Multi-band Frequency Reconfigurable Planar Bow-tie Antenna

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ABSTRACT

A multi-band frequency reconfigurable planar bow-tie antenna is designed and simulated in this paper. Firstly, a self-complementary bow-tie antenna is designed and implemented; this antenna is characterized by a simple feeding. It is directly matched to the SMA connector via 50Ω micro-strip feed line. Second, a rectangular slot and a PIN diode are added to adjust electronically the bow-tie antenna over (1.7-6GHz) frequency band. The proposed antenna shows two different states by switch the PIN diode. In ON state, the antenna covers DCS, Bluetooth and Wlan bands and in OFF state the antenna covers the wide-band (2-4.9GHz) and Wlan band. Moreover, hexagonic parasitic elements are integrated in the bottom and in the top side of the substrate to cover (1.49-1.7GHz) and (1.77-1.85GHz) bands. By switching PIN diode, multi-band frequencies' are shown in the ON and the OFF states with a gain varied between 0.5 and 3.5dB.

Keywords: ***Bow-tie antenna, PIN diode, Frequency-reconfigurable antenna, multi-band frequency antenna***

I. INTRODUCTION

With the development of the modern communication system, antennas covering different frequency bands are required. For that reason, many researches are developed to realize wideband and multiband antennas.

As well as, in [1] wide band printed bow-tie antenna is proposed to cover the C and X band (5.5-12.5GHz). This antenna is characterized with small size and wide band width. In [2] authors propose a simple technique to feed bow-tie antenna over a UWB band using the self complementary method. The integration of UWB band with extra wireless narrow bands is proposed in [13]; when similar strips are attached to the high concentrated current area of elliptical monopole antenna. The antenna shows a small size and covers GSM, Bluetooth and UWB bands. On the other hand, Frequency reconfigurable antenna is more desirable in modern communication system. This antenna is characterized by an adjusted operated band and it is used in many application areas such as: radar system, satellite communication, airborne vehicle (UVA) radar and smart Weapon protection. Several research works are developed to realize the reconfigurability such as in [3] when the mecanical control method is used to tune the frequency of the antenna. However, the electronical control method is very fast and more commonly used [4], [5] and [7]. PIN diodes, MEMS switches and varactor diodes are applied to tune the frequency band of the electronic reconfigurable antenna.

In [6] a novel frequency reconfigurable bow-tie antenna operating over 3-6 GHz is proposed. Using a pair of PIN and a pair of varactor diodes, the antenna achieves a wide and a continuous tuning frequency range from 3.04 to 5.89GHz. In [8] PIN diodes are integrated over the bow-tie arms to switch the antenna between Bluetooth, Wimax and Wlan bands. The reconfigurable antenna shows good results.

The proposed reconfigurable antenna can switch between wideband and lower frequency narrow band. this antenna is characterized by a small size, simple feeding and easy implementation design. Therefore, the proposed reconfigurable multi-band planar bow-tie antenna operating from 1.4GHz to 6.2GHz is designed only using a simple PIN diode and two parasitical elements.

Indeed, the second section describes the design, the simulated results and the measured of SCBT antenna characterized by a wideband width, easy design and simple feeding.

In section 3, a simple PIN diode is used to design a reconfigurable SCBT antenna which is operated among the frequency bands (1.7-2.43GHz) and (4.9-5.7GHz) in ON state and between the frequency bands (2.07-4.77GHz) and (5.2-5.8GHz) in OFF state.

Finally, two hexagonal parasitic elements are added in the top and in the bottom of the substrate to create a resonance at 1.57GHz and 1.8GHz. So, using this configuration, we can realize a simple and low cost multi-band reconfigurable frequency antenna.

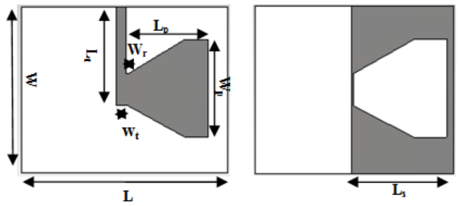
II. SELF COMPLEMENTARY BOW-TIE ANTENNA

A. Design and Simulation

The evolution of modern wireless communication systems requires the development of new technique to design wideband, compact and low cost micro-strip antenna. Indeed, Bow-tie antenna shows excellent performance in UWB communication [9-10-11].

In [2] a self-complementary bow-tie antenna is designed and implemented. The antenna is characterized by a wideband width, easy design and implementation. Thus, it is fed directly via a (50Ω) right-angle bended rectangular micro-strip line. The simulation results are checked through experimental measures and they show good results [2].

So, based on this work, a planar modified bow-tie antenna fed by a (50Ω) micro-strip line is realized to cover 2-5.5 GHz. This antenna is printed on a FR4 substrate of dielectric constant of 4.34 and a thickness of 1.6mm. The top and bottom views of the proposed antenna are shown in Fig. 1.



(a) (b)

Fig.1. Structure of SCBT bow-tie antenna: (a) top views (b) bottom views

The relations proposed in [11] are used to determine the dimension of the bow-tie antenna.

$$F_1 = \frac{7.2}{(L_t + r + p)\times k} GHZ$$

$$r = \frac{W_t}{4\pi}$$

$$L_t = \frac{\sqrt{3}W_t}{2}$$

$$K = \sqrt{\varepsilon_{eff}}$$

P=feed probe length, gap between the radiating structure and the ground plane (in cm)

r=the radius of the equivalent cylindrical monopole (in cm)

Lt= the height of equivalent cylinder which is taken equal to that of the triangular monopole patch (in cm)

Wt = the base of the triangular patch (in cm)

ε eff = effective dielectric constant

The proposed Antenna structure is designed and simulated using CST simulation software and the results are presented in Fig. 2 and Fig. 3. Thus, the dimensions of this antenna are optimized via CST and they are equal to: L=54.4mm; W=41.07mm; Wt =2.4mm; Lt =23mm; Wp =25.6mm; Lp =21.5mm; Ls =28.6mm; Wr =0.6mm.

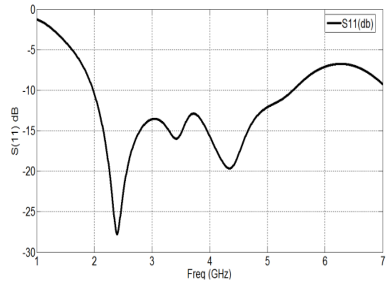
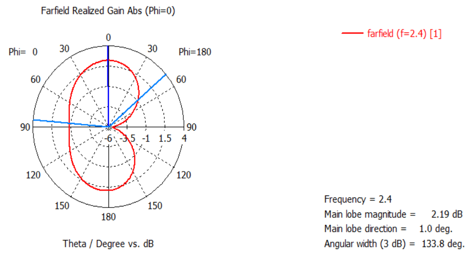
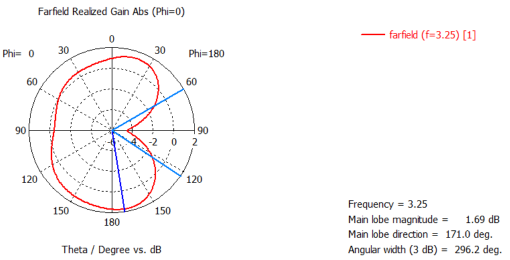


Fig.2. Reflection coefficient of bow-tie antenna

The simulation results in fig.2 present an insertion loss less than -10 dB over (2-5.5GHz). The lowest frequency is indicated in simulation at (2GHz).



(a)



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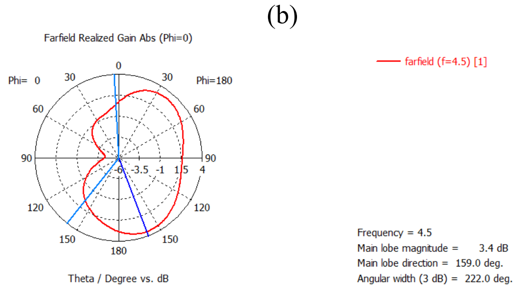


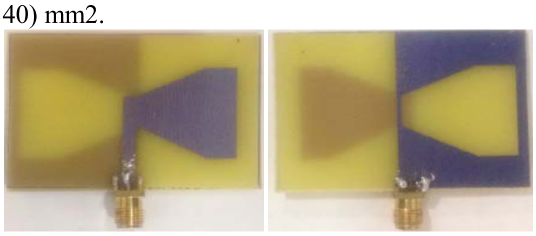
(c)

Fig.3. Radiation patterns of the antenna for the three frequencies 2.4, 3.25 and 4.5GHz

Gain generated with the modified SCBT antenna is varied between 2dB and 4 dB over (2-5.5GHz) in E plane and the results show bidirectional radiation patterns.

B. Fabrication and measured

The modified structure of the SCBT antenna is implemented on FR4 substrate. The top and bottom views of the prototype are shown in Fig 4. The antenna size is (50×40) mm2.



(a) (b)

Fig. 4. Fabricated SCBT (a) top view (b) bottom view

The return loss is computed using CST soft ware package and it is measured using vector network analyzer operating between (1-4GHz) and they are shown in Fig 5.

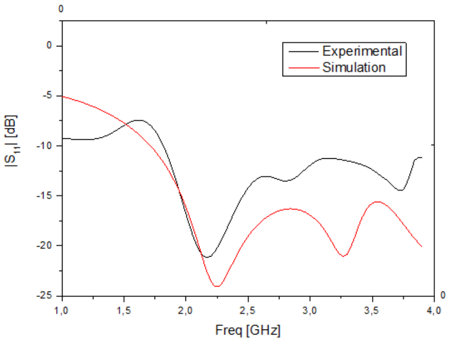


Fig. 5. Measured and simulated return loss for SCBT antenna

III. RECONFIGURABLE SCBT ANTENNA INTEGRATED WITH PIN DIODE

A. Design and Simulation

To develop a reconfigurable SCBT antenna, a rectangular slot is added firstly in the top side of the substrate. Then, BAR64-0.5w PIN diode is integrated to switch between different frequency bands fig.6. When the dc voltage is applied (V=0.82v), the diode is tuned ON and it is equivalent to the resistance R=2.7Ω. Therefore, the antenna is operated in multi frequency band. The first band is varied among lower frequencies (1.65-2.43GHz). The second band is varied among higher frequencies (4.9-5.7GHz). However, when the no bias voltage is applied (V=0); the diode is switched off and it is equivalent to the capacitor C= 0.22pf. Thus, the antenna is operated in another dual frequency band. First band is varied between (2.07-4.77GHz) and the second is varied between (5.2-5.8GHz). The antenna is printed on FR4 substrate of a dielectric constant of 4.34 a conductor loss of 0.002 and thickness of 1.6mm.

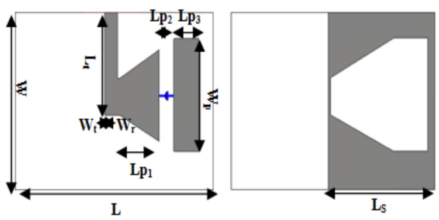


Fig.6. Structure of reconfigurable SCBT bow-tie antenna using PIN diode: (a) top view (b) bottom view

To optimize the antenna dimensions, CST soft ware package is used: L=54.4mm; W=41.07mm; Wt =2.4mm; Lt =23mm; Wp =25.6mm; Lp1 =11.8 mm; Lp2 =3 mm; Lp3 =6.9mm; Ls =28.6mm; Wr =0.6mm. The return loss of reconfigurable SCBT antenna is computed using CST soft ware package and it is shown in fig .7.

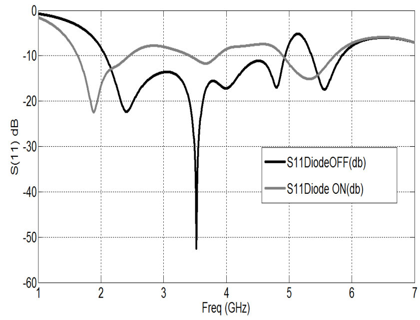
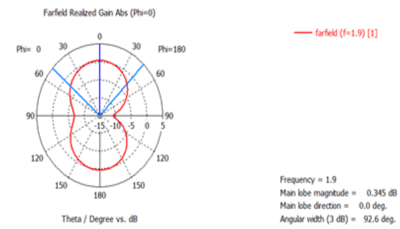
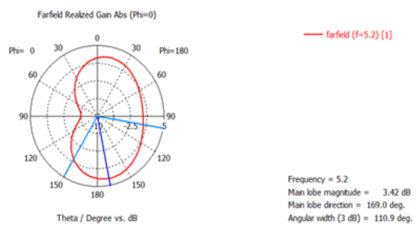


Fig.7. Simulation Results of reconfigurable antenna in ON and OFF states

Indeed, the return loss of the ON state is better than -10dB in the two different bands (1.65-2.4GHz), (4.9-5.7GHz). In the off state, the return loss is better than –10dB over the lower frequency band (2.1-4.8GHz) and the higher frequency band (5.2-5.8GHz). Fig.8 shows the radiation patterns in ON states of the antenna at 1.9 and 5.5GHz. The radiation patterns in OFF states at 2.4, 3.5, and 5.5GHz are shown in fig.8.

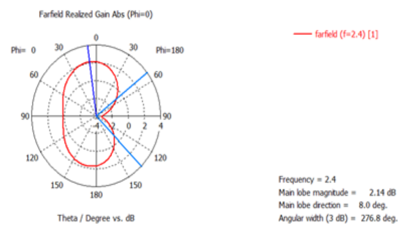


(a)

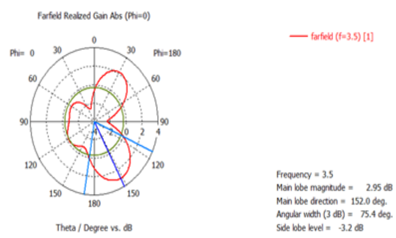


(b)

Fig. 8. Simulated Radiation patterns in ON state at (a) 1.9GHz, (c) and 5.2GHz



(a)



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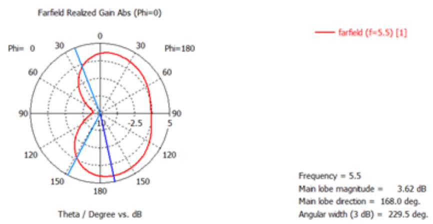


(c)

Fig.9. Simulated Radiation patterns in OFF state at (a) 2.4 GHz, (b) 3.5GHz, (c) and (d) 5.5GHz

The simulation results in ON state show a gain varied between 0.5dB and 3.5dB in different operated frequency. While in OFF state, the gain is varied between 2.5dB and 3 dB in lower frequency band and is better than 1.1dB in higher frequency band. The results show a bidirectional radiation patterns in E plane. It can be noted that the radiation characteristics are not a stable in the two states. The side lobes are appeared at some frequencies which achieve that the side lobe level is equal to -3.2dB at 3.5GHz in OFF state. Many methods are used to reduce the side lobe level such as in [14], [15] and [16].

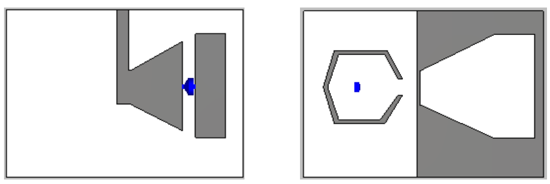
IV. RECONFIGURABLE SCBT INTEGRATED WITH PIN DIODE AND PARASITIC ELEMENT

A. Reconfigurable SCBT with a simple parasitical elements

In this section, a simple hexagonal parasitic element is added in the bottom side of the substrate to introduce a resonance at 1.57GHz. Indeed, the antenna can cover the GPS band.

This idea is inspired from Tawk [12] when circular and hexagonal slots are integrated in different parts of single antenna to create a resonant frequency in 2 and 3 GHz.

The dimensions of hexagonal element are optimized using CST and the structure of the proposed antenna is illustrated in Fig.10.



(a) (b)

Fig.10. Structure of reconfigurable SCBT bow-tie antenna with PIN diode and parasitic element: (a) Top view (b) Bottom view

Compared with the results obtained in the second section, this antenna can be operated in two different states when each state presents multi-band frequency. Therefore, switching the PIN diode in ON state the antenna is operated in (1.46-1.66GHz), (2.1-4.5GHz) and (5.3-5.7GHz) frequency bands. When the PIN diode is turned OFF the antenna is operated in another frequency band (2.1-5GHz) and (5.6-5.9GHz). Fig.11 presents the simulation results of the proposed antenna in the two states.

Simulation results show three frequency bands in ON state when the voltage bias is applied (V=0.82 V) and the PIN diode is equivalent to a resistance. The return loss is better than -10dB over the different operated frequency band and the resonances frequencies are at 1.57GHz, 3.5GHz and 5.5GHz

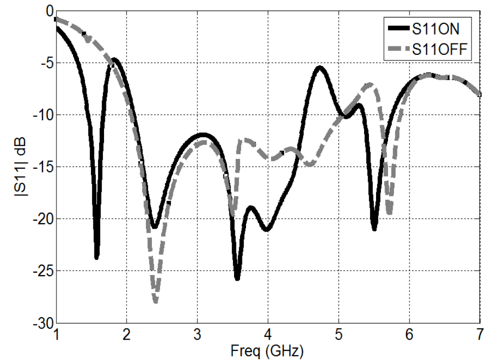
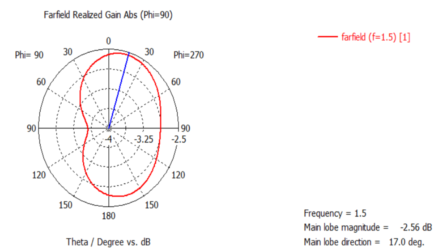


Fig.11. Simulation Results: (a) ON State, (b) OFF state

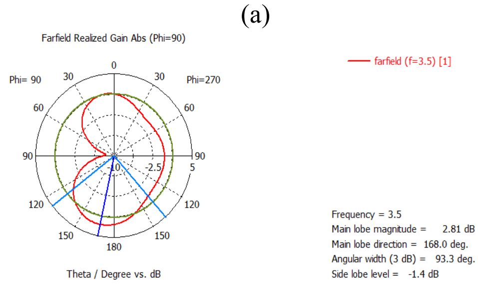
Simulation results show three frequency band in ON states when the voltage bias is applied (V=0.82 V) and the PIN diode is equivalent to a resistance. The return loss is better than -10dB over the different operated frequency band and the resonances frequencies are at 1.57GHz, 3.5GHz and 5.5GHz.

In OFF state, simulation results show another frequency band with a return loss better than -10dB. The resonances frequencies are at 2.4GHz and 5.7GHz.

Fig.12 and fig.13show respectively the radiation patterns of the antenna in ON and OFF states.



(a)



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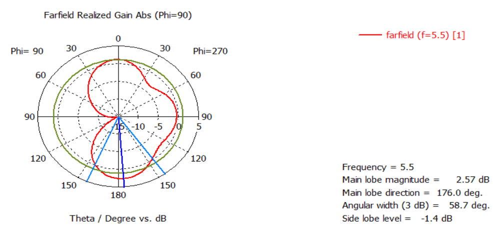
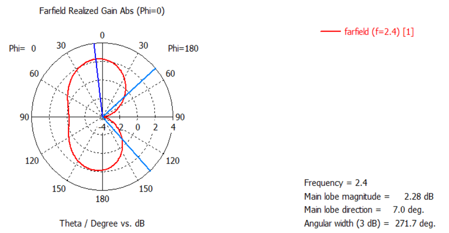
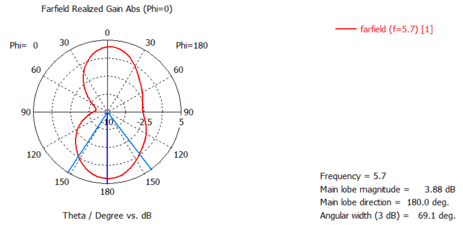


(c)

Fig.12. Simulated Radiation patterns in ON state at 1.5GHz (a), (b) 3.5GHz, (c) 5.5GHz



(a)



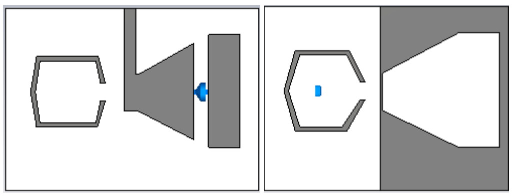
(b)

Fig.13. Simulated Radiation patterns in OFF state at 2.4GHz (a), (b) 5.7GHz

The gain obtained by simulation is varied between -2.56dB and 4dB in different operated frequencies in the two states in E plane and the results show bidirectional radiation patterns.

V. RECONFIGURABLE SCBT INTEGRATED WITH TWO PARASITIC ELEMENTS

Currently, a second hexagonal parasitic element is integrated in the top side of the substrate. The dimensions of this parasitic element are determined to create a resonance at 1.8GHz. The prototype design is presented in fig.14.



(c) (b)

Fig.14. Structure of reconfigurable SCBT bow-tie antenna with two parasitic elements: (a) Top view (b) Bottom view

Using this configuration, a new frequency bands (1.77-1.85GHz) is created in the off state and the antenna can cover the GMS band. The return loss of the proposed antenna is achieved in Fig.15.

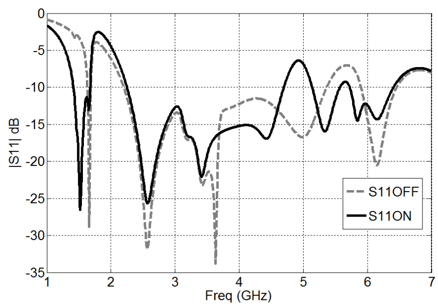
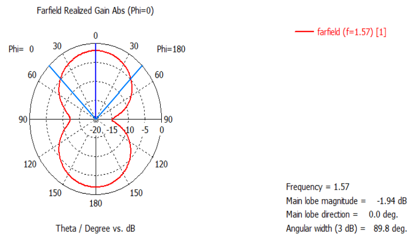


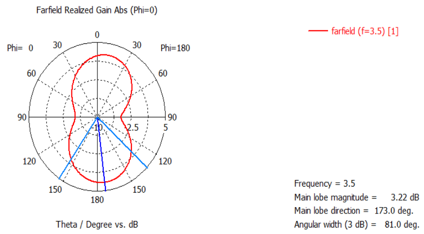
Fig.15. Simulation Results: (a) ON State, (b) OFF state

In ON state, the antenna operates in three frequency band (1.49-1.7GHz), (2.29-4.6GHz) and (5.1-5.9GHz) with insertion loss less than -10dB. The resonances frequencies are at 1.57GHz, 3.5GHz and 5.7GHz. However, another frequency bands are created in OFF state and the antenna covers (1.77-1.85GHz), (2.24-5.1GHz) and (5.8-6GHz) frequency bands with insertion loss less than -10dB. In this state, the resonances frequencies are at 1.8 GHz, 2.4 GHz and 5.8 GHz.

Fig.16 and fig.17 show respectively the radiation patterns of the antenna in ON and OFF states.



(a)



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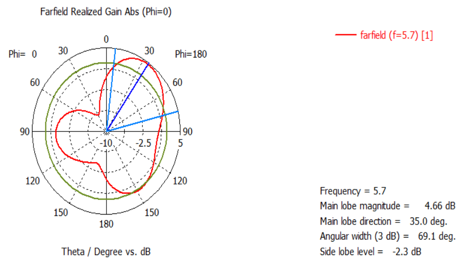
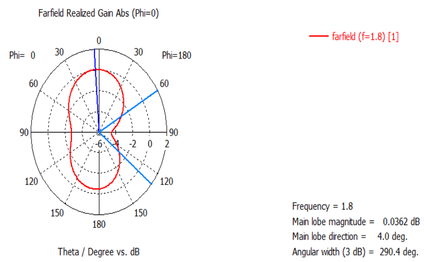
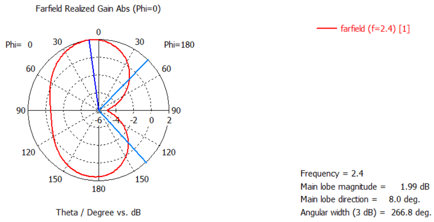


(c)

Fig.16. Simulated Radiation patterns in ON state at 1.5GHz (a), (b) 3.5GHz, (c) 5.7GHz



(a)



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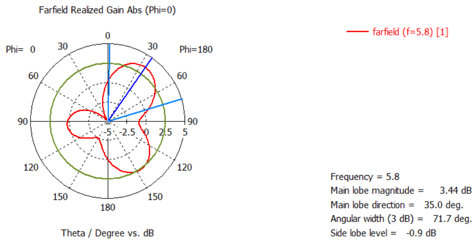

(c)

Fig.17. Simulated Radiation patterns in OFF state at 1.8GHz (a), (b) 2.4GHz, (c) 5.8GHz

The gain generated in ON state is equal to -1.9dB at 1.57GHz and varied between 2dB and 4.5dB in the other operated frequencies.

In OFF state, gain doesn't overstep 4dB in the different operated frequencies and the results show bidirectional radiation patterns in E plane.

VI. CONCLUSION

In this paper a PIN diode and a rectangular slot are integrated into the top side of SCBT antenna to switch the antenna between two states. The novel structure shows a good return loss and a gain varied between 0.5dB and 3.5dB in the two different states. Two hexagonal parasitical elements are added in the bottom and the top side of the substrate to create new narrow bands (1.49-1.7GHz) and (1.77-1.85GHz) in ON and in OFF state, respectively. So, the novel antenna structure can switch between two states; when each state covers a lower frequency narrow band and a wide band. The different structures size is (50×40mm).

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