s$ )	30.8
Dielectric constant ( $\epsilon_r$ )	4.3
Height of the substrate ( $h$ )	1.67
Height of the patch and ground	0.05
Microstrip feed length ( $L_m$ )	9
Microstrip feed width ( $W_m$ )	2
Inset width ( $W_i$ )	0.7
Inset length ( $L_i$ )	4.8

### 3 Frequency Reconfigurable Antenna Configuration and Design

Now, to get switchable multiple frequencies, slots are cut in ground plane. From the Fig. 3 it can be seen that slots are not of symmetrical shape. Change in slots geometry has been made to make antenna resonate at some specific frequencies.

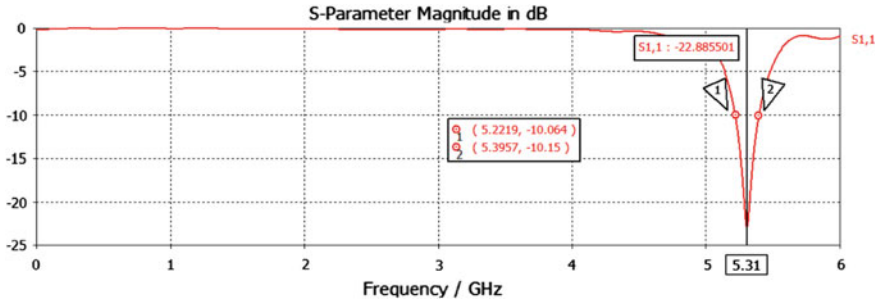
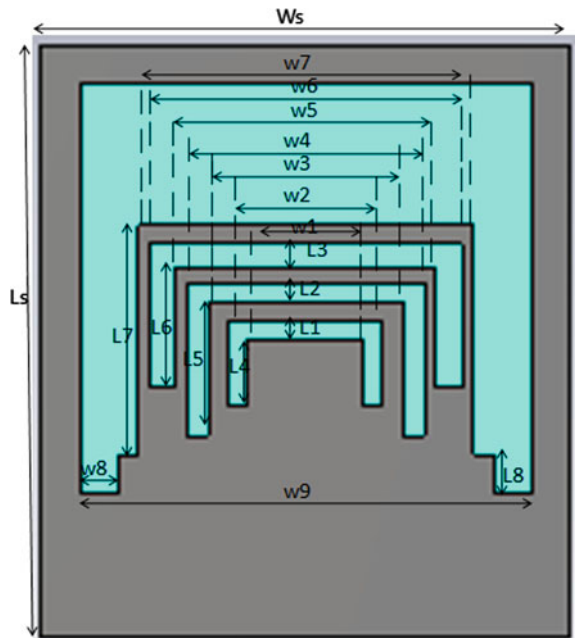


Fig. 2 Return loss of base microstrip patch antenna

Fig. 3 Proposed frequency reconfigurable antenna without switch (Back-view)

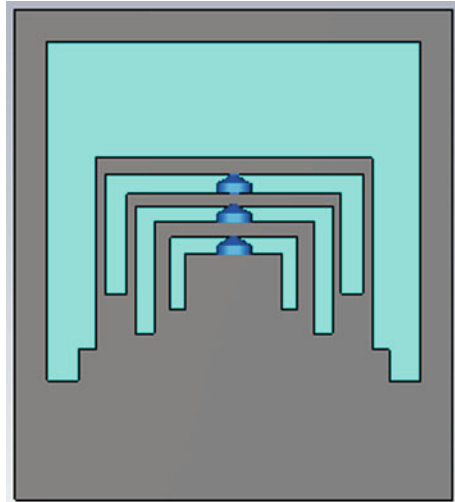


Three switches are loaded in slots. Here, HPND-4005 beam lead PIN diodes are used as a switch. In ON state, diode is modeled by a  $1.5 \Omega$  register and in OFF mode modeled by a  $0.017 \text{ pF}$  capacitor (Fig. 4 and Table 2).

### 3.1 Simulated Results

Based on the ON/OFF state of the PIN diode and using different combination of these switches' state proposed antenna will work in six modes. At particular

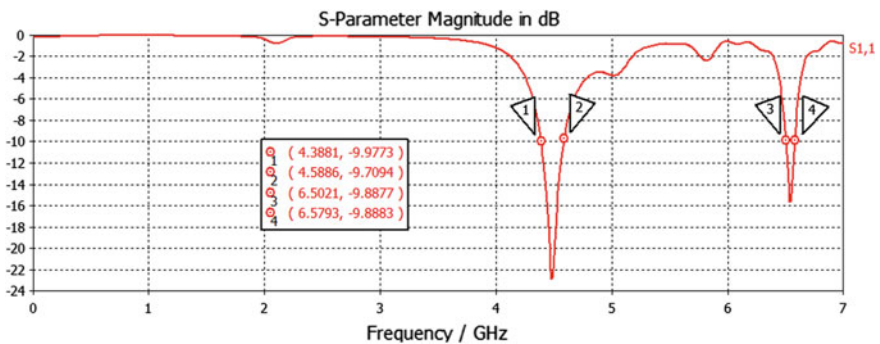
**Fig. 4** Proposed frequency reconfigurable antenna with switches (*Back-view*)



**Table 2** Dimensions of slots of ground plane

W1	W2	W3	W4	W5	W6	W7	W8	W9	Ws
6	8	10	12.4	13.4	16.2	17.4	1.96	23.42	27.42
L1	L2	L3	L4	L5	L6	L7	L8	Ls	
1	0.98	1.25	3.5	7	6.1	11.98	2	30.8	

instance, when ON/OFF state of three diodes take place, then according to the activation of the one or more slots, surface current distribution will change which then affects the resonant frequency. This is the basic phenomenon of switching here (Figs. 5, 6, 7, 8, 9, 10, 11 and Tables 3 and 4).



**Fig. 5** Return loss plot for mode I

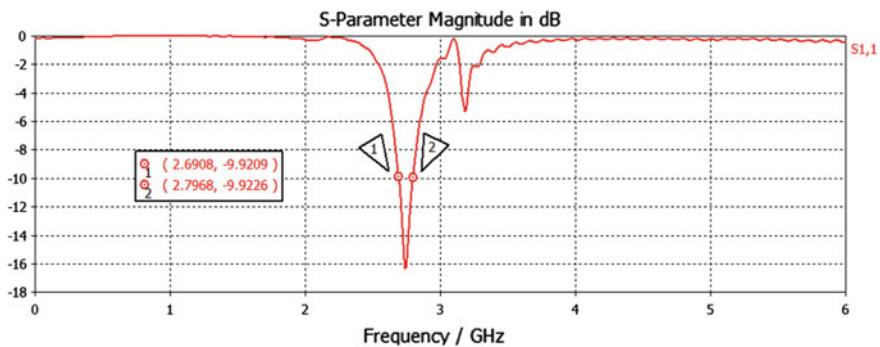


Fig. 6 Return loss plot for mode II

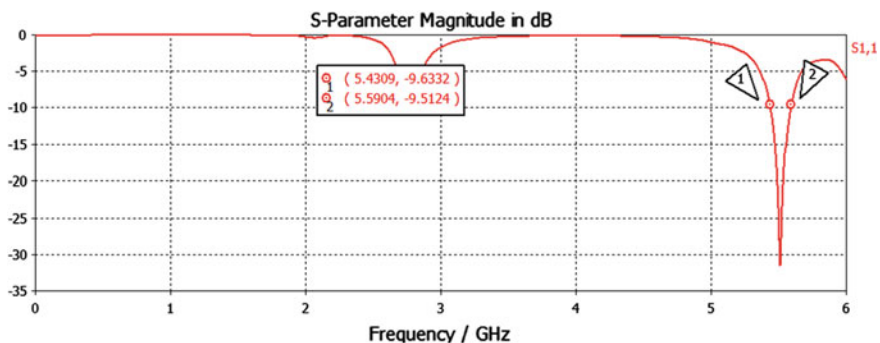


Fig. 7 Return loss plot for mode III

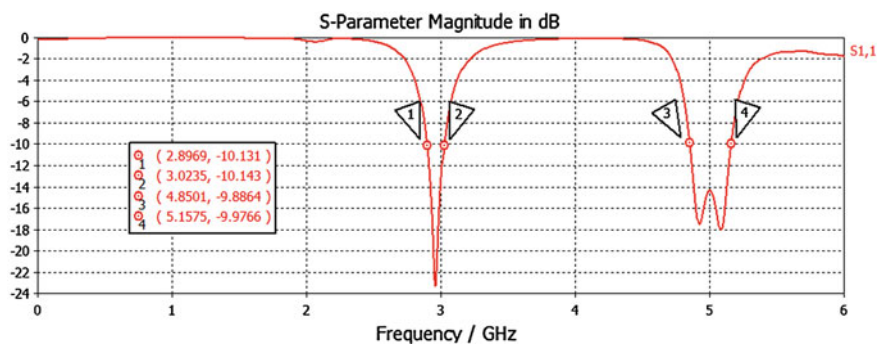


Fig. 8 Return loss plot for mode IV

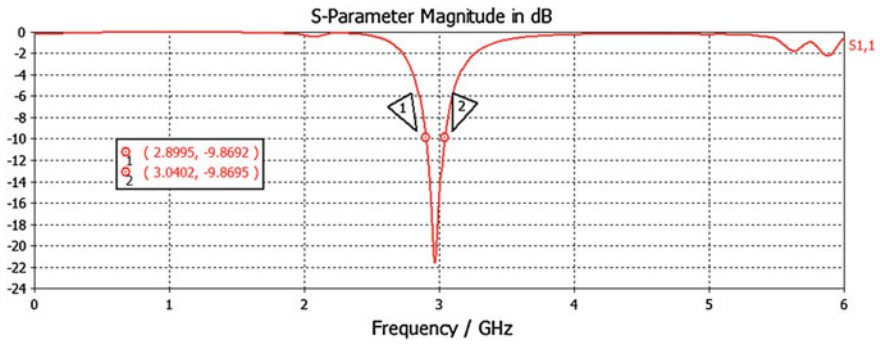


Fig. 9 Return loss plot for mode V

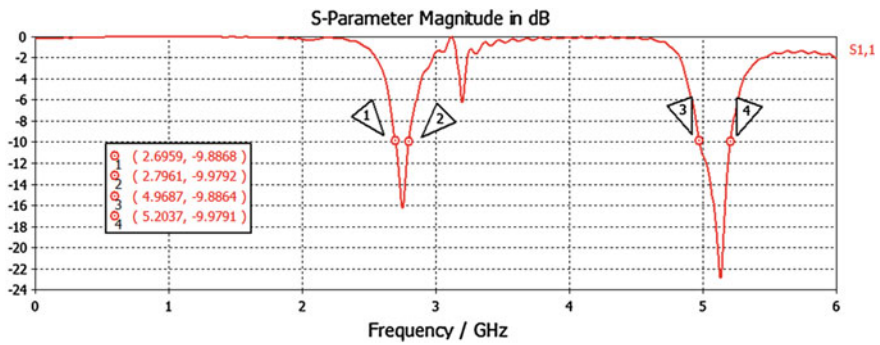
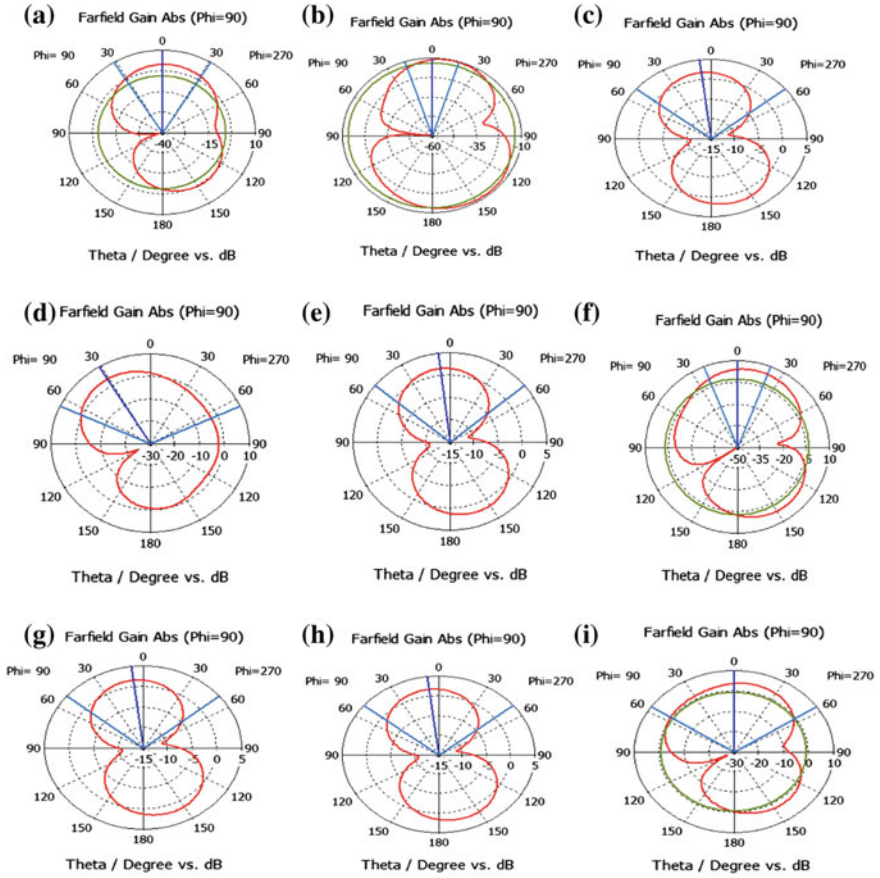


Fig. 10 Return loss plot for mode VI

### 4 Results and Discussion

To design and simulate the proposed frequency reconfigurable antenna, CST microwave studio is used. Reconfigurable frequency bands are achieved using ON/OFF states of the PIN diodes. Seven different frequency bands are obtained with center frequency 4.4 GHz (Rx frequency for INSAT), 6.5 GHz (Tx frequency for extended c-band), 2.7 GHz (WISP/NLOS/802.16), 5.5 GHz (UI-wireless), 2.9 GHz, 5 GHz (Wi-fi and WLAN), and 5.12 GHz (UNII-1) 12.3 GHz. Return loss and gain has been analyzed for individual mode and presented systematically. Because of its multifunctional property, antenna is operable for multiple wireless applications.



**Fig. 11** Gain for six modes—**a, b** for mode I, **c** for mode II, **d** for mode III, **e, f** for mode IV, **g** for mode V, **h, i** for mode VI

**Table 3** Summarized results for proposed antenna for OFF state and ON state (in terms of operating frequency/ies)

Mode	Switch state			Center frequency (bands in GHz)
	S1	S2	S3	
I	ON	ON	ON	4.47 GHz (4.38–4.58), 6.53 GHz (6.50–6.57)
II	ON	OFF	OFF	2.73 GHz (2.69–2.79)
III	ON	ON	OFF	5.5 GHz (5.43–5.59)
IV	OFF	OFF	ON	2.95 GHz (2.89–3.02), 5 GHz (4.85–5.15)
V	ON	OFF	ON	2.96 GHz (2.89–3.02)
VI	OFF	OFF	OFF	2.74 GHz (2.69–2.79), 5.12 GHz (4.96–5.20)



**Table 4** Summarized return loss and gain results

Mode	Return loss	Gain (dB)
I	-23 dB at 4.47 GHz, -15 dB at 6.53 GHz	1.1 and 3.5
II	-16 dB 2.73 GHz	1.9
III	-32 dB at 5.5 GHz	3.3
IV	-23 dB at 2.95 GHz, -16 dB at 5 GHz	1.6, 4.1
V	-22 dB at 2.96 GHz	1.7
VI	-16 dB at 2.74 GHz, 5.12 GHz at -23 dB	1.9, 3.8

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