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A Switchless Pentagon-shaped Reconfigurable Antenna for Radar Applications

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Abstract. This paper proposes a switchless pentagon-shaped microstrip patch antenna for radar and radionavigation applications. The antenna is built on Rogers RT5880 substrate with five rectangular radiating elements on top. Five ports have been set up to operate at 13.5 GHz resonant frequency. Besides having reflection coefficient below -10 dB, the antenna also offers high gain when about 8.29 dB is achieved. The proposed antenna also has a bi-directional radiation pattern with 360° of beam steering.

1. Introduction

The reconfiguration of an antenna represents its capability in changing its operating frequency, impedance bandwidth, polarization, radiation pattern or a combination of some of these properties [1]. The study of reconfigurable antenna become attractive as it offers a lot of advantages and can be used for many applications, e.g., radar system, wireless and satellite communications. The reconfigurable antenna is widely used in communication and radar systems as low cost is needed and easy to integrate with switching devices and control circuit.

Many reconfigurable elements have been proposed such as by using single-pole double-throw (SPDT) transmitter/receiver (T/R) switch and PIN diode in a miniaturized reconfigurable multifunction microstrip array antenna [2]. Besides that, the ideal switches are used in smart UWB antenna design in order to overcome the interferences come from WIMAX, WLAN and ITU bands [3-4]. Apart from that, RF MEMS switches also have been introduced [5]. By integrating those switches into antenna design, the operating frequency changes from 1.5 to 5.5 GHz in four bands making it useful for spectrum monitoring or to suppress jamming signal [6].

However the used of switches caused many disadvantages such as increased the size of the antenna and caused the complexity of the antenna design [7][10]. Therefore a switchless pentagon-shaped antenna is proposed in this letter. This type of antenna is realized by using multiple ports to generate a radiation pattern that steered in 360° [9]. The geometry of the proposed antenna is given in Section 2. In Section 3 the simulated results are discussed and a conclusion is drawn in section 4.

2. Antenna Design

The aim of this study is to design a new antenna structure for radar and radionavigation applications. According to spectrum allocation in Malaysia [11], the desired applications are conveniently used at the frequency band from 13.4 to 14.4 GHz. Therefore the proposed antenna is designed to be executed at resonant frequency, f_r=13.5 GHz. A switchless pentagon-shaped microstrip patch antenna is designed on Rogers RT5880 substrate (h=0.508 mm and tanδ=0.0009) with relative permittivity

ε_r=2.2. Five patches are added as the radiating elements with fully ground at the bottom of the substrate. The antenna also consists of five ports as presented in Figure 1. To reduce the effect of mutual coupling between the patches, the distance between the edges of each patch should be at least λ/2 [12]. The dimension of the final structure is tabulated in Table I.

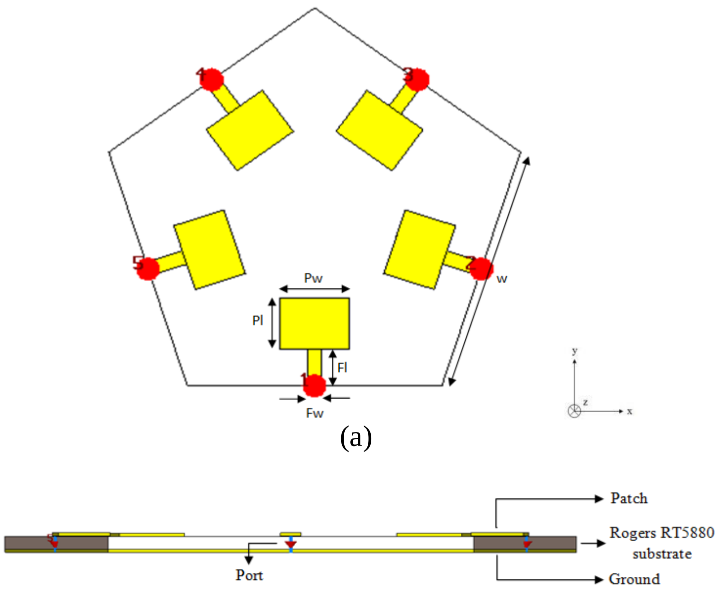


Figure 1. The proposed antenna geometry. (a) Top view (b) Side view

Table 1. Parameters of the proposed antenna

Parameters	Value (mm)
W	52.9
Pw	14.43
Pl	10.98
Fw	3
Fl	7.95

3. Results and Discussion

To test the reconfigurability of the proposed antenna, the activation of the ports plays an important role [13]. One port or more have been chose to activate while other ports are deactivated. In this case, only patch with activated port will radiate while other become parasitic patches. Figure 2 shows the surface current distributions according to the activated ports. It is clearly seen that the current distributes to only the activated port, hence there is no effect of mutual coupling detected to the proposed antenna.

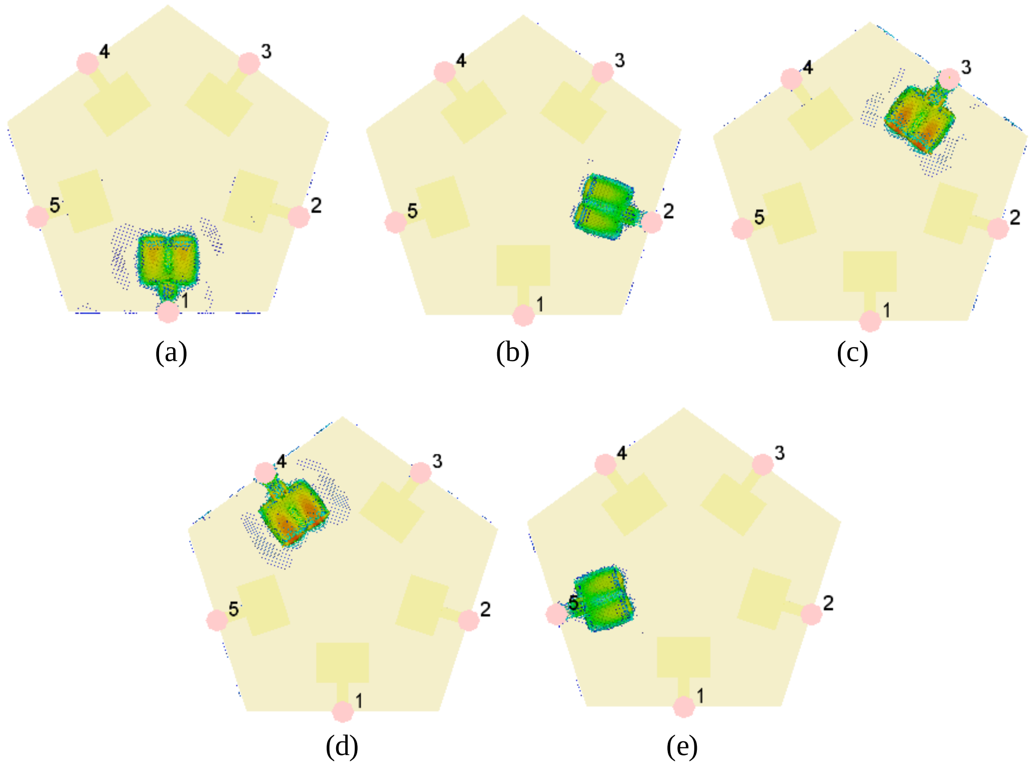
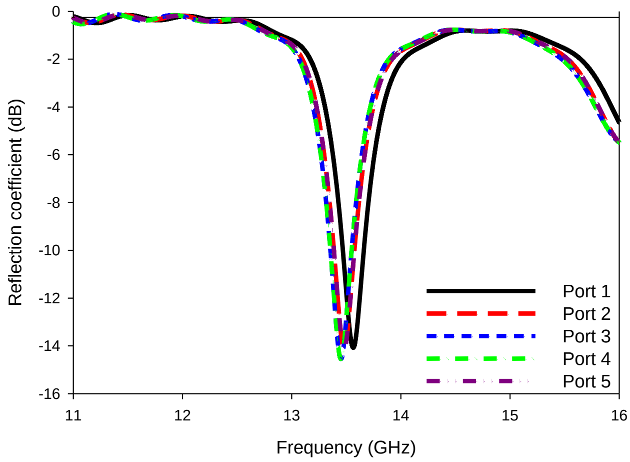


Figure 2. Surface current distributions when each port is activated (a) Port 1 (b) Port 2 (c) Port 3 (d) Port 4 (e) Port 5

The reflection coefficient (S_{11}) of this switchless pentagon-shaped patch antenna are shown in Figure 3. Based on the results, the antenna has good impedance matching when S_{11} are below -10 dB at 13.5 GHz [16-17]. As depicts in the figure, the reflection coefficient of Port 2 equals to the reflection coefficient of Port 5. On the other hand, the reflection coefficient of Port 3 equals to the reflection coefficient of Port 4. This happened because of the symmetry created by the pentagon-shaped patch.



(a)

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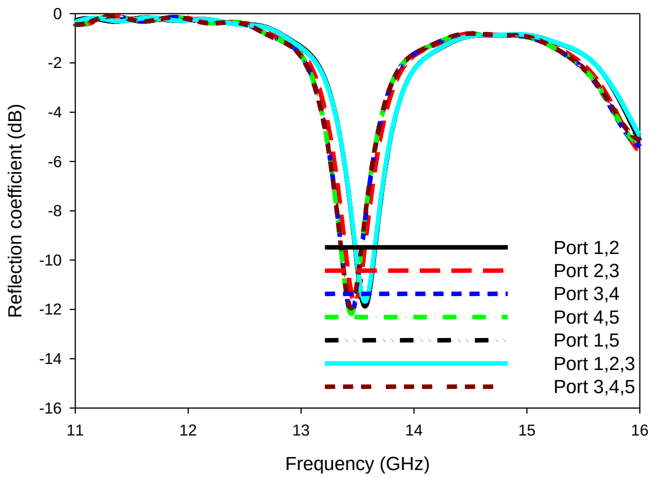
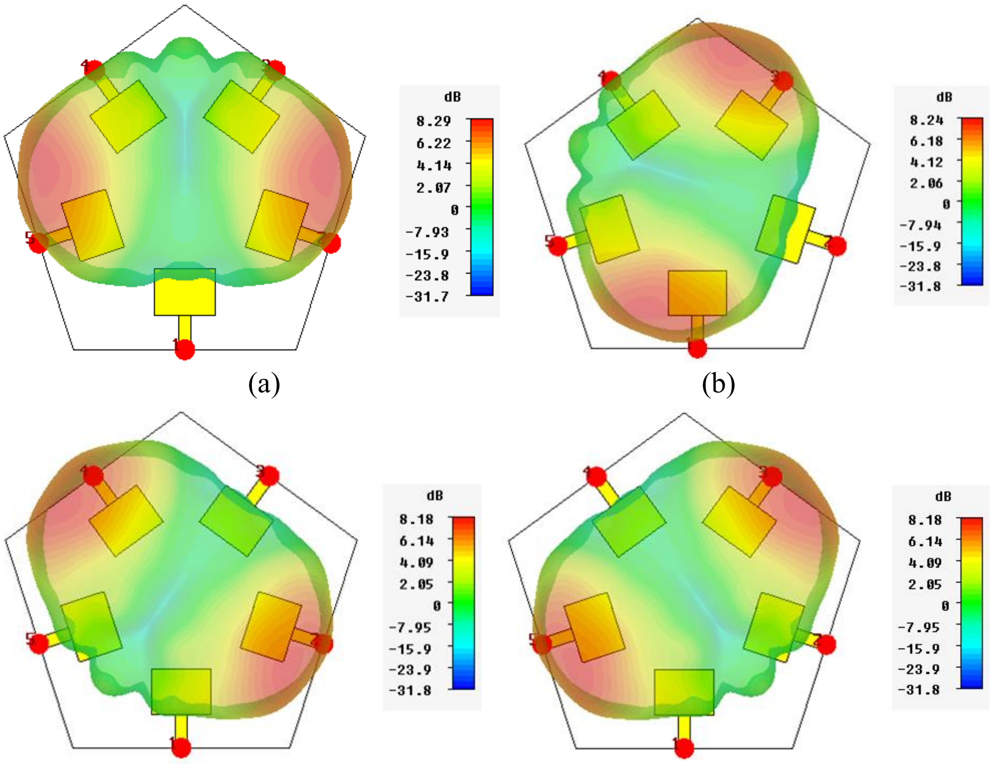


(b)

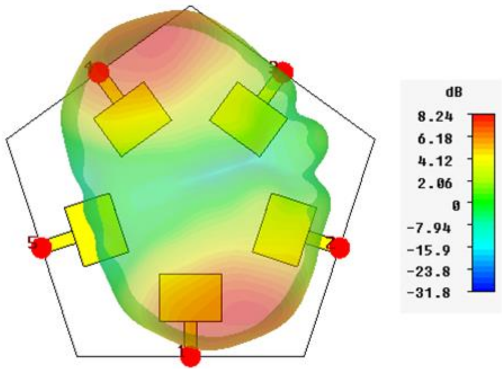
Figure 3. Reflection coefficient of the antenna when (a) one port (b) multiple ports are activated

Figure 4 shows the 3D radiation pattern when one by one port is activated. The pattern is steered in 360° as illustrated in figures below. The highest gain is obtained when Port 1 is activated which is 8.29 dB. Due to the symmetrical design, the antenna achieved 8.18 dB of gain when Port 3 or Port 4 is activated. Besides that, the proposed antenna also obtained the similar gain which is 8.24 dB when Port 2 or Port 5 is activated.



(a) (b)

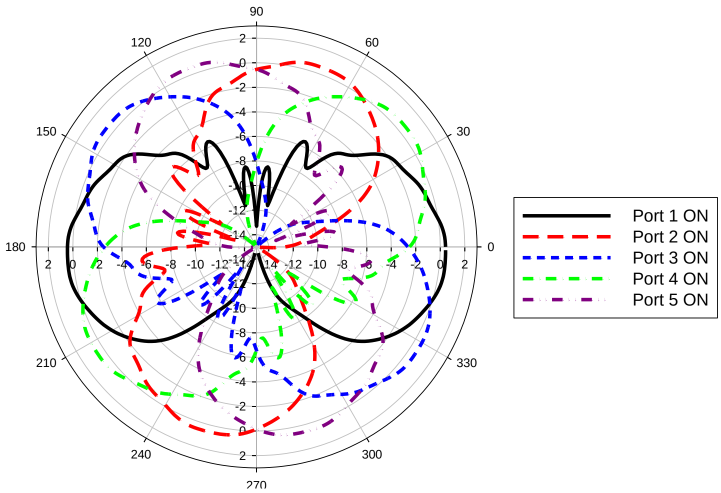
(c) (d)



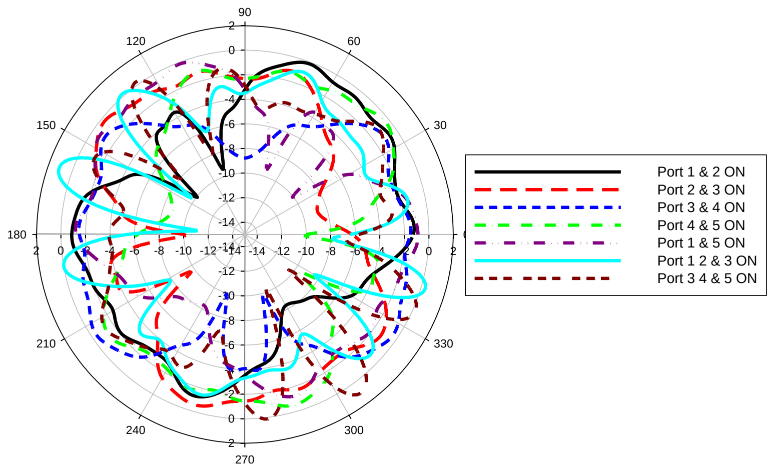
(e)

Figure 4. 3D radiation pattern when each port is activated (a) Port 1 (b) Port 2 (c) Port 3 (d) Port 4 (e) Port 5

The patters of the antenna are then presented in 2D polar plot as illustrated in Figure 5. The beam is in bi-directional pattern and it can be seen that those beams steer 360° when one by one port is activated. However when two or three ports are activated at the same time, the beams become butterfly shaped pattern but still steer in 360° directions. With 8.29 dB of gain achieved and the compact size, the proposed antenna can be a good candidate to be applied in radar and radionavigation applications [14-15].



(a)



(b)

Figure 5. Radiation pattern of the antenna when (a) one port (b) multiple ports are activated.

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4. Conclusion

A switchless pentagon-shaped microstrip patch antenna is designed with five ports to steer the beam in 360° direction. By controlling the activation of the ports, this antenna needs no switch to reconfigure the radiation pattern. With high gain achieved, the proposed antenna can be used for radar and radionavigation applications.

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