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Analysis of Compact Frequency Reconfigurable Monopole Antenna For Wi-Fi/Wi-Max Applications

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Abstract- In this article, a compact, low porfile frequency reconfigurable monopole antenna is proposed. Frequency reconfigurability was achieved by switch which is incorporated between two patches. This antenna resonates at 3.1 GHz when switch is OFF. *The proposed design of reconfigurable antenna in the on state of switching element achieved 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.***

Key words- Current distribution, Monopole antenna, Impedance bandwidth.

1. Introduction

The conventional microstrip antenna offers various advantages virtues like low cost, light weight, ease of integration with other microwave devices [1-3]. The main demerit of theses antennas is narrow impedance bandwidth and resonates at single frequency. For multiband operation, a slot is introduced on the patch which changes the location of resonating frequencies or modes (TM_{10}, TM_{01},TM_{12} and TM_{20}) and phase velocity ($v_p = 1/\sqrt{LC}$) of the resonating modes [4-6]. Multiband antenna transmit or receive the signal at particular frequency bands and rejects other bands. The frequency-reconfigurable antennas also exhibit the multiband operation characteristics. Recently, these antennas have acquired much attention in wireless communication industry due to above mentioned feature. The frequency reconfigurable operations can be achieved by mechanically and electronically [7-8]. A. Iqbal [9] 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. Ling long Meng et.al. proposed a design for novel frequency reconfigurable Microstrip patch antenna and controlled the switching operation with the help of PIN diodes. This structure resonates at three different resonating frequency 5.75 GHz, 5.85 GHz and 6.06 GHz. In this communication, an analysis frequency-reconfigurable antennas is presented and discussed. Section 2 describes the physical structure and parameters of the antenna. The development of the antenna and mathematical modeling are included in section 3 and 4.

2. Physical structure

The physical structure of the monopole antenna without 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 × 37 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.

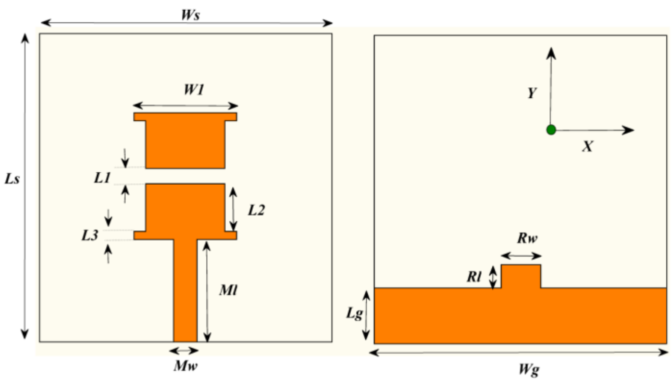


Figure 1 Configuration of the monopole antenna without switch.

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.

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

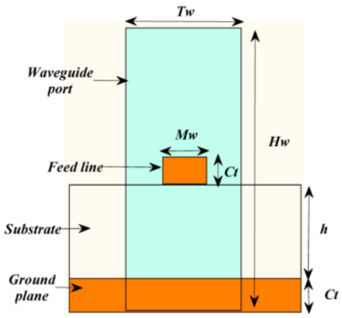
$$T_w = 6 * M_w \quad (2)$$

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.

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

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



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 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	37	W_1	13
L_3	1	M_l	13	W_s	37
L_s	39	M_w	3	R_w	5

The conceptual view of proposed reconfigurable monopole antenna is displayed on Figure 3. It consists of upper patch bottom patch and switch. The main job of switch to provide electrical connection between upper and bottom patch. It also enhances the path length of the current vectors. The dimension of the proposed reconfigurable antenna is similar to above mentioned monopole antenna except width of the ground plane. It this configuration, the width of the ground plane is 25 mm.

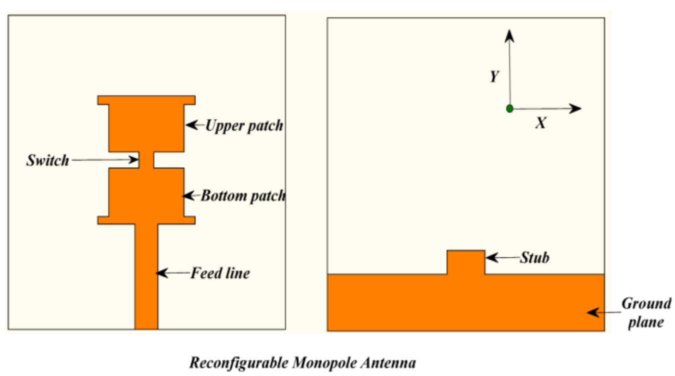


Figure 3 Configuration of the reconfigurable monopole antenna.

3. Frequency formulation of monopole antenna

The lower cut off frequency of the monopole antenna depends on its physical length, gap between and fringing factors. It is calculated by following equations

$$L = 2 * L_3 + 2 * L_2 + L_1 \quad (5)$$

Area of cylindrical monopole = Area of proposed monopole

$$2 * \pi * r * L = Area\ of\ proposed\ monopole = 166\ mm^2$$

$$r = 166/2 * \pi * 16 = 1.65\ mm \quad (6)$$

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$$f_l = \frac{72}{(L+r+p)k} GHz \quad (7)$$

Where L is total length of the monopole and the calculated value of it is 16 mm. r is radius of cylindrical monopole which is equal to 1.65 mm. P is the feed gap which is equal to 4 mm for proposed structure and $k = 1.15$, which is constant. The calculated value of Lower edge frequency is 2.9 GHz (Using equation 7). An error of 1.03 % has been estimated between calculated (2.9 GHz) and simulated (2.86 GHz) lower edge frequency. The frequency response characteristic of the monopole antenna is displayed in Figure 4. This monopole antenna resonates at frequency 3.27 GHz and it exhibits the bandwidth of 32.36 % for $S_{11} < -10\, dB$ which covers the frequency range from 2.9 to 4.02 GHz. Figure 5 illustrates the input impedance characteristic of the monopole antenna. It is noticed that a loop is formed in side of the VSWR circle. At lower frequency, the input impedance of the antenna is capacitive while at higher frequency it becomes inductive. For frequency range 2.9 to 4.02 GHz the curve lies inside of the VSWR circle which indicates the proper impedance matching.

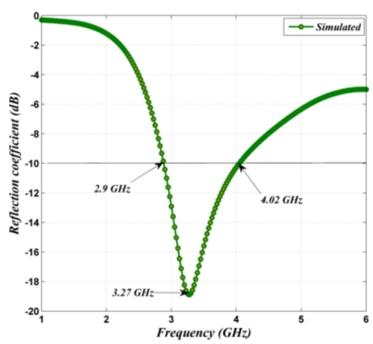

Figure 4 Frequency response characteristic of the monopole antenna.

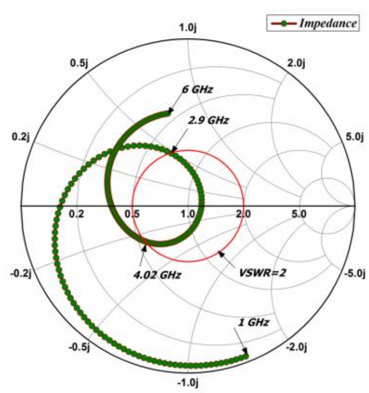

Figure 5 Input impedance characteristic of the monopole antenna.

The resonating frequency 3.27 GHz is developed due to edges of the ground plane. At this frequency current vectors are also scattered on the lower and upper patch. As shown in Figure 6, the current vectors are distributed on the edges of the partial ground plane. By using equations 8 and 9, this frequency can be computed.

$$L_1 = L_g + W_g + R_l = 46\, mm \quad (8)$$

$$f_1 = \frac{c}{L_1\sqrt{\varepsilon_r}} = 3.12\, GHz \quad (9)$$

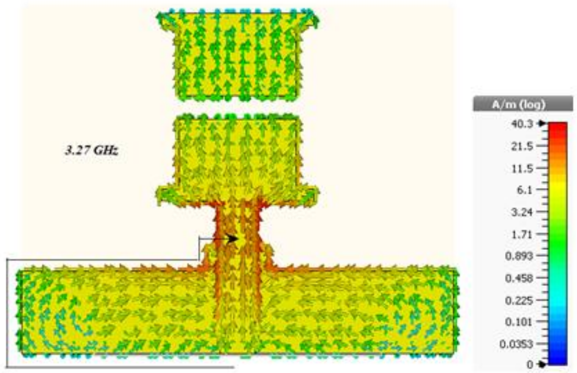

Figure 6.Current distribution at frequency 3.27 GHz.

The calculated value of resonating frequency is 3.12 GHz. An error of 4.58 % (using equation 4.12) is found between simulated and calculated first resonating frequency.

4. Result and discussion

The frequency response characteristic of proposed reconfigurable monopole antenna is illustrated in the Figure 7 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.

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

Figure 8 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.

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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

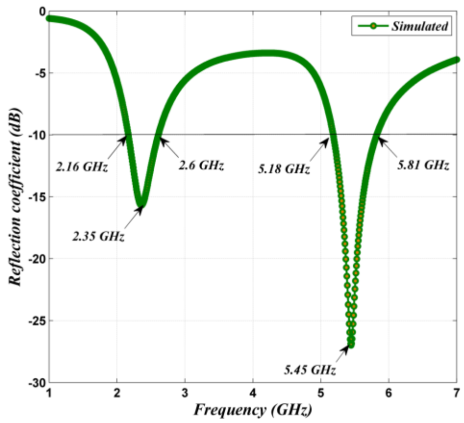

Figure 7 Frequency response characteristic of the reconfigurable monopole antenna.

Due to switch, the total length of the monopole antenna is increased. This physical length and lower cut off frequency are calculated by below equation

$$L_{recon} = 2*L_3 + 2*L_2 + L_1 + 2*\left(\frac{P_w}{2} - 1\right) = 24\ mm \quad (10)$$

$$2*\pi*r_{recon}*L_{recon} = Area\ of\ reconfigurable\ monopole = 150\ mm^2 \quad (11)$$

$$r_{recon} = 150/2*\pi*24 = 1\ mm \quad (12)$$

Where P_w is the width of the lower and bottom patches. The value of P_w is 10 mm. The calculated value of lower cutoff frequency is 2.16 GHz (using equation 7) which exactly matches with simulated value. The frequency 2.35 GHz originates due to radiating patch.

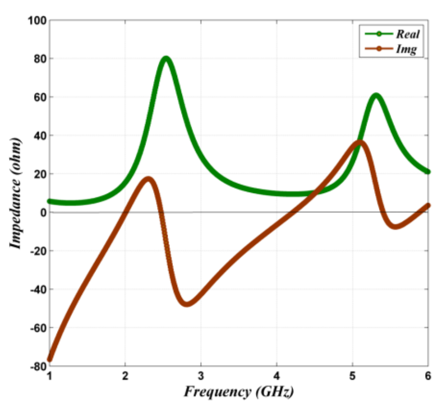

Figure 8 Input impedance characteristic of the reconfigurable monopole antenna.

At this frequency the current vectors are travelled along the edges of the radiating patch (see Figure 9). This frequency can be estimated by following equations.

$$L_1 = 2*L_3 + 2*L_2 + L_1 + 2*\left(\frac{P_w}{2} - 1\right) + \left(\frac{W_1 - M_w}{2}\right) + 2*(W_1 - P_w) \quad (13)$$

$$L_1 = 32\ mm$$

$$f_1 = \frac{c}{2*L_1\sqrt{\varepsilon_r}} = 2.24\ GHz \quad (14)$$

An error of 4.68 % is found between calculated and simulated value. The resonating frequency 5.45 GHz is developed due to the edges of the ground plane. At this frequency the surface current distribution is shown in Figure 10. The frequency formulation at this frequency is given below.

$$L_2 = L_g + \frac{W_g}{2} + R_l + W_x = 25.5\ mm \quad (15)$$

$$f_2 = \frac{c}{L_2\sqrt{\varepsilon_r}} = 5.62\ GHz \quad (16)$$

Where W_x is 4 mm, the calculated value of second resonating frequency is 5.62 GHz. An error of 3.02 % is estimated between calculated and simulated second resonating frequency.

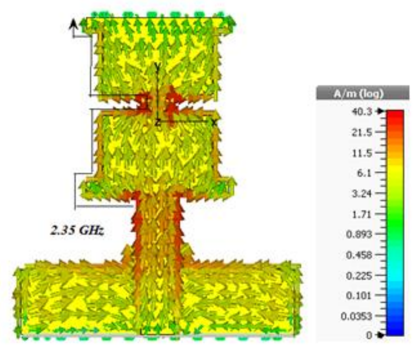

Figure 9 Current distribution at frequency 2.35 GHz.

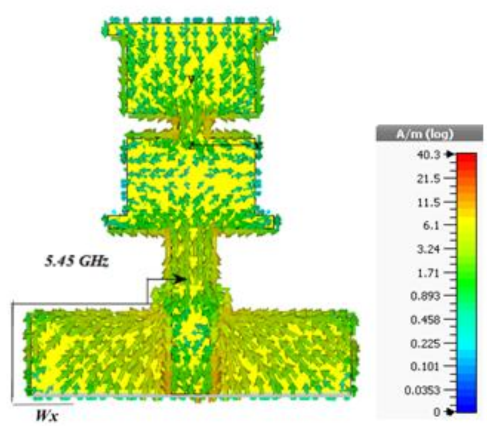

Figure 10 Current distribution at frequency 5.45 GHz.

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5. Far-field pattern of reconfigurable monopole antenna

Figure 11 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 12. 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.

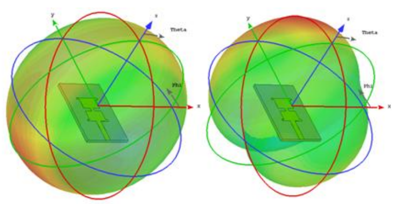
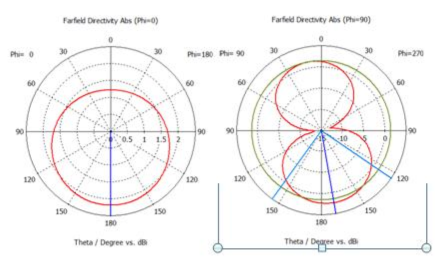
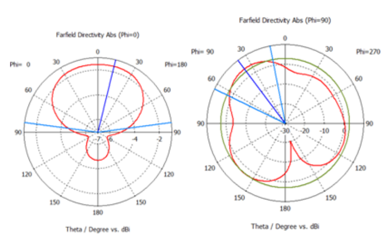


Figure 11 3-D Far field pattern of proposed monopole antenna at 2.35 (left) and 5.45GHz (right)



(2.35GHz)



(5.45GHz)

Figure 12 Far field patterns of proposed antenna at frequencies $f_1 = 2.35$ GHz and $f_2 = 5.45$ GHz.

6. Conclusion

The analysis 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.**

References

1. M. C. Tang, R. W. Ziolkowski, and S. Xiao, “Compact hyper band printed slot antenna with stable radiation properties,” *IEEE Transactions on Antennas and Propagation*, Vol. 62, No. 6, pp. 2962-2969, June 2014.
2. B. K. Shukla, N. Kashyap, and R. K. Baghel, “A novel design of Scarecrow-shaped patch antenna for broadband applications,” *International Journal of Microwave and Wireless Technologies*, vol. 10, no. 3, pp. 351–359, 2018.
3. P. Purohit, B. K. Shukla, and D. K. Raghuvanshi, "A Novel Design of Hybrid Open Slot Antenna with Parasitic Element for Wideband Applications," *Progress In Electromagnetics Research C*, Vol. 90, 95-107, 2019.
4. A. A. Deshmukh, and K. P. Ray, "Formulation of resonance frequencies for dual-band slotted rectangular microstrip antennas," *IEEE Antennas and Propagation Magazine*, Vol. 54, pp. 78-97, 2012.
5. A. A. Deshmukh and K. P. Ray, "Analysis of broadband variations of U-slot cut rectangular microstrip antennas," *IEEE Antennas and Propagation Magazine*, Vol. 57, pp. 181-193, 2015.
6. A., A. Alazza, F. J. Harackiewicz, and H. R. Gorla, "Very compact open-slot antenna for wireless communication systems," *Progress In Electromagnetics Research Letters*, Vol. 51, pp. 73-78, 2015.
7. P. Lotfi, M. Azarmanesh, and S. Soltani, "Rotatable dual-band notched UWB/triple-band WLAN reconfigurable antenna," *IEEE Antennas Propag Lett*, Vol. 12, pp.104–107, 2013.
8. T.Wu, H. Bai, P. Li, and X.W. Shi, "A simple planar monopole UWB slot antenna with dual independently and reconfigurable band-notched characteristics," *Int J RF and Microwave Comput Aided Eng*, pp. 1–7, 2014.
9. Iqbal, A. and Saraereh, O.A., 2017. A compact frequency reconfigurable monopole antenna for Wi-Fi/WLAN applications. *Progress in Electromagnetics Research*, *68*, pp.79-84.

ISSN:-2581-6934|www.jidps.com

10. Meng, Linglong, Weimin Wang, JinchunGao, and YuananLiu."A Novel Frequency Reconfigurable Coupling Microstrip Patch Antenna."In *2018 International Conference on Microwave and Millimeter Wave Technology (ICMMT)*, pp. 1-2.IEEE, 2018.

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