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Design of agile monopole antenna for WiFi and WiMAX applications

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Abstract. A monopole antenna with frequency diversity has been designed. Depending on the state of one PIN diode, this antenna has the ability to alter between two frequencies. The first one is 2.45 GHz which corresponds to the WiFi applications. The second is 3.45 GHz which corresponds to the WiMAX applications. This monopole antenna has been excited by a 50Ω microstrip line. The radiating element and a partial ground plane, that was used to achieve better gain and better bandwidth, have been printed respectively at each side of an FR4 substrate having total dimensions of 30mm × 40mm × 1.6mm. The parameters related to this antenna are analyzed using the HFSS software. For the two cases of operation of the antenna, the reflection coefficient and the gain have been simulated and showed good results. Also, for the two resonance frequencies, the VSWR is strictly lower than the value 1.2.

1 Introduction

Due to the increasing number of consumers of smart devices and the communication between the whole world moving towards to be wireless, the reconfigurable antenna is introduced to improve the network capacity as it can be used as an alternative to several conventional antennas. In general, the agile antenna [1] is able to vary its parameters in terms of polarization [2-4], radiation pattern [5, 6], or frequency [7-9] by mechanically or electrically modifying its architecture.

Frequency reconfigurable antennas are essential features of modern devices which have been designed to support different frequency bands related to various services [7-9]. In this type of reconfiguration, the use of large number of antennas for a device can be limited by using a single agile antenna for different operating frequencies [10-12]. Therefore, the complexity and cost of the overall device will be reduced. Also, frequency diversity can be obtained, without degradation of the radiation pattern and the polarization performances of the antenna. On the other hand, frequency reconfigurable antennas can be used in some applications, such as cognitive radio [13] and interference rejection [14-16]. In this communication, a monopole antenna with frequency agility has been designed. The frequency diversity is realized electrically by exploiting PIN diode. The radiating element is designed on FR4 substrate. By tuning the PIN diode ON or OFF, the monopole antenna resonates at the frequency of 2.45 GHz and 3.45 GHz, respectively, and realizes a good reflection coefficient, gain and VSWR.

2 PIN diode equivalent

The BAR 50-02V PIN diode [17] was used to achieve the frequency reconfiguration. We have chosen this type of PIN diode to ensure a good operation of the antenna at the two operating bands. For the two states (ON and OFF), an inductance L_S = 0.6 nH is introduced in the equivalent models. In the first case, if the switch is ON, the equivalent model contains a resistance R_S = 4.5 Ω with small value which models the insertion losses. In the second case when the switch is OFF, the equivalent model has a parallel combination of R_P = 5 KΩ and C_P = 0.15 pF which models the isolation (Fig. 1).

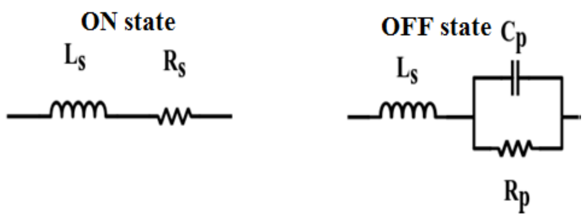

Fig. 1. Equivalent models of the switch diode in two states

3 Frequency monopole antenna geometry

Fig. 2 presents the layout of the monopole antenna with frequency agility. The radiating element and a partial ground plane with width WS and length Lg have been printed respectively at each side of an FR4 substrate having a thickness of 1.6mm and a relative permittivity of 4.4. A 50Ω microstrip line with the width of 3mm is selected to feed the antenna. Values of the dimensions of agile monopole antenna are detailed in Table 1.

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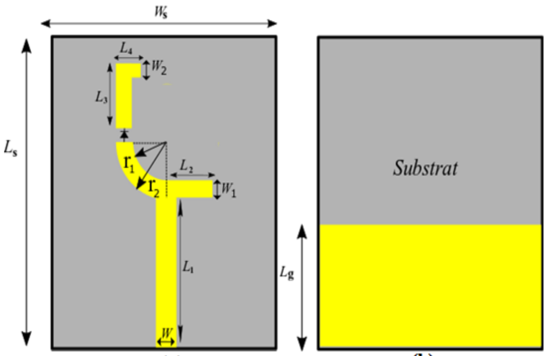


(a) **(b)**

Fig. 2. Monopole antenna with frequency agility: (a) Front view (b) Behind view.

The length of monopole antenna at each resonance frequency f_r is related to the guided wavelength and can be expressed as [18, 19, 20]:

$$L_r = \frac{\lambda_r}{4} \quad (1)$$

$$L_r = \frac{c}{4f_r\sqrt{\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}(1+\frac{12h}{W})^{-0.5}}} \quad (2)$$

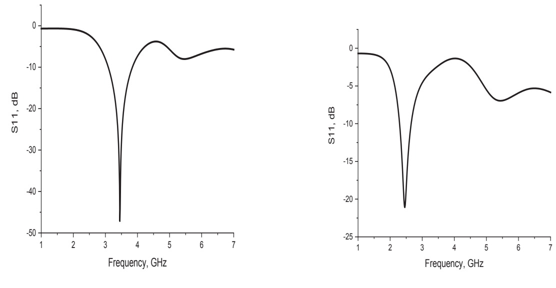
Where c, εr and h are the speed of light, the permittivity and the thickness of the substrate, respectively.

Table 1. Dimensions of the monopole antenna with frequency diversity illustrated in Figure 2

Dimensions	Values	Dimensions	Values
Ws	30	W_1	2.5
Ls	40	W_2	3
W	3	L_1	10
Lg	11.5	L_2	4.8
L_1	14	r_1	6
L_2	8.5	r_2	8.5

4 Simulations and results

The performances of the agile monopole antenna are analyzed using HFSS software. Firstly, if the switch is turned OFF, the reflection coefficient is found to be -43.13 dB at the operational frequency of 3.45 GHz (Fig. 3 (a)). Secondly, if the switch is turned ON, the reflection coefficient is -23.12 dB at 2.45 GHz (Fig. 3 (b)). The bandwidths are 770 MHz and 360 MHz when the switch is turning OFF and ON, respectively.



(a) **(b)**

Fig. 3. Reflection coefficient of agile monopole antenna for two states of switch diode: (a) OFF state and (b) ON state

Table 2 illustrates the states of switch diode and the corresponding operating bands.

Table 2. States of switch diode and the corresponding frequency bands.

PIN diode	Frequency band (GHz)
off	3.45
on	2.45

The 3D gain of the monopole antenna corresponding to 3.45 GHZ and 2.45 GHz are presented in fig. 4. The maximum gains are 2.72 dB and 1.55 dB if the switch diode is turned OFF or ON, respectively.

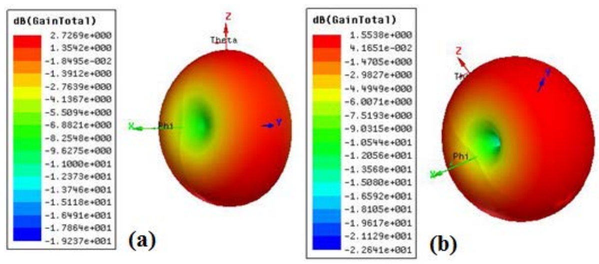


Fig. 4. Simulated 3D gain: (a) OFF state, (b) ON state.

To observe the effective resonant lengths at the radiating frequency, the surface electric fields for the frequencies of 2.45 GHz and 3.45 GHz are illustrated in Fig. 5. From this figure, it can be seen that the quarter-circle line is mainly responsible for the radiation at 3.45 GHz, while the rest of the antenna which connected to the quarter-circle line is responsible for radiation at 2.45 GHz.

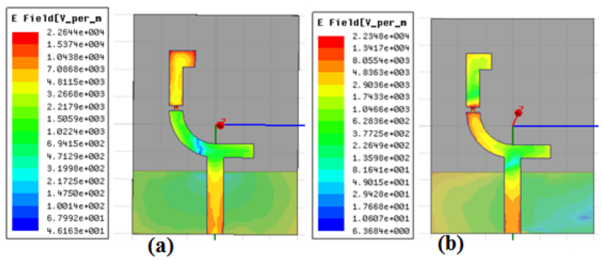


Fig. 5. Surface electric fields for (a) 2.45 GHz and (b) 3.45 GHz.

The voltage standing wave ratios (VSWR) of agile monopole antenna at the states OFF and ON of the

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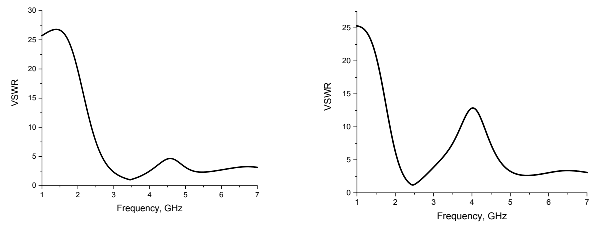
switch diode are respectively depicted in Fig. 6 (a) and Fig. 6 (b). At the frequency of 3.45 GHz, VSWR = 1.01, while VSWR = 1.15 at a frequency of 2.45 GHz. These results mean that the antenna is well suited and can radiate efficiently at these resonance frequencies.



(a) **(b)**

Fig. 6. VSWR of agile monopole antenna: (a) OFF state and (b) ON state

5 Conclusion

A frequency agile monopole antenna using PIN diode has been presented. Depending on the state of PIN diode, this antenna can changes its effective length and consequently alter between two resonance frequencies. If the switch diode is turned ON, the antenna radiates at 2.45 GHz assigned to Wi-Fi applications, however it radiates at a frequency of 3.45 assigned to WiMAX applications if the switch diode is turned OFF. The reflection coefficient achieves a value of -43.13 dB with a wide bandwidth of 770 MHz for the frequency of 3.45 GHz and achieves a value of -23.12 dB with a wide bandwidth of 360 MHz. This antenna realizes maximum gains of 1.55 dB and 2.72 dB respectively at 2.45 GHz and 3.5 GHz. The voltage standing wave ratios at 3.45 GHz and 2.45 GHz are 1.01 and 1.15 respectively, which means that the antenna is well suited and is operating efficiently.

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