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A Novel Dual Ports Antenna for Handheld RFID Reader Applications

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Abstract: A compact antenna utilizes two ports to transmit and receive signal separately, different with conventional handheld RFID readers with single port. The proposed antenna can enhance receive sensitivity of handheld RFID readers, since the strong transmitting signal of reader with single port is usually highly coupled with weak receiving backscatter signal of tag. The antenna uses U-shape aperture coupled patch structure that occupies less volume and provides further space-saving efficiency. It is fed by two T-shape microstrip lines with rectangle stubs. The U-shape apertures are used to excite two orthogonal modes for dual polarized operation. The height of the air substrate is reduced to only 4 mm (0.032 wavelength) and the volume of antenna is 80 mm×80 mm×6.8 mm, which is easy to integrate in Handheld RFID readers. The measured results show -10 dB matching band and -25 dB isolation band from 2.2 GHz to 2.6 GHz and from 2 GHz to 2.6 GHz, respectively. The minimum isolation is -50 dB at 2.48 GHz. The antenna is suitable for applications in handheld RFID readers.

Keywords: handheld RFID reader antenna; two ports; high isolation

Nova dvovhodna antenna za ročne RFID bralnike

Izvleček: Kompaktna antena ima dva vhoda za ločeno pošiljanje in sprejemanje signala, kar je različno od običajnih enovhodnih RFID bralnikov. Predlagana antena omogoča večjo sprejemno občutljivost, jas je močen oddajen signal enovhodnih bralnikov večinoma močno sklopljen s šibkim bralnim signalom. U oblika antene porabi manj prostora in omogoča dva ortogonalna načina delovanja za dvopolarizirano delovanje. Napajana je z dvemi T trakastimi linijami T oblike. Višina zračnega substrata je le 4 mm (0.032 valovne dolžine), velikost 80 mm×80 mm×6.8 mm, kar omogoča enostavno integracijo v ročne RFID bralnike. Meritve izkazujejo ujetost -10 dB in izolativnost pasu -25 dB v območju 2.2 do 2.6 GHz. Najmanjša izolativnost pri 2.48 GHz je -50 dB.

Ključne besede: ročna RFID bralna antena; dva vhoda; visoka izolativnost

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1 Introduction

Recently, the use of radio frequency identification (RFID) systems has become widespread in a variety of applications. Furthermore, handheld RFID readers have become very popular with users, particularly in applications that need to control large and heavy products, which are not easy to move.

Handheld RFID readers reported are most single port with various structures [1-7]. RFID system consists of a tag and reader. The reader transmits a continuous wave (CW) signal and the tag backscatters transmission from the reader to send back data. In a backscatter reader, the transmitted CW signal may be directly coupled to the receiving part of the reader to drastically degrade the receiving sensitivity. The directly coupled CW signal is much larger than the backscatter signal from the tag, and the receiving part of the reader should detect the weak signal close to such a strong in-band interfere. Therefore, it is essential to separate transmitting and receiving parts with dual ports to achieve high isolation between them.

Over the past years, dual ports reader antenna designs have received considerable attention. Among dual polarized antenna designs, aperture coupled microstrip patch antenna are the most suitable candidates for RFID application [8-17]. Aperture coupling is preferred to other feeding mechanisms of microstrip patch antenna due to its greater design flexibility, easier fabrication and lower cost. The antenna in [8] is utilizes a resonant annular ring slot and a T-shaped microstrip feedline to coupled with radiating patch, thus exciting dual orthogonal linearly polarized mode. The 2×2 array employing two symmetric dog-bone shaped coupling apertures is proposed to introduce dual linearly

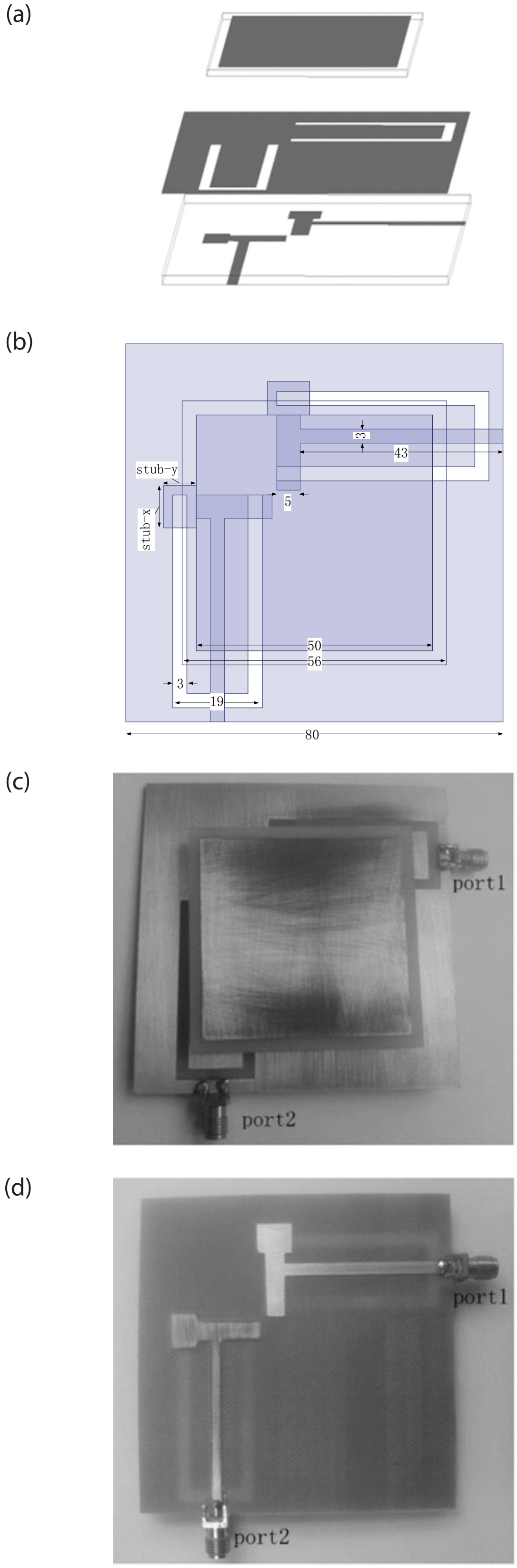


Figure 1: (a) Side view of the proposed antenna (b) configurations of the proposed antenna (c) top view of the fabricate antenna (d) bottom view of the fabricate antenna

polarized mode [9]. A common method to increase ports isolation is combining branch line with antennas [10-12]. In [13], the antenna is designed with simple microstrip feedline to couple with radiating patch, but performs badly ports isolation with 20 dB. Majority of aperture coupled antennas apply the approach for addressing the requirement for low signal correlation is to increase the height of air substrate to achieve high ports isolation [14-17]. Since, the antenna is to be used with a handheld RFID reader, the size of the antenna in general should be around 100 mm length and width, and around 10 mm in thickness [3]. Therefore, most of open literatures including [8-17] described reader antennas with dual ports are comparable large to be mounted onto a handheld RFID reader, however they are suitable for stationary readers.

The rest sections are arranged as followed: section II presents the detail design and principle of the aperture coupled patch antenna. The measured isolation and impedance matching of the proposed antenna are discussed in section III. In section IV, the parameters of stubs are simulated and analysis. Finally, the conclusions are given in section V.

2 Antenna structure and design

In traditional designs of aperture coupled antenna, they are using various shapes of apertures in the ground plane. But these apertures technique requires high air layer in order to reduce the coupling between the two feeding lines, thus increase the volume of antenna inconvenient of integrated in the handheld RFID reader. So this paper applies a novel shape aperture to decrease the air layer.

The configuration of a dual feeding aperture coupled square patch antenna is shown in Figure 1. It consists of two FR4 substrates with dielectric constant of 4.4 and loss tangent of 0.02. A single-layer substrate (56mm×56mm×1.2mm) is suspended 4 mm (0.032 λ_0 , λ_0 is free space wavelength) above the double-layer substrate (80mm×80mm×1.6mm). A square patch of 50mm×50mm is etched on the top side of the single-layer substrate. The overall volume of proposed antenna is 80mm×80mm×6.8mm. Two 50 Ω modified T-shape microstrip lines with width of W_f = 3 mm and length of L_s = 43 mm are fed by separate port 1 and port 2 on the bottom side of double-layer substrate. The ground plane with U-slots is etched on the top side. The optimized values of stub width stub-x and length stub-y are 9 mm and 7 mm, respectively. The mathematical equations for calculating the W_f and L_s are as follows:

$$\frac{W_f}{h} = \left(\frac{1}{8} e^{A} - \frac{1}{4e^{A}} \right)^{-1} \quad (1)$$

$$A = \frac{Z_c \sqrt{2(\varepsilon_r + 1)}}{119.9} + \frac{1}{2} \frac{\varepsilon_r - 1}{\varepsilon_r + 1} \left(\ln \frac{\pi}{2} + \frac{1}{\varepsilon_r} \ln \frac{4}{\pi} \right) \quad (2)$$

$$L_s \approx \frac{\lambda_g}{4} \quad (3)$$

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_r}} \quad (4)$$

Where λ_g is the dielectric wavelength, λ_0 is the air wavelength, ε_r is the effective dielectric constant and h the substrate thickness. The substrate thickness, h, in this paper is 1.6 mm.

The microwave signal is transmitting or receiving through feeding lines. Since the electromagnetic energy is along the feeding lines, the apertures are etched above feeding lines in the ground plane to couple energy to the patch. The square patch is served as a radiator to transmit or receive signals. The feeding line of port 1 excites horizon linear polarization, while that of port 2 excites vertical linear polarization. The two orthogonal polarizations decrease the coupling between two ports. Furthermore, this paper adds two stubs in the end of the feed lines to improve impedance matching and isolation. The current concentrates in the stubs, thus introduces capacitive couple to the square patch. The stubs increase effectively the isolation and impedance matching of proposed antenna. In addition, spurious radiation from the feeding lines is eliminated due to ground plane shielding, resulting in a very low cross polarization level.

An aperture coupled antenna has a narrow bandwidth and poor isolation. Additional stacked patch is utilized to improve the bandwidth. The resonant frequency is mainly determined by the size of the square patch and the amount of coupling is dependent on the aperture length. The advantage of isolating the patch from the feeding line, better radiation pattern symmetry caused by the apertures and impedance matching was obtained through the use of aperture coupled patch antenna. For dual polarization radiation, a square patch is coupled to a pair of microstrip lines through U-shape apertures located beneath the patch, which improves the radiation characteristics of the antenna. The length and width of the aperture have been optimized for acceptable optimum isolation and return loss in the desired band.

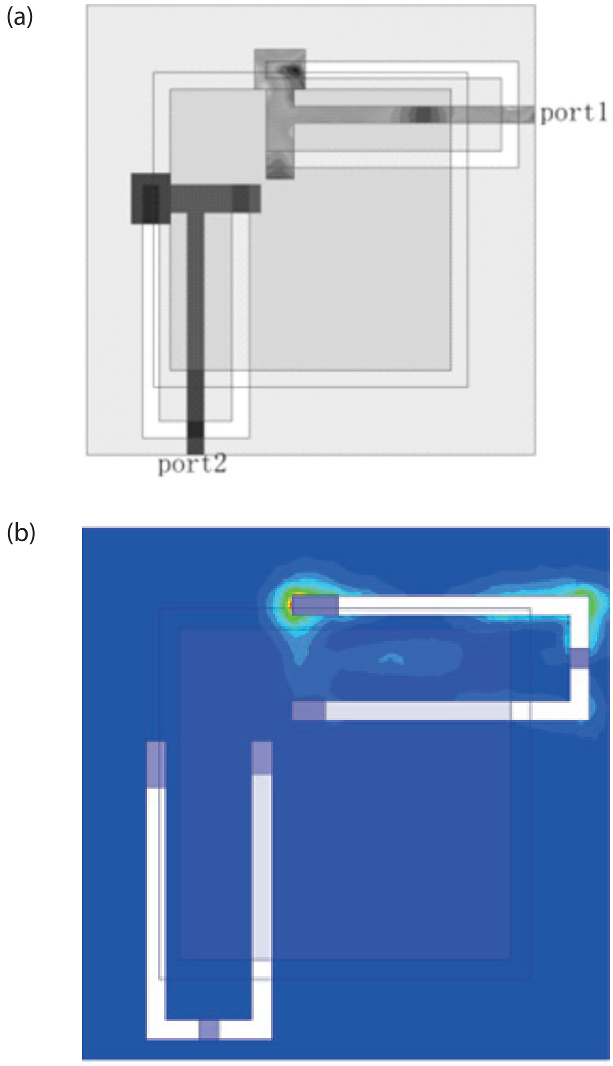
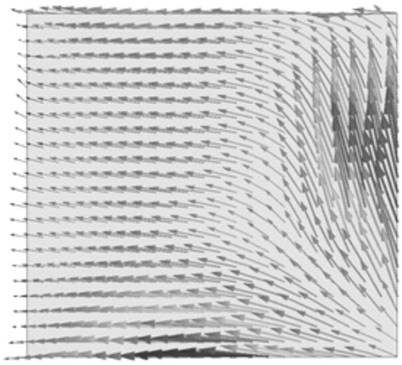


Figure 2: Surface current distribution of proposed antenna on (a) Feeding lines (b) Ground plane

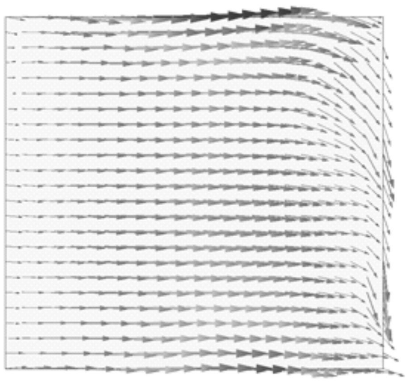
To investigate the mechanism of mutual coupling between two ports, current distributions in different layers under the patch have been simulated with port 1 excited and port 2 terminated. Thus, we simulate the proposed antenna and get the surface current distribution at 2.45 GHz on the ground plane and feeding lines shown in Figure 2. Figure 2(a) demonstrates that the microwave energy concentrates in junction and stub of T-shape feed line. It can be seen in Figure 2(a) that surface current is flowing along the feeding line from port 1 to port 2, and gradually attenuated. The current around port 2 is greatly weaker than that around port 1. It is demonstrated an excellent isolation between port 1 and port 2. Figure 2(b) describes that currents concentrate in the specific region of ground plane which is above the stub of feed line and the other end of feed line without stub has less currents. It is concluded that stub has much effects on increasing currents.

Figure 2(b) shows the current around U-slot is decreasing much, attribution to impedance matching.

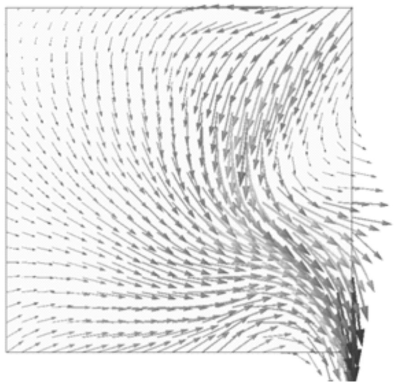
(a)



(b)



(c)



(d)

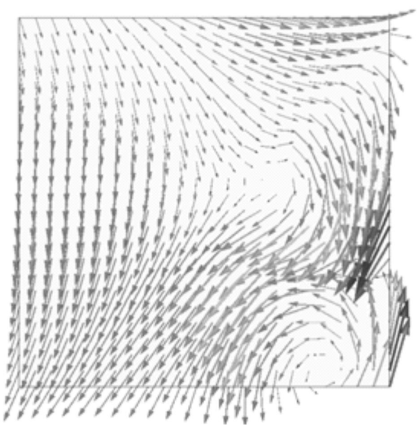


Figure 3: Radiating patch surface current distributions for two different phase intervals. (a) 0° of port 1(b)90° of port 1(c) 0° of port 2(d)90° of port 2

To better understand the excitation behavior of the antenna, Figure 3 only shows the current distributions of phase 0° and 90° in port 1 and port 2, respectively, since those of 180° and 270° are equal in magnitude and opposite in phase of 0° and 90°. It is clearly displayed that surface currents cause linear polarization with time and two ports produces orthogonal fields. Due to the symmetrical structure of the proposed antenna, the Tx and Rx port can interchange to create linear polarization. Thus, the proposed antenna has dual linear polarization in one structure, orthogonal polarization improves isolation between two ports.

3 Performance of aperture coupled patch antenna

Figure 4(a) shows the simulated and measured return loss of the antenna. The simulated return loss is less than -10 dB over the frequency band of 2.19 GHz to 2.58 GHz, while the measured return loss bandwidth is 400 MHz from 2.2 GHz to 2.6 GHz. It is clearly seen in Figure 4(b) that the measured -25 dB bandwidth of 2-2.6 GHz is obtained with minimum -50 dB at 2.48 GHz, corresponding to the simulated bandwidth of 510 MHz. The simulated and measured peak gain is illustrated in Figure 4(c). The antenna exhibits the measured peak gain from 1.5-3.1 dBi according to the frequency band of 2.4-2.48 GHz. The measured and simulated return loss, isolation and peak gain show good agreement. In microwave band, antenna gain is not as critical since active tags are commonly used in many applications.

Figure 5 shows the measured radiation patterns at 2.45 GHz in the orthogonal XOZ (phi=0°) and YOZ (phi=90°) planes with angular step of 20°. The radiation pattern in YOZ plane is like bow-tie, but that in XOZ plane is unidirectional.

4 Parameters simulation and analysis

The parameters simulation is carried out to provide antenna engineers with the information for antenna design and optimization. The length stub-x and stub-y of the stub are the prime parameters that determine the amount of power concentrated in the stub and coupled to the radiating patch such that effect the impedance matching and isolation of proposed antenna. One physical attribute of the antenna is independently varied, while the other parameter is kept unchanged. For clearly visualize, the finial optimized parameters are depicted with red line in each simulation figure. Software High Frequency Structure Simulation (HFSS)

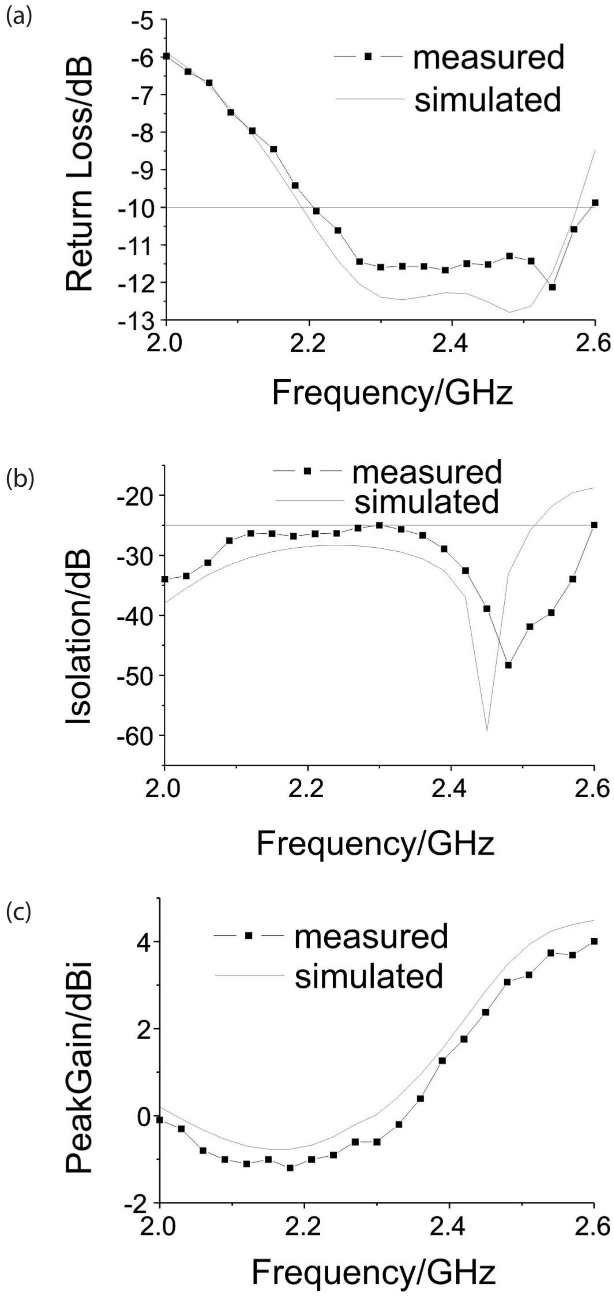


Figure 4: The characters of proposed antenna(a) Return loss (b) Isolation (c) Peak gain

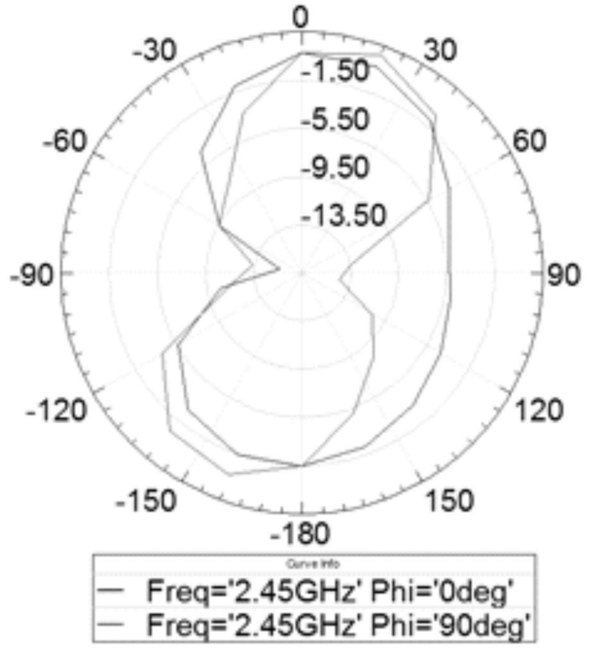


Figure 5: Measured radiation patterns of proposed antenna at 2.45 GHz

based on finite element method is used in this analysis. The finally optimized values are stub-x=9 mm, stub-y=7 mm.

The dependencies of the return loss and isolation on stub-x are described in Figure 6. Figure 6(a) and Figure 6(b) describe that the bandwidth of return loss (<-10 dB) and isolation (<-25 dB) are expanding with decreasing length of stub-x. Figure 6(a) shows that the return loss bandwidth is decreasing and resonate frequency is shift to lower frequency as the length of stub-x increasing. It is observed that isolation is reducing dramatical-

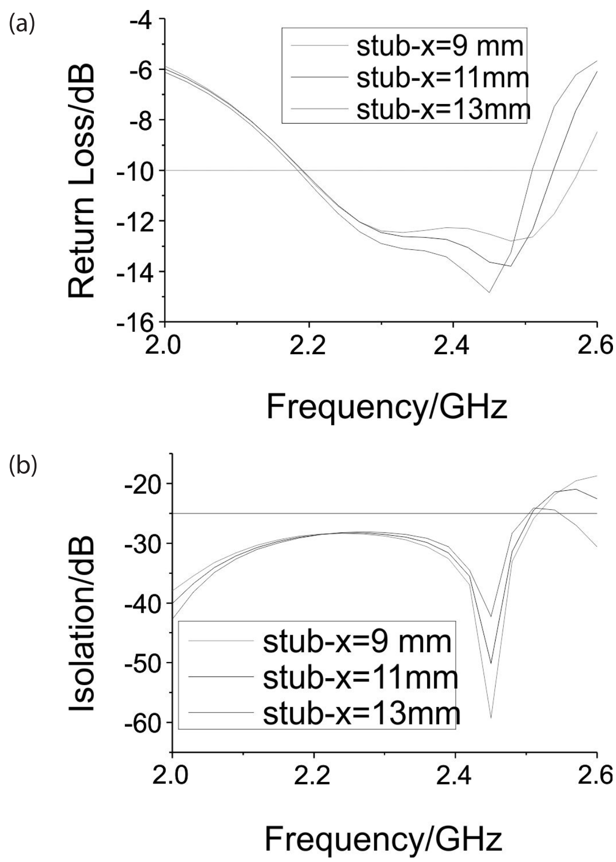


Figure 6: Antenna characters for different values of stub-x. (a)Return loss (b)Isolation

ly as the length of stub-x increasing in Figure 6(b). The minimum of isolation with stub-x of 9 mm is -60 dB at 2.45 GHz. The stub length stub-x determines the coupling strength between the feed line and ground. So it has an impact on both of the return loss and isolation.

(a)

(b)

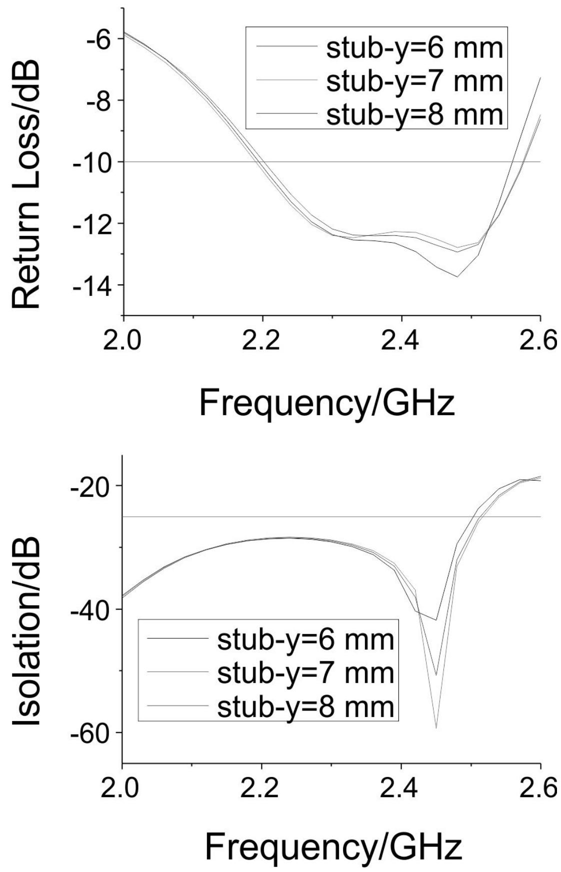


Figure 7: Antenna characters for different values of stub-y. (a)Return loss (b)Isolation

In Figure 7, the effects of various dimensions of stub-y on return loss and isolation are shown. The variation of stub-y affects slightly on return loss, but severely on isolation value. The bandwidths of return loss and isolation are almost same, but optimized value of stub-y of 7 mm shows the best isolation in 2.4 GHz-2.48 GHz.

5 Conclusion

A compact antenna with two ports is designed for Handheld RFID reader to enhance receive sensitivity. It is low cost and easy to integrate in the Handheld RFID reader for its height of 6.8 mm. The proposed antenna presents impedance matching of -10 dB and isolation of -35 dB. The -10 dB matching band and -25 dB isolation band cover from 2.2 GHz to 2.6 GHz and from 2 GHz to 2.6 GHz, respectively.

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