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A Compact Frequency Reconfigurable Monopole Antenna for Wi-Fi/WLAN Applications

Amjad Iqbal[1, *] and Omar A. Saraereh[2]

Abstract—In this paper, a compact reconfigurable monopole antenna is proposed working at three different frequencies depending upon the condition of the optical switch. The proposed reconfigurable antenna in the state of ON switch has resonant frequencies of 2.45 GHz and 5.4 GHz covering the band of 1.8–2.7 GHz (Wi-Fi) and 5.26–5.99 GHz (WLAN) respectively. The same antenna during OFF state of switch operates only at 3 GHz covering the band of 2.49–3.84 GHz. The proposed multiband reconfigurable antenna is designed and fabricated on an FR-4 substrate having relative permittivity of 4.4, loss tangent of 0.02 and thickness of 1.6 mm. The antenna is fabricated and tested in the laboratory to validate the simulated results. A good agreement between the simulated and measured results is obtained in term of radiation pattern and return loss. The performance of the reconfigurable antenna under both states of switch is examined on the basis of the antenna parameters such as return loss, radiation pattern and gain.

1. INTRODUCTION

Reconfigurable antennas have as of late gotten much consideration because of their important applications in wireless communications and electronic reconnaissance, by adjusting their properties to accomplish selectivity in frequency, Bandwidth, polarization and gain.

In contrast with wide-band antennas, tunable antennas put forward the favorable circumstances of small size, comparative radiation pattern for all multiple frequency bands, productive utilization of electromagnetic range and frequency discernment helpful for decreasing the antagonistic impacts of co-site interference and jamming [1]. Multiple band frequency tunable microstrip antennas can put forward extra advantage of reuse of frequency for multiplying the capacity of the system and polarization assorted qualities for excellent performance of reception and transmission into single antenna for decreasing the antenna size [2]. Preparatory studies in reconfigurable microstrip antennas reported as of late have received incredible consideration. A linearly polarized spiral antenna is proposed for frequency and pattern reconfigurbility in [3]. Switchable apertures for left- and right-hand circular polarization diversity are implemented on the reconfigurable microstrip antenna in [4]. A remarkable methodology of electronic tuning varactor diode combined dual-frequency dipole antenna is proposed, which provides gorgeous features of electronic control [5]. Frequency reconfigurability of dual-band antenna is as of late accounted in [6] by using PIN diode for controlling frequency shifting. With the help of varactor diode and PIN diode, a wide range of tenability is obtained whereas keeping the same radiation pattern during the whole frequency range [7]. Vivaldi antenna reconfigurabality was attained in [8], putting up three narrowband and a wideband task. Vigorous mechanism of band rejection along with a wideband state was achieved in [9] using PIN diodes.

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* Corresponding author: Amjad Iqbal (amjad730@gmail.com).
[1] Department of Electrical Engineering, CECOS University Peshawar, Pakistan. [2] Department of Electrical Engineering, The Hashemite University, Zarqa, Jordan.

In this paper, a compact dual-band frequency reconfigurable antenna for portable wireless communication is presented. The proposed antenna is able to operate at three different frequencies depending on the state of the optical switch. On the switch off state, the antenna can operate at WLAN and Wi-Fi bands. Optical switch is used for the switching purposes because of its advantage over the other techniques as no need of biased lines (PIN Diodes). A proposed antenna is fabricated on an FR-4 substrate, and its measurements are taken and show a reasonable agreement with the results of simulated ones.

2. CHARACTERIZATION OF THE PROPOSED MONOPOLE ANTENNA

The dimensions and geometry of the proposed frequency reconfigurable monopole antenna is shown in Figure 1. The substrate used for the design of the antenna is FR-4 ($\varepsilon_r = 4.4$ and $h = 1.6$ mm).

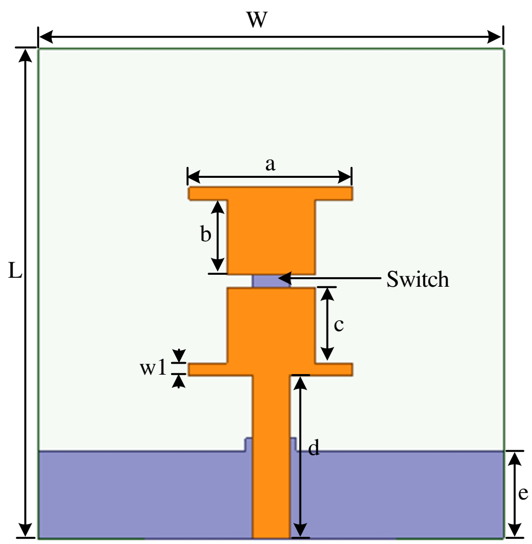


Figure 1. Diagram of proposed antenna.

Length 'L' and width 'W' of the substrate are 39 mm and 37 mm, respectively. Table 1 tabulates different parameters of the proposed antenna. Transmission line width is adjusted to 3 mm to have 50 Ω impedance matching.

Table 1. Different parameter and values of the antenna.

Parameter	Dimensions (mm)	Parameter	Dimensions (mm)	Parameter	Dimensions (mm)
L	39	a	13	b	6
W	37	c	6	d	13
e	7	$W1$	1		

All the values of length of the monopole patch are calculated using the following equations [10].

$$f = \frac{c}{\sqrt{\varepsilon_{eff}} \cdot \lambda_g}$$

$$\varepsilon_{eff} \approx \frac{\varepsilon_r + 1}{2}$$

where c = speed of light in free space, λ_g = the guided wavelength calculated at the desired frequency and ε_{eff} = the effective dielectric constant.

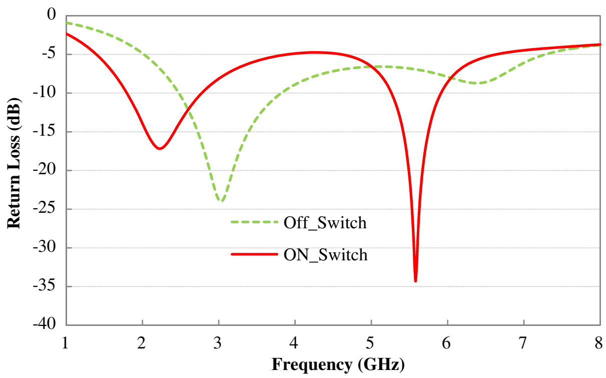


Figure 2. Return loss of the proposed antenna in OFF and ON state of switch.

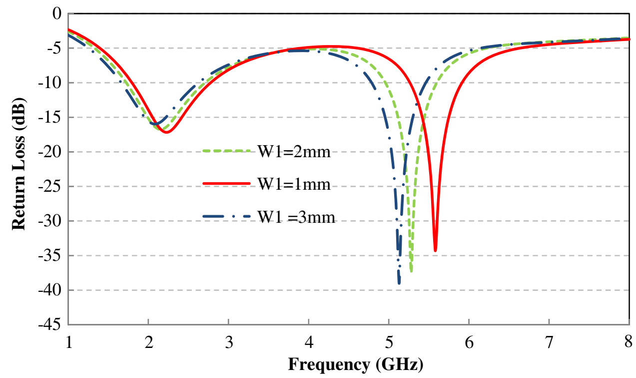


Figure 3. S_{11} against varied $W1$.

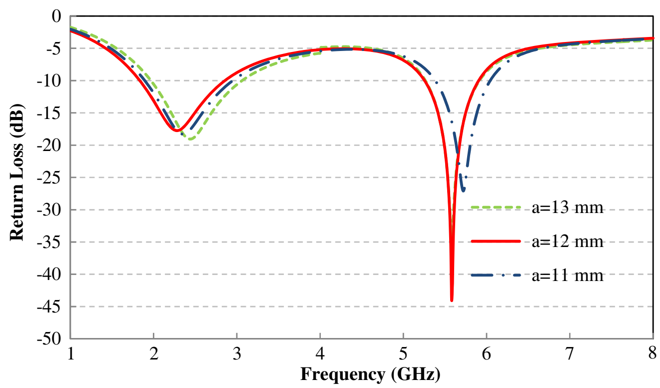


Figure 4. S_{11} against varied a.

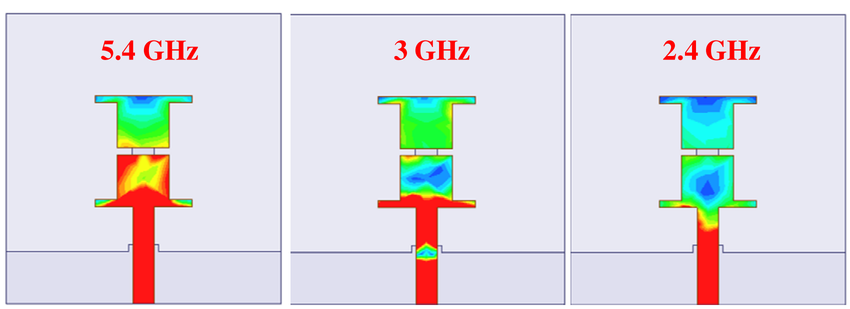


Figure 5. Current distribution at 5.4 GHz, 3 GHz and 2.4 GHz.

The simulated return loss (S_{11}) of the antenna in the case of ON switch and OFF switch is shown in Figure 2. The proposed design is simulated on full wave electromagnetic (EM) simulator HFSS 13.0.

Parametric analysis of different parameters of the proposed antenna is performed in order to evaluate the effect of those parameters on the return loss, resonant frequencies and bandwidth. It is very clear from the current distribution of the proposed antenna at different frequencies that parameter "$W1$" has very high contribution in the resonant frequency at 5.4 GHz. So it can be derived from the graph that 2nd frequency band can be adjusted at desired frequency by changing the parameter "$W1$". Figure 3 shows the simulated S_{11} of the proposed antenna versus varied $W1$.

It is clear from Figure 4 that by increasing the parameter "a", the 1st frequency band shifts right, and the 2nd frequency band is not much more affected because parameter "a" has very little effect on the 1st frequency band. Hence the 1st frequency band can be optimized and placed on the desire frequency range by changing parameter "a".

To further characterize the behavior of the proposed antenna, the surface current distributions at 3 GHz, 2.45 GHz and 5.4 GHz are shown in Figure 5. It is clear from Figure 5 that each frequency has a quite different surface current distribution. Every parameter has some effects on the resonant frequencies of either band. Every band can be controlled or changed by varying respective parameter. Some parametric analysis is shown in Figure 3 and Figure 4.

3. RESULTS AND DISCUSSION

Based on the proposed designed antenna mentioned above, the antenna is fabricated. The designed frequency reconfigurable antenna is fabricated on a commercially available substrate FR-4 having dielectric constant of 4.4, loss tangent of 0.02 and height of 1.6 mm. The fabricated antenna is shown in Figure 6 and Figure 7. The physical dimensions of the final design are shown in Table 1.

The simulated and measured results for OFF and ON switch states are shown in Figure 6 and Figure 7, respectively.

Reflection coefficient (S_{11}) shows the fraction of power being reflected backwards from the antenna input to the excitation port. It is measured in decibel (dB) and given by [11]:

$$S_{11} = -20 \log_{10} \left| \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \right| \tag{1}$$

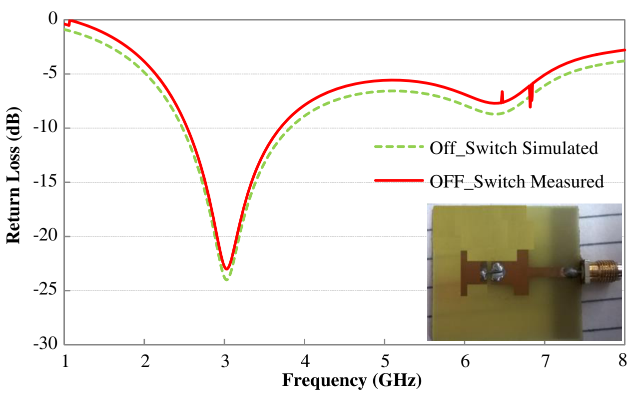


Figure 6. Simulated and measured results of antenna in OFF switch.

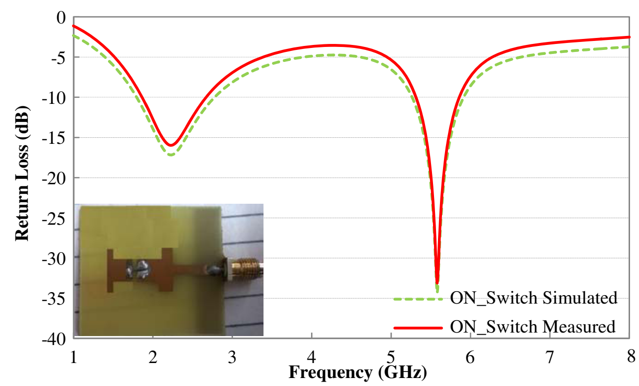
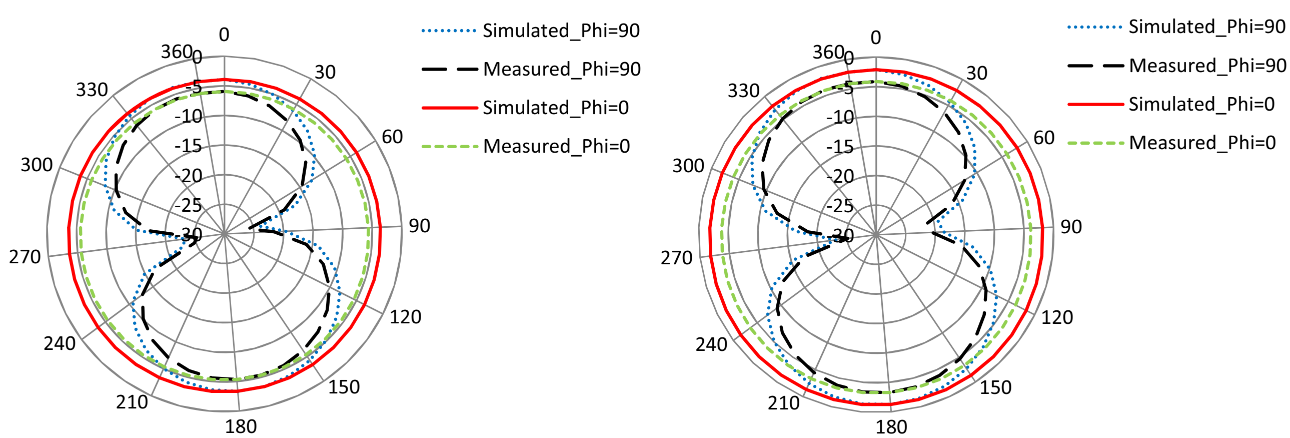
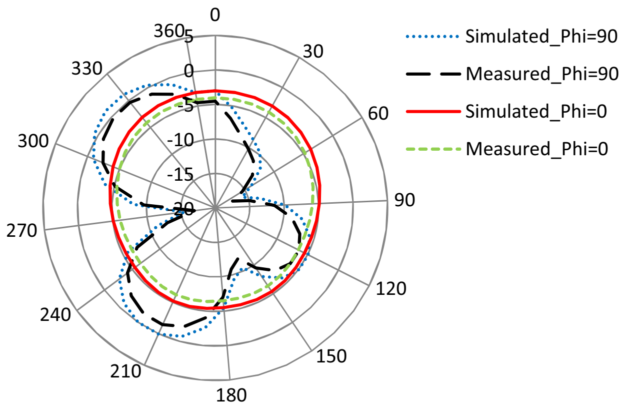


Figure 7. Simulated and measured results of antenna in ON switch.



(a) (b)



(c)

Figure 8. Simulated and measured radiation pattern for (a) 2.4 GHz, (b) 3 GHz, (c) 5.4 GHz.

where, Z_{in} is the driving point impedance of the proposed antenna and Z_0 the characteristic impedance of the 50 Ω SMA port.

The proposed antenna has resonant frequency of 3 GHz covering 10 dB bandwidth of 1.35 GHz as shown in Figure 6 when optical switch is OFF. The antenna has resonant frequencies of 2.45 GHz and 5.4 GHz when the optical switch of the proposed antenna is ON. Obvious from Figure 7, the simulated and measured results show that the antenna covers both the bands of Wi-Fi and WLAN when the switch is in the ON state. A good isolation between the bands is achieved, and sufficient low band return loss is obtained. A little difference in the simulated and measured results is observed which may be due to fabrication error.

The radiation characteristics at Phi = 0° and Phi = 90° of the proposed frequency reconfigurable monopole antenna is presented in Figures 8(a), (b) and (c). It is very clear from the presented figures that radiation patterns for the designed antenna at 2.45 GHz, 3 GHz are omnidirectional while a little distortion is observed from the figure at higher frequency (5.4 GHz).

4. CONCLUSION

In this paper, a frequency reconfigurable multi-band monopole antenna for Wi-Fi and WLAN application is constructed, measured and analyzed. The proposed antenna is switch dependent and has different behaviors for ON and OFF switch states. The antenna is successfully tested for both ON and OFF states of the switch. The same antenna can work at three unique frequencies, relying on the condition of the switch. A good agreement between simulated and measured results is observed. The antenna has good gain and directivity in both states of the switch.

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