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Design and Simulation of Compact Microstrip Patch Antenna for Frequency Diversity Application

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Abstract—In this paper, a Compact low profile Microstrip patch antenna is proposed for frequency diversity application. To achieve frequency diversity, antenna is required to transmit at different frequencies. This can be achieved by using frequency re-configurability in antennas. Frequency re- configurability is attained by switching ON or switching off the semiconductor like PIN diodes. Thereby proposed antenna achieves frequency re- configurability under four different mode of operation.
Keywords—Microstrip patch antenna, PIN Diode, Re- configurability.

I. INTRODUCTION

Wireless communication systems have experienced enormous development over the past two decades. An antenna as a front component is required to have a wide band, good radiation performances and sometimes switchable ability. To obtain the switchable ability of the antenna, the concept of a reconfigurable antenna was proposed a few years ago. A reconfigurable antenna is an antenna capable of modifying its frequency and radiation properties dynamically, in a controlled and reversible manner. Frequency re-configurability in this antenna is attained by varying the effective length of the radiating slot by the use of semiconductor switches. Re-configurable antennas are popular because of their capability to operate multiple frequencies for multiple applications. Advantage of using reconfigurable antennas is that, these antennas can be designed with no considerable effect on increase in the size of the antenna.

Microstrip patch antenna is used for frequency diversity application due to its low profile and easy design [2]. They are mechanically strong and can be fit in any physical structure [2]. Proposed antenna consists of radiating patch and a slot in the patch which is embedded with PIN Diodes. This antenna structure provides seven different frequencies of operation in the range of 2.6GHz to 3.9GHz using RF PIN diode switch placed in the slot. The antenna is simulated using HFSS.

II. LITERATURE REVIEW

1. K. Srinivasan, et all, 2021 "Design and Analysis of Microstrip Slot Antenna": The microstrip slot antenna is designed to perform from five to 10GHz. The corresponding return loss to proposed antenna is -21 dB at 5Hz and -29 dB at 10GHz and the acquired VSWR is less than 2 which gives better impedance matching. The antenna can be exhaustively used for c band applications. The proposed structure has been simulated through the usage of Ansys HFSS software tool.
2. Suganya J, 2020 "Microstrip Patch - Slot Antenna with High Gain for Frequency Diversity Applications": The proposed antenna provides frequency reconfiguration by switching ON or switching OFF the PIN diodes. Thereby frequency re-configurability with three resonant frequencies (3.963 GHz, 3.074 GHz and 2.95 GHz) under three different modes of operation are achieved. Proposed antenna has dual-band of operation for MIMO in WLAN system and 4G.
3. Sonal Dubal et all, 2020 "Multiband

Reconfigurable Antenna for Wireless Applications": A hook shaped compact triband monopole antenna of area 20 x 20 mm2 is proposed and analysed for reconfigurability. The radiator accompanied with p-i-n diode as switching components alter the active path of patch resulting in frequency reconfigurability. The antenna switches between three bands (1.9 GHz - 2.1 GHz, 2.7 GHz - 3.1 GHz, and 4.9 GHz - 8.3 GHz) as per the diode states for different wireless applications such as WLAN, Wi-Max, UMTS, ITS.

4. Minakshmi Shaw, et all, 2020 "Frequency Reconfigurable Microstrip Patch Antenna for IRNSS Applications": This paper presents a compact frequency reconfigurable antenna for IRNSS applications. The proposed antenna can switch the frequency between L5-band and S-band. The reconfigurability for the designed antenna is achieved by incorporating RF PIN (three) diode between the radiating element and resonance slot. The proposed antenna is resonated at 1.1753 GHz (1.16 GHz to 1.19 GHz) and 2.4895 GHz (2.47 GHZ to 2.51 GHz) with ON and OFF condition of PIN diodes, respectively. It is compact and low-profile structure with maximum gain of 8.51 dBi with low cross polarization (CP) of approximate < −30 dB and length and width size are 120X120 mm.

5. Wahaj Abbas Awan, et all 2019" Frequency Reconfigurable patch antenna for millimetre wave applications": The presented work is a "Y" slotted mm-wave reconfigurable patch antenna, suitable for radar, satellite communications, 5G generation wireless network and millimetre wave energy harvesting. The frequency reconfigurability is achieved using 2 PIN diodes integrated into the radiating element of the antenna. Four frequencies are produced using our proposed antenna, which is respectively 49.84GHz, 31.65GHz, 31,4GHz and 45,45GHz, showing strong performance in term of return loss, bandwidth, directivity, and VSWR.

III. DESIGN AND IMPLIMENTATION

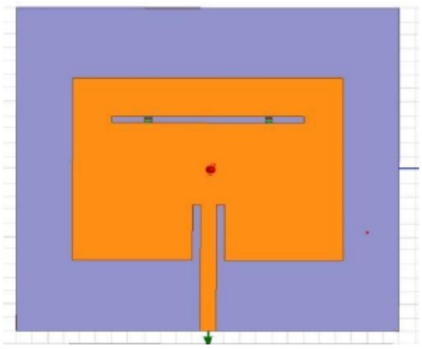

Fig 3.1 Designed Antenna

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

The Patch length is calculated using the equation:

$$L = \frac{c}{2 f_0 \sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (3)$$

where,

$$\Delta L = 0.412h \frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \qquad (4)$$

h = Height of substrate

ε_r = Relative Permittivity

C = speed of light

Figure 3.1 illustrates the structural geometry of the designed microstrip patch antenna. The antenna is designed on Roger RT/Duroid 5880 substrate with dielectric constant (ε_r) 2.2, loss tangent of 0.0009, and a thickness of h = 3.2mm. With the help of the mentioned parameters, Length, Width, feedline, slot, and matching system parameters were calculated. Additionally, Two BAP65-02,115 pin diode models were placed at corners of the slot as shown in Figure 3.2. In ON state, both the switches were fed forward biased resistor R_s = 1ohm and parasitic inductance of L_{pr} = 0.6nH. In OFF state, the switches were fed inversed biased resistor R_p = 20kohm and a reversed biased parasitic capacitance C_t = 0.5pF. Capacitor of 1uf was also used as DC blocker.

Fig 3.2 PIN Diodes in the slot.

The Patch width is calculated using the equation from [2]:

$$\square = \frac{\square}{2\square}\sqrt{\frac{2}{\square_r+1}} \quad (1)$$

The Effective dielectric constant for patch is calculated using the equation from [2]:

Table 4.2 shows the details of switch configuration.

Configuration	S1	S2
F1	ON	ON
F2	ON	OFF
F3	OFF	ON
F4	OFF	OFF

Table 4.2. Details of Switch Configuration

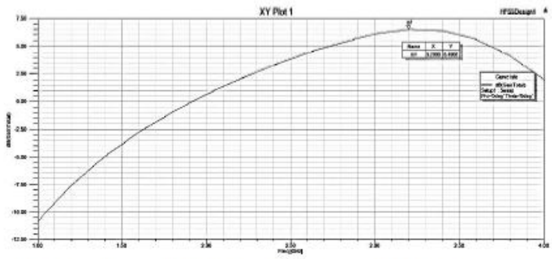

Fig 4.1 Gain of designed antenna in ON-ON Mode

Fig 4.2 Gain of designed antenna in ON-OFF Mode.

IV. RESULT AND DISCUSSIONS

Table 4.1 shows the calculated dimensions of the designed antenna using the equations.

Parameter	Symbol	Value
Resonant Frequency	f_r	3.5GHz
Length of Patch	L_p	26.89mm
Width of Patch	W_p	33.88mm
Thickness of Substrate	h	3.2mm
Relative Dielectric Constant	ε_r	2.2
Insert Feed Length	L_f	23.94mm
Feed Width	W_f	2mm
Ground Length	L_g	47.89mm
Ground Width	W_g	47.89mm
Thickness of the Slot	H_{slot}	1.25mm
Width of the Slot	W_{slot}	24mm

Table 4.1. Calculated Dimensions of Designed antenna.

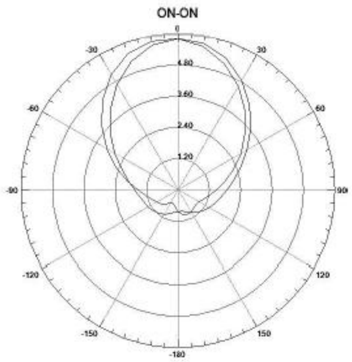

Figure 4.5 Radiation Pattern of designed antenna in ON-ON Mode

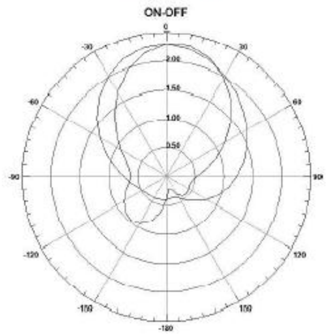

Figure 4.6 Radiation Pattern of designed antenna in ON-OFF Mode.

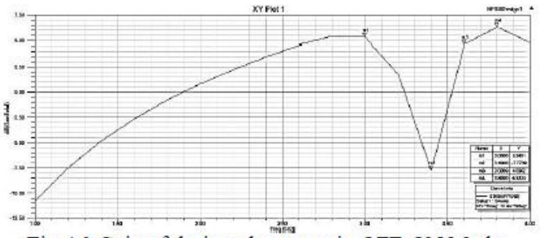

Fig 4.3 Gain of designed antenna in OFF-ON Mode.

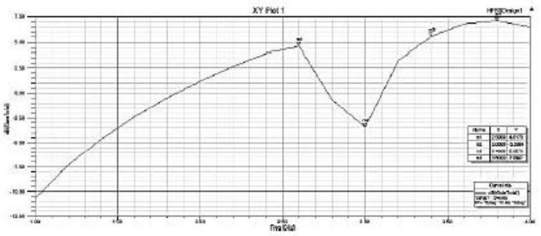

Fig 4.4 Gain of designed antenna in OFF-OFF Mode.

As Figure 4.1 – 4.4 shows that the maximum gain of the designed antenna is 7.059dB in OFF-OFF mode.

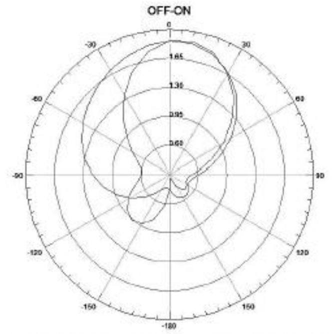

Figure 4.7 Radiation Pattern of designed antenna in OFF-ON Mode.

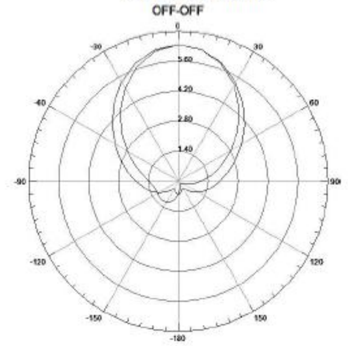

Figure 4.8 Radiation Pattern of designed antenna in OFF-OFF Mode.
Figure 4.5-4.8 shows the radiation pattern of the designed antenna.

V. CONCLUSION

In this paper A compacted frequency-switchable slotted microstrip patch antenna has been explained. The designed antenna has the capability to reconfigure up to eight different bands ranging from 2.60 to 3.8GHz, thus suitable for quite number of wireless applications including LTE and WiMAX. Maximum gain is 7.059dB. This further strengthened the use of the antenna in smartphones.

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