Designing of Frequency Reconfigurable Monopole Antenna for Wireless Applications

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***Abstract*: In this article, a rigorous analysis of frequency reconfigurable monopole antenna is presented. Frequency reconfigurability was achieved by switch which is incorporated between two patches.** The proposed design of reconfigurable antenna (when switch is ON) exhibited two resonating frequency 2.35 GHz and 5.45 GHz **for $S_{11} < -10\ dB$,** which are covering the band of 2.16-2.6 GHz (Wi-Fi) and 5.18-5.81 GHz (WLAN) respectively**. The surface current distribution is analyzed at frequencies 2.45, 3.1 and 5.4 GHz. A mathematical equations are developed with the help of current distribution.**

***Keywords*: Current distribution, Monopole antenna, Impedance bandwidth.**

1. Introduction- Multiband antennas exhibits various virtues like low cost, light weight, ease of integration with other microwave devices which is similar to conventional microstrip antenna. The multiband frequency operation can be achieved by incorporating slots on patch. For proper operation the location and size of the slot are prominent factors. Slots and notches play a prominent role in the entity of the planar printed antenna. Basically, slots modify the position of fundamental mode (TM_{10} or TM_{01}) and higher order modes (TM_{12}, TM_{20}) or create new resonating frequency [1-6]. The frequency-reconfigurable antennas also show the multiband operation characteristics. The frequency reconfigurable operations can be achieved by mechanically, electronically, with the help of PIN diode and varactor diode [7-11]. A. Iqbal [7] designed compact reconfigurable monopole antenna and fabricated on an FR-4 substrate having relative permittivity of 4.4, loss tangent of 0.02 and thickness of 1.6 mm. By using the switch, single and multiband operation can be achieved which covers the two frequency band (the band of 1.8–2.7GHz (Wi-Fi) and 5.26–5.99 GHz (WLAN) when switch is on state. In this communication, an analysis frequency-reconfigurable antennas is presented and discussed. Section 2 describes the physical structure and parameters of the antenna. The parametric study is done in section 3. The detailed study of the proposed antenna is given below.

2. Physical structure-

The physical structure of the proposed reconfigurable monopole antenna with switch is shown in Figure 1. It contains stub loaded ground plane, a feed structure, and radiating element. This antenna is placed on *XY=0* plane and designed on FR-4 substrate with the dimension of 39 mm × 25 mm. The properties of the chosen substrate are tangent loss $\tan(\delta) = 0.02$, permittivity $\varepsilon_r = 4.3$ and height $h = 1.6$ mm. The thickness of the conducting layer (C_t)is taken 0.035 mm. In simulation, the waveguide port delivers the electromagnetic energy to the radiating structure.

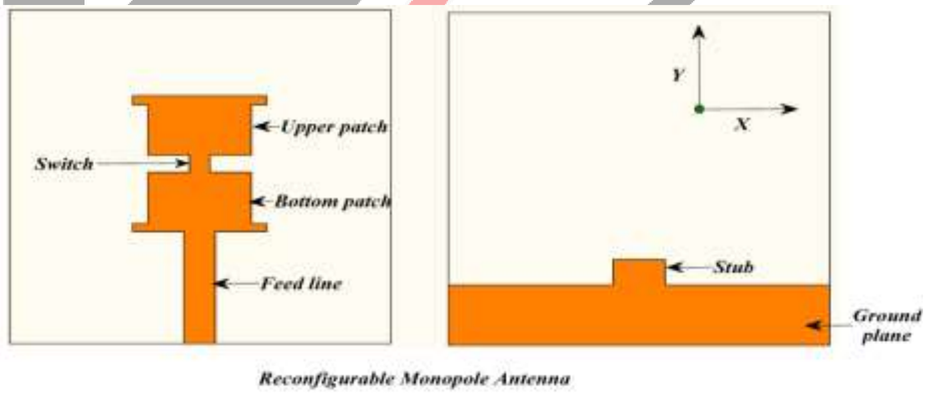


Figure 1 Configuration of the reconfigurable monopole antenna.

The physical dimension of the waveguide port is depicted in Figure 2. By using equation 1 and 2 the height (H_w)and width (T_w) of the port can be computed. The estimated value of H_w and T_w are 8.035 mm and 18 mm respectively.

$$H_w = 5h + C_t \quad (1)$$

$$T_w = 6 * M_w \quad (2)$$

Where,M_w is the width of the feed line.

The feed line is defined by its width (M_w) and length (M_l). It is Boolean added with lower radiating patch. The calculated value of the width of the feed line is 3.03 mm which is estimated by equation 3 and 4. The impedance of the feed line depends on the width of it. The width of the feed line is calculated by following equations.

$$H' = \frac{Z_0\sqrt{2(\varepsilon_r+1)}}{119.9} + \frac{1}{2}\left(\frac{(\varepsilon_r-1)}{(\varepsilon_r+1)}\right)\left(ln\frac{\pi}{2} + \frac{1}{\varepsilon_r}ln\frac{4}{\pi}\right) \quad (3)$$

$$M_w = h * \left(\frac{expH'}{8} - \frac{1}{4expH'}\right) \quad (4)$$

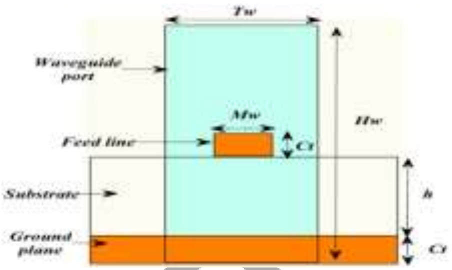


Figure 2 Configuration of Waveguide port.

A finite ground plane is designed on the back side of the substrate and it is defined by two parameters L_g and W_g. A stub is loaded on the top edge of the partial ground plane. This element improves the impedance matching the parameters of stub is R_w and R_l. The dimensions and parameters of the monopole antenna are listed on table 1.

Table 1 The optimized dimension of the proposed reconfigurable monopole antenna.

Parameter	Dimension (mm)	Parameter	Dimension (mm)	Parameter	Dimension (mm)
L_1	2	L_g	7	R_l	2
L_2	6	W_g	25	W_1	13
L_3	1	M_l	13	W_s	37
L_s	39	M_w	3	R_w	5

3. Parametric study-To know the effect of key parameters on bandwidth and impedance matching, the parameters are varied in a specified range. In this section, we also study the drift of best matching frequency due to the tuning of parameters. In this study, the onlya single parameter is varied at a time.

3.1 Influence of width of the ground plane-The impact of W_g (width of the ground plane) on $|S_{11}|$ characteristic of the proposed antenna is illustrated in Figure 3. It is noticed that by increasing W_g, the first frequency resonating (f_{r1}) and second resonating frequency (f_{r2}) are not drifted in the any direction. It is also noticed that increment in W_g decreases the bandwidth of the second resonating frequency band and return loss also. A small change in return loss is observed at first frequency resonating (f_{r1}). The value of W_g is varied from 9.5 mm to 12.5 mm. The optimized value of W_g is chosen 12.5 mm.

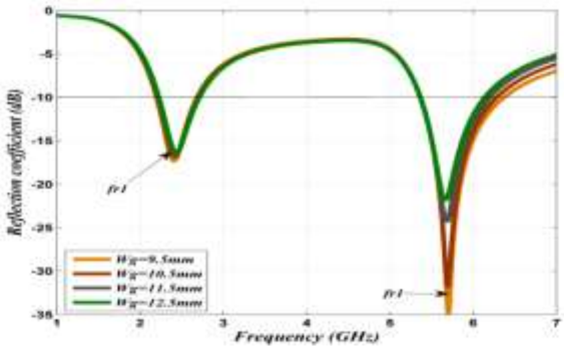


Figure 3 Simulated reflection coefficient characteristic versus frequency for different value of width of the ground plane.

3.2 Influence of length of the ground plane

The impact of L_g(length of the ground plane) on $|S_{11}|$ characteristic of the proposed antenna is illustrated in Figure 4. It is noticed that by increasing L_g, the first frequency resonating (f_{r1}) is drifted in the leftward direction while second resonating frequency (f_{r2}) is drifted in the rightward direction. It is also noticed that increment in L_g changes the bandwidth of the second resonating frequency band. This parameter also changes the value of return loss at both frequency bands. The value of L_g is varied from 5 mm to 9 mm. The optimized value of L_g is chosen 6 mm.

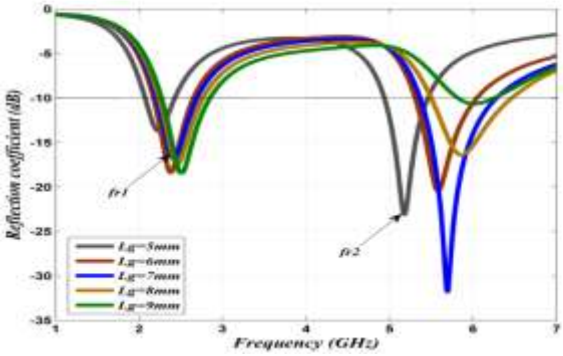


Figure 4 Simulated reflection coefficient characteristic versus frequency for different value of length of the ground plane.

3.3 Influence of length of the stub

The impact of R_l(length of the stub) on $|S_{11}|$ characteristic of the proposed antenna is illustrated in Figure 5. It is noticed that by increasing R_l, the first frequency resonating (f_{r1}) and second resonating frequency (f_{r2}) are drifted in the rightward direction.It is also noticed that increment in R_l changes the bandwidth of the first and second resonating frequency band. This parameter also changes the value of return loss at both frequency bands. The value of R_l is varied from 0 mm to 4 mm. The optimized value of R_l is chosen 2 mm.

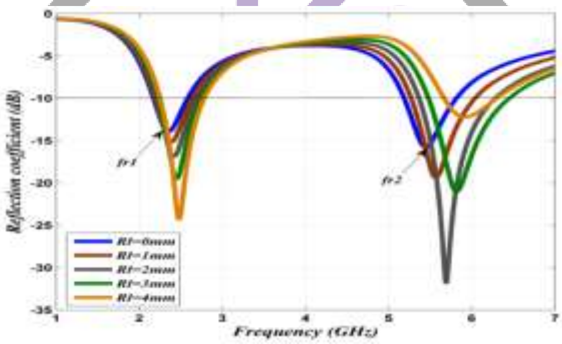


Figure 5 Simulated reflection coefficient characteristic versus frequency for different value of length of the stub.

3.4 Influence of width of the stub

It is noticed that by increasing R_w, the first frequency resonating (f_{r1}) and second resonating frequency (f_{r2}) are drifted in the rightward direction.It is also noticed that increment in $R_w$changes the bandwidth of the first and second resonating frequency band. This parameter also changes the value of return loss and impedance matching at both frequency bands. The value of R_w is varied from 1 mm to 9 mm. The optimized value of R_w is chosen 5 mm.

3.5 Influence of W_1

The impact of W_1(width of the bar) on $|S_{11}|$ characteristic of the proposed antenna is illustrated in Figure 7. It is noticed that by increasing W_1, the first frequency resonating (f_{r1}) and second resonating frequency (f_{r2}) are drifted in the leftward direction. It is also noticed that increment in W_1changes the impedance matching and bandwidth at first and second resonating frequency band. This parameter also changes the value of return loss at both frequency bands. The value of $W_1$is varied from 9 mm to 17 mm. The optimized value of $W_1$is chosen 13 mm.

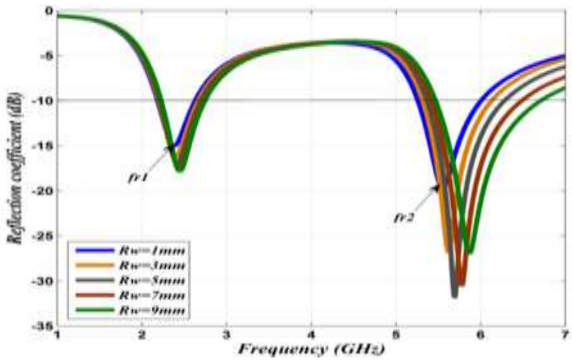


Figure 6.Simulated reflection coefficient characteristic versus frequency for different value of width

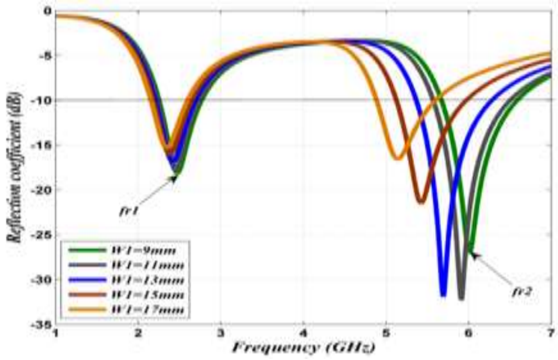


Figure 7.Simulated reflection coefficient characteristic versus frequency for different value of W_1.

3.6 Influence of P_w

The impact of P_w(width of the patch) on $|S_{11}|$ characteristic of the proposed antenna is illustrated in Figure 8. It is noticed that by increasing P_w, the first frequency resonating (f_{r1}) is stable and second resonating frequency (f_{r2}) are drifted in the leftward direction.It is also noticed that increment in $P_w$changes the impedance matching at first and second resonating frequency band. This parameter also changes the value of return loss at both frequency bands. It is also observed that this parameter changes the impedance bandwidth at second resonating band. The value of $P_w$is varied from 6 mm to 14 mm. The optimized value of $P_w$is chosen 10 mm.

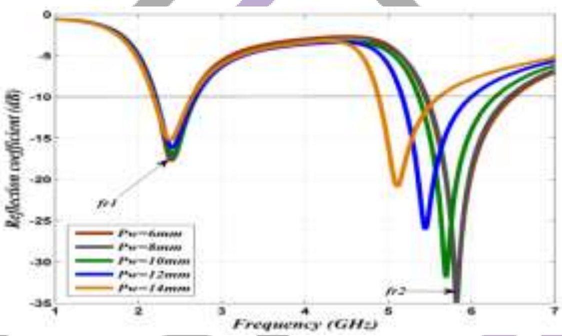


Figure 8 Simulated reflection coefficient characteristic versus frequency for different value of P_w.

3.7 Influence of M_w

The impact of M_w(width of the feed line) on $|S_{11}|$ characteristic of the proposed antenna is illustrated in Figure 9. For $M_w = 1\ mm$, the impedance matching is very poor. It occurs due to poor impedance matching between feed line and radiating patch. The characteristic impedance of the feed line depends on the width of the feed line. It is noticed that by increasing $M_w > 1\ mm$, the first frequency resonating (f_{r1}) is shifted in the left direction while second resonating frequency (f_{r2}) is drifted in the rightward direction.It is also noticed that increment in $M_w$changes the impedance matching at first and second resonating frequency band. This parameter also changes the value of return loss at both frequency bands. The value of $M_w$is varied from 1 mm to 5 mm. The optimized value of $M_w$is chosen 3 mm.

4. Result and discussion

The frequency response characteristic of proposed reconfigurable monopole antenna is illustrated in the Figure 10 which shows dual band response. Due to switch, the patch length of the current vectors is modified. Improved path length of the vector changes the position of the resonating frequency. The performance characteristic of proposed reconfigurable antenna is listed in table 2. Figure 11 illustrates the trace of the real and imaginary part of the input impedance (Z_{in}) which is the function of frequency. It is noticed that maximum resistance is 80 ohm at frequency 2.44 GHz while it is 60 ohm at frequency 5.4 GHz. Table 3 illustrates the value of impedance at resonating frequencies. It is also noticed that the value of imaginary part is zero at resonating frequencies.

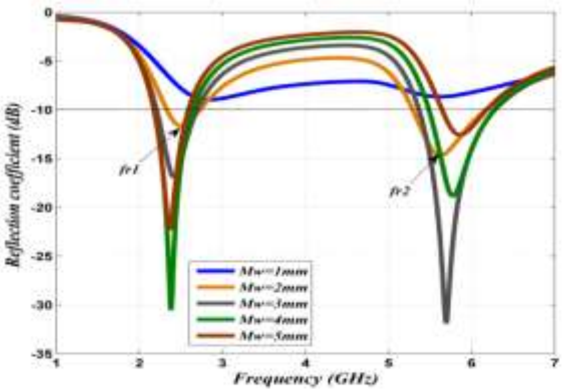


Figure 9.Simulated reflection coefficient characteristic versus frequency for different value of M_w.

Table 2 Performance of the proposed reconfigurable monopole antenna.

Frequency band	Frequency span (GHz)	Bandwidth (%)	Resonating frequency (GHz)	Maximum return loss (dB)
I	2.16 to 2.6	18.48	2.35	-15.68
II	5.18 to 5.81	11.46	5.45	-26.99

Table 3 Input impedance of reconfigurable monopole antenna.

Frequency (GHz)	Real part of the impedance (ohm)	Imaginary part of the impedance (ohm)	Frequency (GHz)	Real part of the impedance (ohm)	Imaginary part of the impedance (ohm)
2.162	27.26	11.46	5.186	50.633	32.64
2.358	56.9	15.94	5.452	51.35	-4.106
2.603	76.7	-29.846	5.816	25.88	-2.11

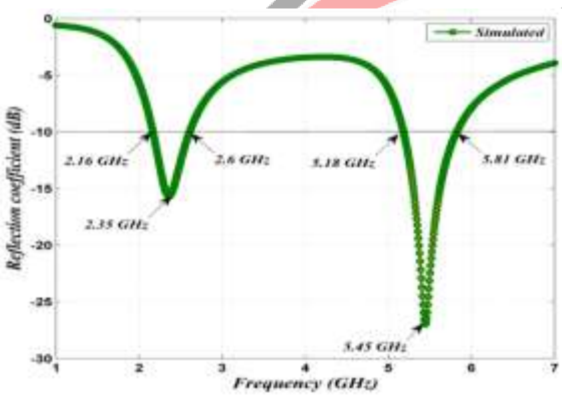


Figure 10 Frequency response characteristic of the reconfigurable monopole antenna.

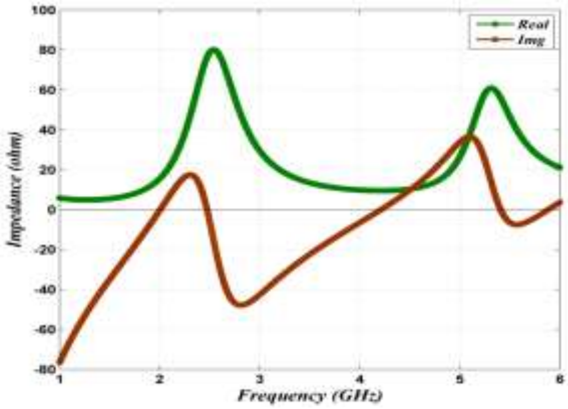


Figure 11 Input impedance characteristic of the reconfigurable monopole antenna.

5. Far-field pattern of reconfigurable monopole antenna

Figure 12 illustrates 3-D far field pattern of proposed reconfigurable monopole antenna at 2.35 and 5.45 GHz. 2-D far field pattern of proposed reconfigurable monopole antenna is depicted in Figure 13. At resonating frequency 2.35 GHz, a directional pattern is found in both planes. It is noticed that the shape of the pattern in H plane at frequency 5.45 GHz is distorted. It happens due to presence of higher order modes. A frequency 5.45 GHz, again a direction pattern is noticed in the E plane.

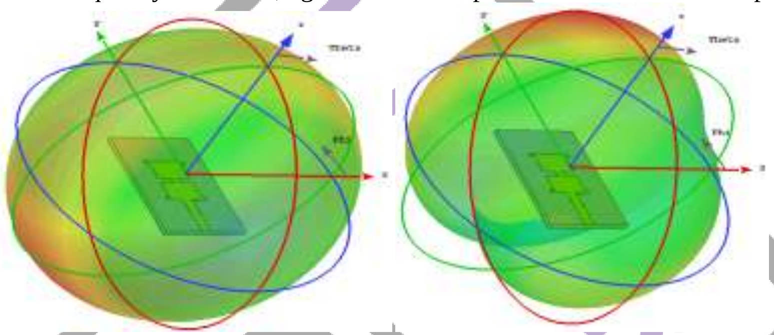
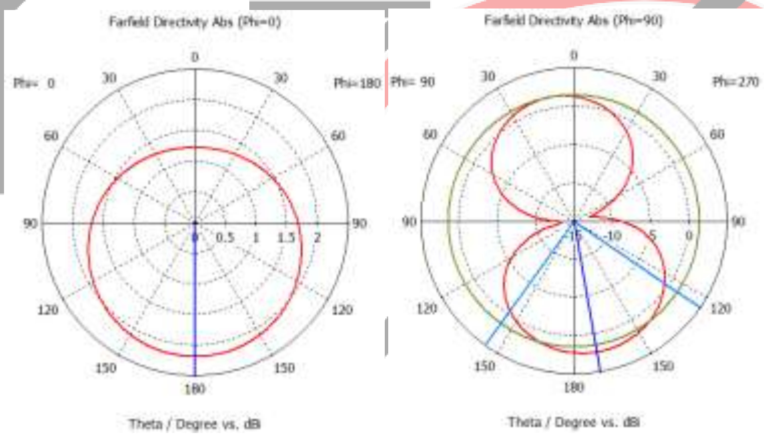
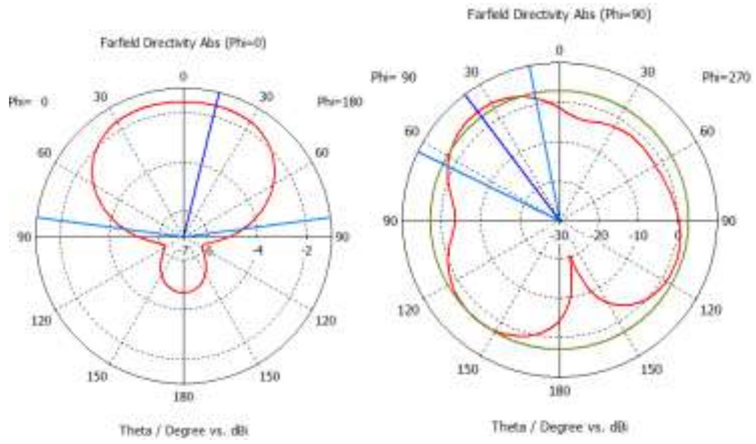


Figure 12 3-D Far field pattern of proposed monopole antenna at 2.35 (left) and 5.45GHz (right)



(2.35GHz)



(5.45GHz)

Figure 13 Far field patterns of proposed antenna at frequencies f_1= 2.35 GHz and f_2 = 5.45 GHz.

6. Conclusion

An investigation of frequency reconfigurable antenna is carried out. The proposed antenna is dependent on switching element which has different behaviors for ON and OFF switching condition. The proposed design of reconfigurable antenna in the on state of switching element achieved two resonating frequency 2.35 GHz and 5.45 GHz which are covering the band of 2.16-2.6 GHz (Wi-Fi) and 5.18-5.81 GHz (WLAN) respectively.

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