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2.45 GHz Broadband Monopole RFID Reader Antenna Buried in the Ground of Parking Lot near the Curb

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***Abstract*—In this paper, a compact broadband monopole RFID reader antenna with operating frequency of 2.45 GHz is designed for vehicle detection application. This reader antenna is buried in the ground of parking lot along the curb. The antenna comprises a planar loop monopole element which is fed by a microstrip line. The proposed antenna is simulated using HFSS (High Frequency Structure Simulator) as a 3D electromagnetic field simulator. The antenna is deployed on an FR4-Epoxy dielectric substrate with the dimension of 34 mm $\times$ 16 mm and the thickness of 1.6 mm. The permittivity and loss tangent of the substrate are 4.4 and 0.02, respectively. The measured results show that the characteristics of realized antenna have good agreements with the simulated ones. The bandwidth for the linear polarized antenna is more than 280 MHz (2.27-2.55 GHz) and the return loss is less than -10 dB.**

***Index Terms*—Microstrip-fed; vehicle detector; monopole reader antenna; WLAN; RFID.**

I. Introduction

With the rapid development of wireless communication technologies in recent years, short-range wireless communication such as Bluetooth, 802.11 (WiFi), wireless local area network (WLAN) et al. are widely used. In wireless communication systems, antenna is one of key components. Some challenges have been put forward to antenna designer to design high performance and low profile antennas in order to ensure a good communication quality. For this purpose, the microstrip patch antenna is one of solutions to be considered due to its light weight, small dimension, low profile, and better efficiency with good degree of compactness and easy integration [1], [2]. In addition, microstrip antennas are easily designed and operated in linear polarization, circular polarization and multiband enviroments [3], [4], [5], [6].

Performance and compactness need to be considered while an antenna is designed. Several methods have been described in literature [7] to obtain performance and compactness. we all know that a microstrip patch antenna may have a very narrow bandwidth due to surface wave losses. Therefore, some techniques such as cutting slot at the ground plane, using short-circuit stub and inspired metamaterial [8] are proposed and developed to achieve wide-band operation and reduce the dimension of microstrip patch antenna. In order to improve the performance of return loss and gain of the patch antenna, a notch technique [9], a stub technique [10] and low-loss paper substrate method [11] are proposed. To increase impedance bandwidth, artificial magnetic conductor (AMC) [12] is investigated and various shapes of slots [13] are analyzed.

In this paper, a compact monopole antenna with single frequency band is proposed for vehicle detection application. The monopole type of antenna, which has some advantages such as small, almost omnidirectional radiation pattern and easy integration on the circuit board, is chosen. According to the simulation results, the proposed antenna is to have center frequency of 2.45 GHz for WLAN applications. The -10 dB bandwidth is more than 270 MHz (2.27-2.55 GHz), which can meet broadband applications. This paper is organized as follows. Section II provides detailed design, and parametric analysis are presented in Section III. Results are analyzed and discussed in Section IV while Section V concludes the paper.

II. ANTENNA DESIGN

Basically, a microstrip antenna with dual and multiband capability developed from single and double U slot has been investigated [10]. Inspired from this shape of antenna, a planar loop monopole antenna is proposed. Fig. 1 shows a prototype of proposed antenna. It consists of two sides which are deployed on an FR4 Epoxy dielectric substrate. The dimension, thickness, and $\tan\delta$ of dielectric substrate are $L{\times}W$=34 mm $\times$ 16 mm, H=1.6 mm, and 0.02, respectively.

The radiating element which comprises a rectangular loop and a monopole is fabricated using PCB technology and on the top side of the FR4 substrate. It is the most important part fed by microstrip line. The microstrip line is not only a feeding line but also a part to match the impedance of radiating element. The radiating element which is made by metal copper has a resonant frequency of 2.45 GHz for the WLAN applications. The optimized design parameters of the antenna are shown in Table I.

III. Parametric Analysis

To achieve wide impedance bandwidth and resonant frequency, some important parameters of the proposed antenna are analyzed.

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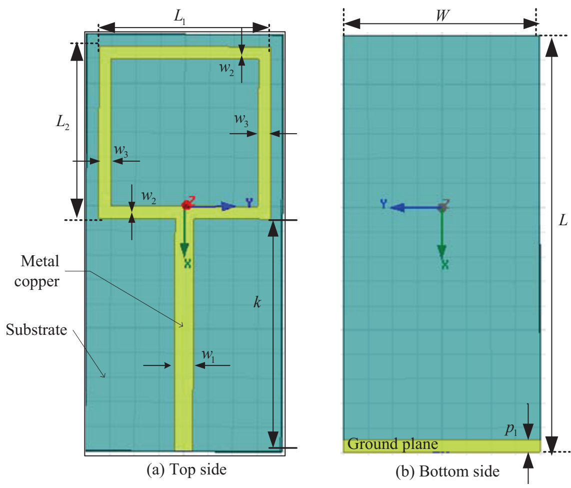


Fig. 1. The top view and bottom view of the proposed antenna.

TABLE I
OPTIMIZED DESIGN PARAMETERS OF THE PROPOSED RFID READER ANTENNA

Symbol	Value(mm)	Symbol	Value(mm)
L	34	w_3	1
W	16	L_1	14
k	19	L_2	14
w_1	1.5	p_1	1
w_2	1	H	1.6

A. Effect of microstrip

The parametric analysis of the microstrip is carried out to obtain resonant frequency.

Fig. 2 illustrates the trend of return loss for the values of 17 mm, 19 mm, 20 mm and 21 mm of the microstrip length. By changing the length of microstrip k, the resonant frequency is shifted and becomes lower with increasing of the length k. After the parametric analysis, the optimum lengths of microstrip k is selected as 19 mm for desired results.

In addition, the width of microstrip w_1 with different values is investigated as shown in Fig. 3. As the width of microstrip w_1 is changed, the center frequency and return loss have a remarkable change. Optimum width of 1.5 mm for microstrip w_1 is selected after parametric analysis.

B. Effect of loop

In order to study the effect of loop element to the performance of the proposed antenna, parametric analysis of w_2 and w_3 are executed to achieve good impedance matching. Fig. 4 and Fig. 5 explain the return loss trends with the varying the width of w_2 and w_3.

From the Fig. 4 and Fig. 5, with the size of w_2 and w_3 increasing, it can be seen that there are no significant effect on center frequency but the bandwidth becomes narrow and the return loss of resonant frequency deteriorates. After parametric analysis, the optimum width of w_2 is selected as

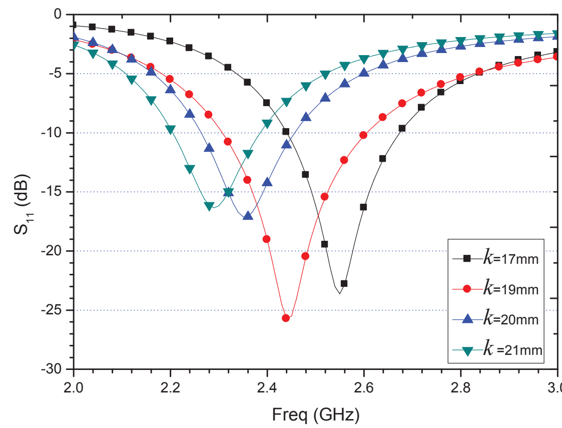


Fig. 2. Parametric analysis of microstrip length k at w_1=1.5 mm, w_2=1 mm, w_3=1 mm and p_1=1 mm.

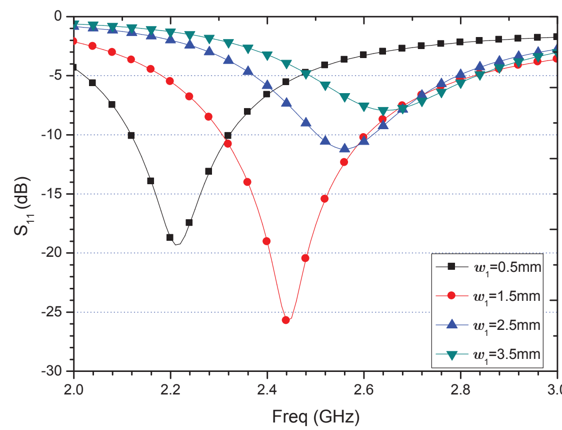


Fig. 3. Parametric analysis of microstirp width w_1 at k=19 mm, w_2=1 mm, w_3=1 mm and p_1=1 mm.

1 mm and the width of w_3 is also 1 mm. In this case, the return loss is less than -25 dB at center frequency.

C. Effect of ground plane

The parametric analysis of the ground plane is also carried out. With the size of the ground plane $p1$ varied, the shifting of the center frequency and the changing of bandwidth can be observed in Fig. 6. By the parametric sweep analysis, the optimal size of 1 mm is selected for the ground plane by which we achieve a good impedance matching for reasonable return loss.

IV. RESULTS

The results for return loss, surface current, radiation pattern are plotted in Fig. 7, Fig. 8, Fig. 9, respectively.

A. Return loss

All of the numerical simulations and their optimizations reported here were performed using the frequency domain ANSYS/ANSOFT high frequency structure simulator (HFSS).

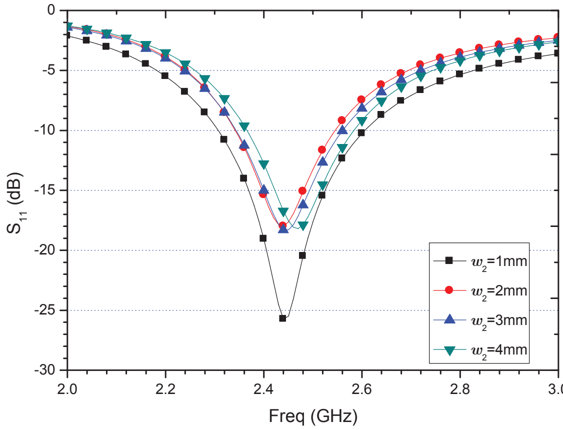


Fig. 4. Parametric analysis of w_2 at k=19 mm, w_1=1.5 mm, w_3=1 mm and p_1=1 mm.

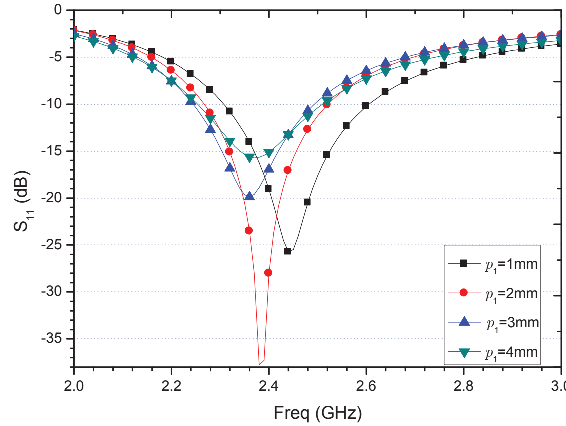


Fig. 6. Parametric analysis of ground plane size p_1 at k=19 mm, w_1=1.5 mm, w_2=1 mm and w_3=1 mm.

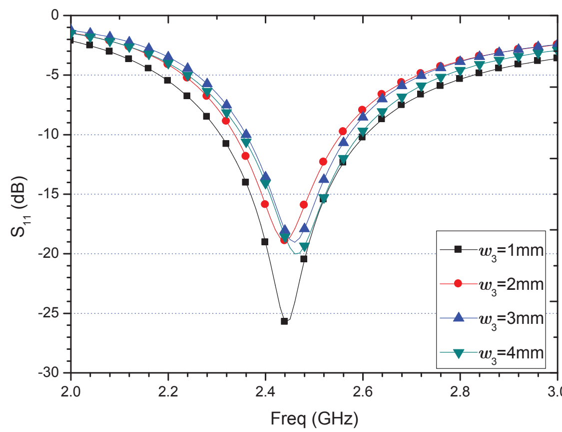


Fig. 5. Parametric analysis of w_3 at k=19 mm, w_1=1.5 mm, w_2=1 mm and p_1=1 mm.

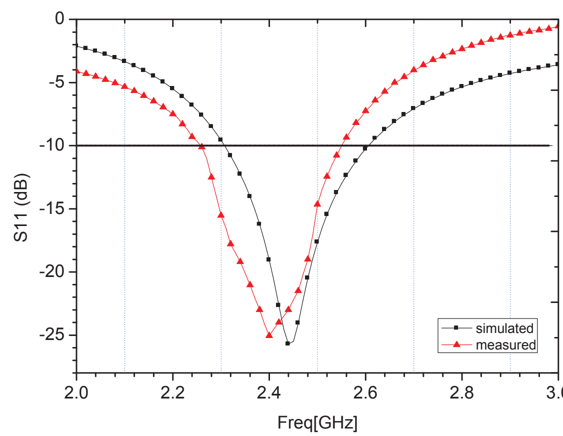


Fig. 7. Simulated and measured return loss of the proposed antenna.

Fig. 7 exhibits the simulated and measured return loss of the proposed antenna. Measured results show that although the resonant frequency shifts a little to become lower comparing with the simulated results, the bandwidth is still 280 MHz (2.27-2.55 GHz) with reference to -10 dB and is suitable for Bluetooth, WLAN and Wi-Fi applications.

B. Surface Current

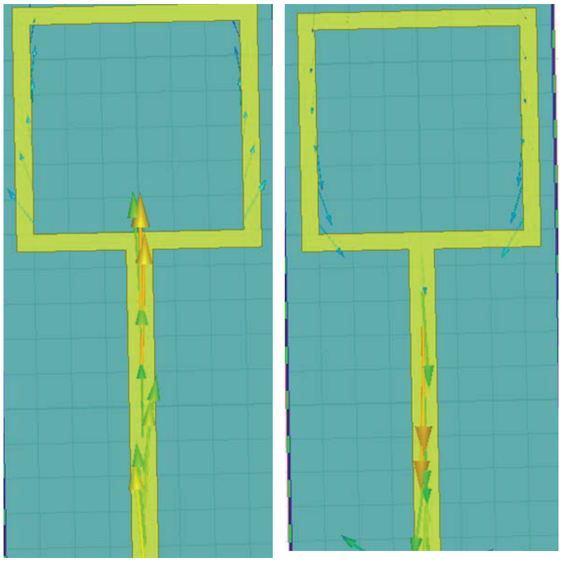
Besides, the orientation of polarization can be determined based on the rotation of surface current which is analyzed using the HFSS software. When the arrows of surface current are changed alternately, this means that the antenna is performed as linear polarized. Fig. 8 depicts the surface current of that changed alternately at 2.45 GHz, and this indicated that it is a linear polarized antenna.

C. Radiation pattern

Fig. 9 (a) and (b) show the simulated radiation pattern of xy-plane (H-plane) and yz-plane (E-plane) and simulated 3-D radiation pattern of proposed antenna at 2.45 GHz, respectively. From the results, we can see that the radiation pattern of proposed antenna has the characteristics that comply to omnidirectional pattern without cross-polarization above -40 dB. This is one of characteristic advantages of monopole antenna compared to the conventional microstrip antenna.

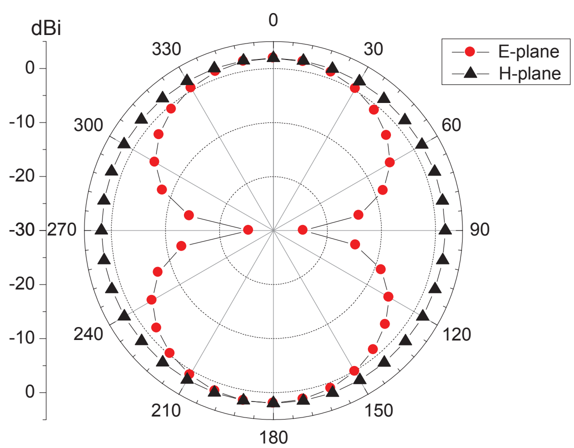
D. Prototype and an application scenario

Fig. 10 (a), (b) and (c) show a planar loop monopole antenna, a vehicle detector and an application scenario, respectively. Conventional vehicle detectors don't have a reader antenna and only have a trigger function–detecting variation of geomagnetic field intensity. Thus, there is not an on-board equipment (OBE, or a tag) in the car. The payment is made by manual method such as a user's or a toll collector's APP software. Based on conventional vehicle detectors, our vehicle detectors include a reader antenna and there is an on-board equipment (or a tag) in the car. The payment will be automatically made. In Fig 10(c), when one car arrived at a parking lot near the curb, the car will trigger a vehicle detector, where the reader antenna in a vehicle detector will

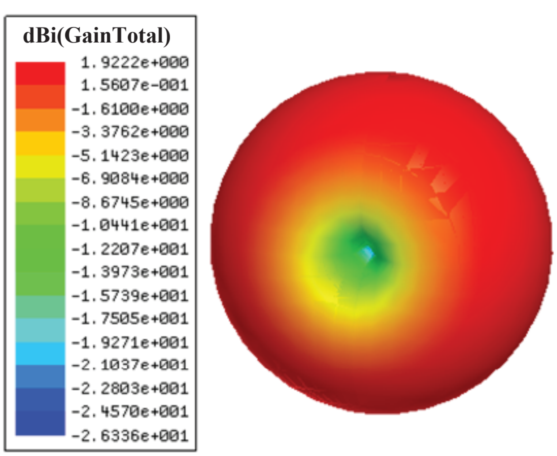


(a) (b)

Fig. 8. Surface current for the proposed antenna. (a) 0° (b) 180°.

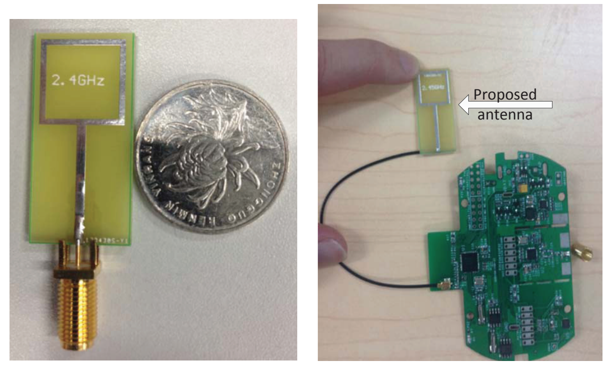


(a)



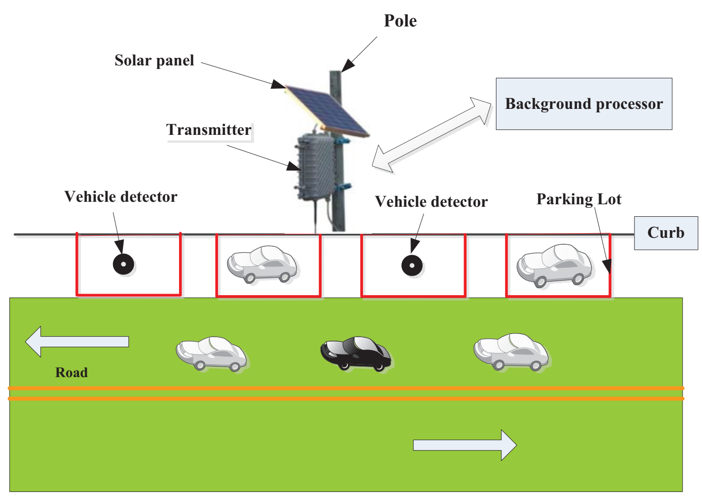
(b)

Fig. 9. (a)Simulated E- and H-plane radiation patterns and (b)Simulated 3-D radiation pattern of proposed antenna at 2.45 GHz.



(a) (b)

(c) (d)



(e)

Fig. 10. (a) A planar loop monopole antenna; (b) Vehicle detector (interior); (c) Vehicle detector (exterior); (d) OBE; (e) An application scenario.

send one signal to the tag in the car. Meanwhile, the reader antenna will communicate with the tag in the car and the related information will be sent to the transmitter near the road. Finally, the transmitter will send the related instruction to background processor, where the charge process is finished.

V. Conclusion

A RFID reader antenna with simple structure, wide bandwidth and radiation performance has been proposed. The monopole antenna with broadband effect from 2.27-2.55 GHz is also achieved in the design. The obtained bandwidth covers the band of Wi-Fi/WLAN/IEEE 802.11 2.4 GHz (2412-2484 MHz) and Bluetooth (2400-2484 MHz). All the features shown above are suitable for WLAN applications. Although there are some slight deviations between the measured results and simulated results in term of resonant frequency and working bandwidth, due to the different values of material properties used in the simulation and realization, i.e. relative permittivity and loss of dielectric substrate, in general the realized antenna has shown good agreements qualitatively with the simulation results. In conclusion, this type of antenna is suitable for many actual applications, especially for vehicle detection application.

ACKNOWLEDGEMENT

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