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A Miniaturized Compact Wideband Partial Ground Antenna Used in RFID Systems

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ABSTRACT

In this paper, a new compact waveguide-fed flexible antenna is presented for RFID applications. This antenna is operated at the resonant frequency of 2.45 GHz. The proposed antenna is designed with small size on (43 × 30) mm2 epoxy substrate material type (FR4) used in the proposed antenna that has a dielectric thickness of 1.6 mm, the relative permittivity of 4.3 and tangent loss of 0.025 where the FR4 dielectric combines good electrical features, price, and availability. The return loss is less than −10 dB in the frequency interval (2.1 − 2.98) GHz. The maximum gain of the proposed antenna is 2.47 dB. The proposed antenna has a wide impedance bandwidth, and an omnidirectional radiation pattern with a small size has been achieved. The overall size of the compact antenna are (43 × 30 × 1.67) mm3. The Computer Simulation Technology (CST) microwave studio software is used for simulation.

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تصميم هوائي مصغر ذو ارضي جزئي يستخدم في نظام الكشف باستخدام الترددات الراديوية

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الخلاصة

في هذه البحث، تم تقديم هوائي جديد كشريحة دقيقة مرنة يستعمل لتطبيقات تحديد هوية التردد الراديوي (RFID). يعمل هذا الهوائي بتردد رنين قدره 2.45 كيكاهرتز. تم تصميم الهوائي المقترح بحجم صغير على (43 × 30) ملم مربع ، نوع مادة الركيزة الاساس هي الإيبوكسي نوع (FR4) المستخدمة في الهوائي المقترح الذي يبلغ سُمك المادة العازلة 1.6 ملم ، والنفاذية النسبية 4.3 وخسارة الانحراف هي 0.025 حيث يمتلك العازل FR4 ميزات كهربائية جيدة وسعر جيد وتوافر جيد. وتكون خسارة الارتداد أقل من -10 ديسيبل في مدى التردد (2.1 – 2.98) كيكاهرتز. الربح الأقصى للهوائي المقترح هو 2.47 ديسيبل. يحتوي الهوائي المقترح على عرض نطاق واسع للمعاوقة وقد حقق نمط اشعاع متعدد الاتجاهات ويملك حجم صغير. الحجم الكلي للهوائي المضغوط (43 × 30 × 1.67) ملم مكعب. يتم استخدام الحقيبة البرمجية للتصميم والمحاكاة هي (CST).

الكلمات الدالة: الهوائي، الربح، خسائر الارتداد، تحديد هوية التردد الراديوي، النطاق الترددي العالي.

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1. INTRODUCTION

Radio Frequency Identification (RFID) is rapidly growing technology for automatic identification, and it is being exploited in many areas such as healthcare, airport, libraries, military, passport, supply chain, etc. [1]. The prodigious development in the field of RFID corresponding uses and applications has increased the requirement of smaller size and low-profile components that can be feasible for implementation in RFID systems. RFID technology has attracted high attention to achieve various commercial applications, such as automatic retail management, industrial and manufacturing, security, access control, transportation, distribution systems, and electronic toll collection [2]. A typical RFID system consists of an RFID tag and an RFID reader device. The reader's antenna sends a radio-frequency (RF) signal to the tag and receives an information signal from it [3].

The RFID bands are the high frequency (HF) band at 13.56 MHz, ultra-high frequency (UHF) band from 860 to 960 MHz, and Industrial, Scientific, and Medical (ISM) band at 2.4GHz [4, 5]. RFID applications in the UHF band use different frequency bands in different countries. The frequency bands used are as follows: (902 – 928) MHz in North America, (840.5 – 844.5) MHz and (920.5 – 924.5) MHz in China, (950 – 956) MHz in Japan, (866 – 869) MHz in Europe, (920 – 926) MHz in Australia, (865 – 867) MHz band in India, and (908.5 – 914) MHz in South Korea [6–8]. The (UHF) RFID full coverage band in each country is about (840 – 960) MHz.

In practical usage, the tag antennas usually are linearly polarized (LP), and the RFID tags are mostly oriented arbitrarily. A circularly polarized (CP) antenna is necessary for the RFID reader to ensure reliable communication between tags and reader [9]. Several limitations of using microstrip patch antennas exist such as narrow bandwidth, low gain, and low efficiency led to reduce antenna performance [10, 11].

Generally, the basic configuration of conventional microstrip antenna consists of a thin conducting patch that most made adequately of copper or gold printed on the one side of substrate whose dielectric constant typically in the range of $2.2 \leq \varepsilon_r \leq 12$, which mounted on a ground plane on the other side as shown in Fig. 1 [12, 13].

The microstrip antennas have been widely used in RFID systems because of their good characteristics such as; electrically thin, low profile, low cost, conformable, simple, and inexpensive to manufacture. The main disadvantages of microstrip patch antennas are narrow bandwidth, lesser gain, and poor efficiency, which disturbed the efficiency of this antenna. Many substrate types are available for use in the design of microstrip antenna such as Duroid 5880, RO 3003, RO 3010, and FR4. The FR4 is a very popular substrate for microstrip designs that have a dielectric constant of 4.3 with a tangent loss of 0.025[14]. Various researchers currently studied different shapes of antenna design for RFID readers by applying a varied approach of patch and ground geometry. Generally, in order to achieve a smaller size, good directivity, and wider bandwidth of RFID antenna systems are an important topic of most researches.

In [15], a new type of compact antenna made with a size of (30 × 30 × 1.6) mm^3 and narrow bandwidth with appreciate gain value. N. O. Parchin et al. [16] designed an antenna to cover 2.4/ 5.8 GHz RFID operation bands. An antenna structure is like a modified F-shaped radiator. The overall size of (38 × 45 × 1.6) mm^3 and good realized gain is achieved. M. Z. A. Abd Aziz et al. [17] presented the dual-band printed omnidirectional antenna to operate at 2.45 GHz. The substrate that has been used is FR4. Dimensions for the substrate material are (l5 × 85.75) mm^2 and dielectric thickness of 1.6 mm. The return loss of this antenna at 2.45GHz is -10.61dB, and the bandwidth is 122 MHz. The gain that has been achieved for this antenna is 3.798 dB. M. R. Reader [18] presented a compact microstrip stacked patch antenna proposed for a mobile operating at 2.45 GHz passive RFID reader. The antenna has dimensions of (58 × 58) mm^2 with a large thickness of 11mm and narrow bandwidth with a frequency range from 2.31 to 2.56 GHz, and the peak gain achieves 6.32 dB in the center frequency 2.45 GHz.

In this work, a microstrip antenna operates at resonating frequency of 2.45 GHz for the RFID band is presented. The proposed idea is different from general microstip antenna designs, where the proposed design combines the partial ground technique with omnidirectional radiation. Its size of 43 × 30 × 1.67 mm^3 achieves good impedance matching, suitable gain, wide bandwidth, good efficiency, and radiation patterns over the entire operating band. When comparing the performance of the proposed antenna with the other similar antennas, it is explicitly seen that the proposed antenna has a smaller size, a wide bandwidth with improved radiation pattern, and good efficiency. Detailed geometry Structure, design, and experimental results of this antenna are explained and discussed in the following sections.

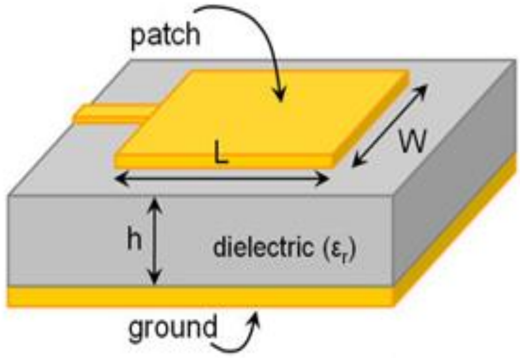

Fig.1. Microstrip antenna configuration

2. ANTENNA DESIGN

The basic idea designed in this paper for an omnidirectional pattern is achieved using a partial ground method. In this method, the return loss is as low as possible at a value of -33.2 dB at a resonant frequency of 2.45 GHz. To miniaturize the proposed antenna, the partial ground and slots are used. Before adding partial ground and slots, the resonance frequency occurred at 3.8 GHz when using the same dimensions of antenna that means the miniaturization in the proposed antenna is approximate to 64.5 %. The geometry of the proposed microstrip patch antenna with the partial ground is shown in Fig. 2. The slotted patch is printed on an FR4–epoxy substrate of thickness, h = 1.6 mm with relative permittivity,$\varepsilon_r = 4.3$, and loss tangent, $\tan\delta = 0.025$ [19]. The designed antenna operates at a frequency range of (2.1 – 2.98) GHz. With respect to the transmission line model, the dimensions of the general microstrip patch antenna have been obtained as follows [20]. The width of the antenna structure depends on the speed of light in free space (c), relative permittivity (ε_r)

and the resonance frequency (f_o) and it is calculated as below.

$$W=\frac{1}{2f_o\sqrt{\mu_o\varepsilon_o}}\sqrt{\frac{2}{\varepsilon_r+1}}=\frac{c}{2f_o}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad \dots(1)$$

Where $c=3\times10^{8}\,m/s$, $\mu_o=4\pi\times10^{-7}\,H/m$ and $\varepsilon_o=8.85\times10^{-12}\,F/m$

The effective permittivity for the patch (ε_{eff}) is calculated as

$$\varepsilon_{eff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+\frac{12h}{W}\right]^{-1/2} \qquad \dots.(2)$$

The length of the antenna increases due to the fringing effect as

$$\frac{\Delta L}{h}=0.412h\frac{\left(\varepsilon_{eff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{eff}-0.258\right)\left(\frac{W}{h}+0.8\right)} \qquad \dots(3)$$

ΔL is the patch length due to fringing

The effective length is calculated by

$$L_{eff}=\frac{1}{2f_o\sqrt{\varepsilon_{reff}}\sqrt{\mu_o\varepsilon_o}}=\frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \qquad \dots(4)$$

The actual length ($L_{act.}$) of the patch is calculated by

$$L_{act.}=L_{eff}-2\Delta L \qquad \dots..(5)$$

The ground plane dimensions, Width (W_g) and Length (L_g) is given by

$$W_{substrate}=W+6h \qquad \dots.(6)$$

$$L_{substrate}=L+6h \qquad \dots..(7)$$

By using the above equations, the dimensions of the antenna are achieved, as shown in Fig. 2.
The technical slots with different dimensions loaded into the patch with dimensions of the antenna are listed in Table 1.

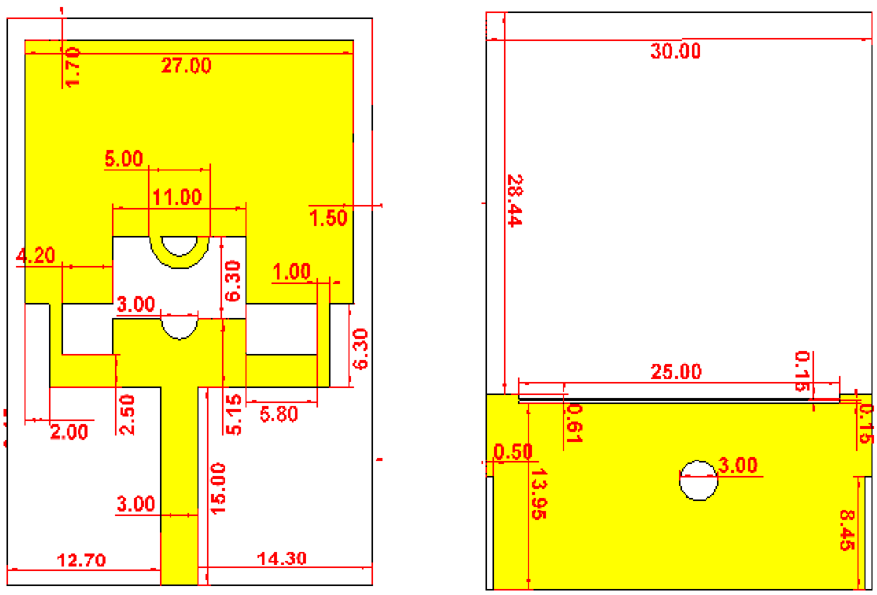

Fig. 2. The geometry of the patch and partial ground antenna

Table 1
Dimensions of the proposed antenna

<table>
<tr><th>Elements</th><th>Material type</th><th colspan="2">Dimensions in mm²</th><th>Thickness (mm)</th></tr>
<tr><td>Substrate</td><td>FR-4</td><td colspan="2">43 × 30</td><td>1.6</td></tr>
<tr><td rowspan="5">Ground plane</td><td rowspan="5">Copper</td><td colspan="2">14 × 30</td><td rowspan="5">0.035</td></tr>
<tr><td>Slots</td><td>Dimensions in mm²</td></tr>
<tr><td>Side slots</td><td>0.5 × 13.95</td></tr>
<tr><td>Circle slot</td><td>Radius = 3 mm</td></tr>
<tr><td>Two upper slots</td><td>0.15 × 25, 0.31 × 25</td></tr>
<tr><td>Patch</td><td>Copper</td><td colspan="2">26.3 × 27</td><td>0.035</td></tr>
<tr><td>Microstrip feed line</td><td>Copper</td><td colspan="2">15 × 3</td><td>0.035</td></tr>
</table>

3. SIMULATION RESULTS

Initially, Return loss or reflection coefficient $|S_{11}|$ calculation with respect to frequency is presented in Fig. 3. The simulated bandwidth evaluated at −10 dB is 878.6 MHz that is measured in the frequency range (2.104 – 2.9826) GHz.

Another critical parameter besides the return loss, which is related to the bandwidth and effects on the performance of the antenna, is Voltage Standing Wave Ratio (VSWR). Typically, $VSWR\le 2$. Therefore, the antenna can be able to operate at frequencies where the value of VSWR is below 2 [21]. The VSWR curve of the proposed antenna is shown in Fig. 4. As can be observed from Fig. 4, the minimum VSWR of the proposed antenna is 1.07 at 2.45 GHz that means the maximum power will be transferred at the operating frequency (2.45 GHz).

By adding slots in the patch and the ground plane, the input impedance is closely 50 Ω with a resonant frequency of 2.45 GHz. The exact value of the real value of impedance is 49.8 Ω, and the imaginary value of impedance approach to zero and equals 0.25 Ω. So, these slots give good antenna performance as well as suitable input impedance in the required band of frequencies. The simulated real and imaginary input impedance of the antenna is shown in Fig. 5 (a) and (b), respectively. In the resonant frequency (2.45 GHz), the input impedance of the proposed antenna is (49.5 + j0.25) Ω, which provides a good impedance matching between the transmission line and antenna.

As depicted from the realized gain curve of the designed antenna in Fig. 6, a good amount of gain 2.47 dB is obtained. Another major design parameter related to gain which is involved in the performance of the antenna is the directivity. Fig. 7 presents the radiation pattern of the designed antenna. Theoretically, the relation between the gain (G) and directivity (D) is related to antenna efficiency factor (η) as in Equation (8).

$$G = \eta D \quad \ldots\ldots\ldots \quad (8)$$

The antenna efficiency factor value is enclosed by (0 ≤ η ≤ 1). If η =1, i.e., for a lossless antenna. In practice, the gain is always less than the directivity D. As observed from Fig. 7, most incident power is radiated with less back lobe. Thus the maximum directivity obtained is 2.84 dB.

The summary of the simulation results for the proposed antenna is presented in Table 2.

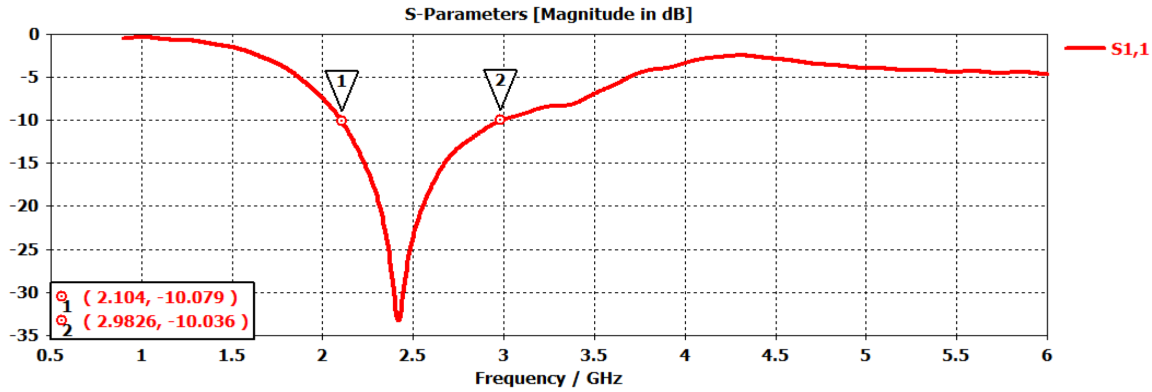

Fig. 3. Return loss versus frequency

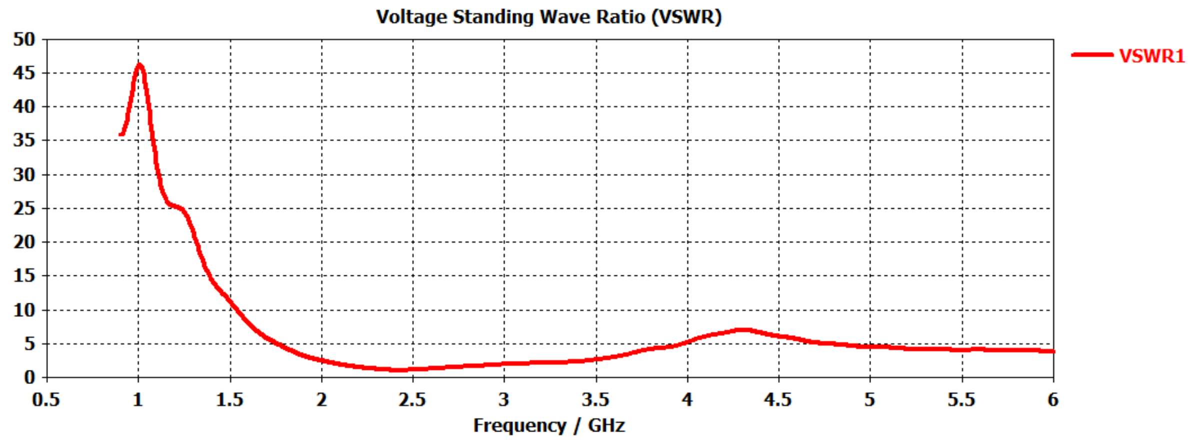

Fig.4. VSWR versus frequency

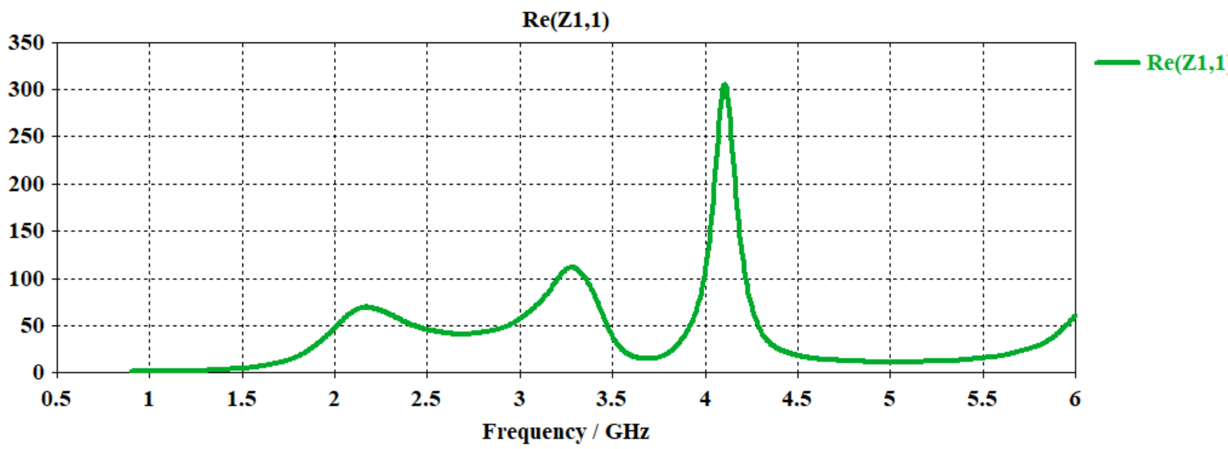

Fig.5. Simulation input resistance (a) real part

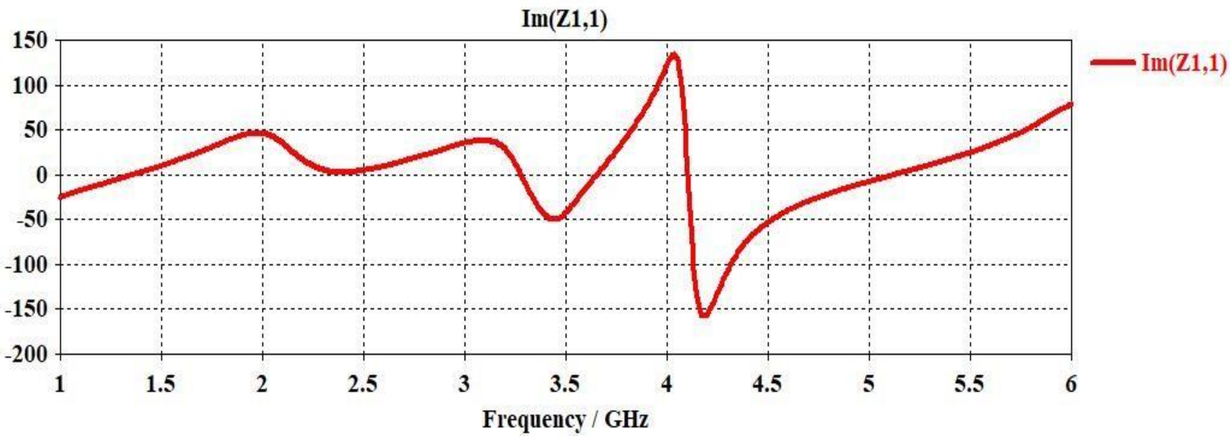

Fig.5. Simulation input resistance (b) imaginary part

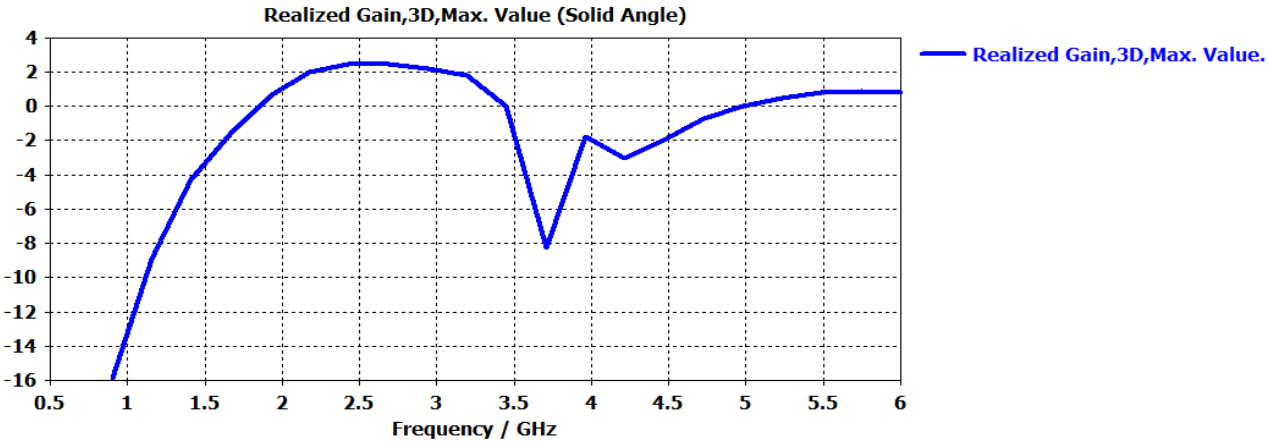

Fig.6. The response of the proposed antenna

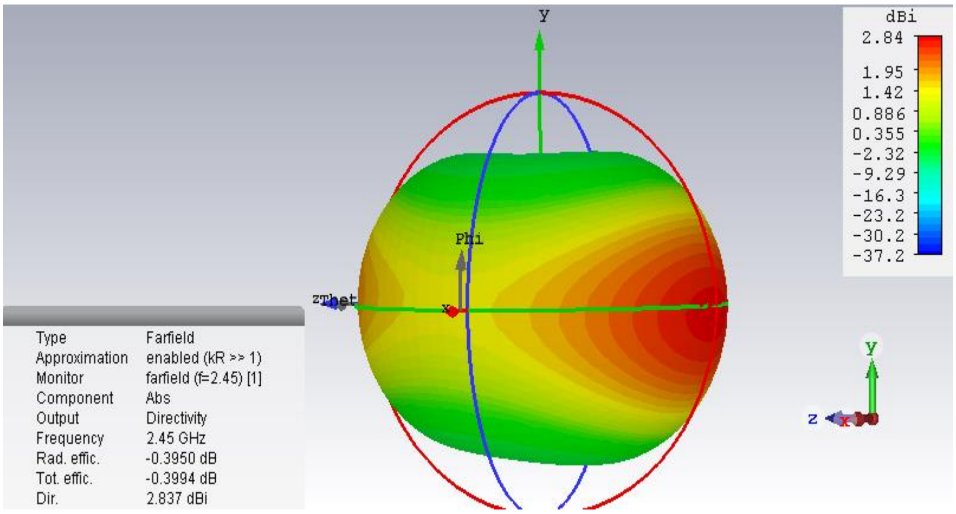

Fig.7. Radiation pattern with total antenna directivity

4. CONCLUSIONS

In this study, a wideband microstrip slot loaded patch antenna with a microstrip feed line has been presented. The proposed microstrip patch antenna operates in a wide range of frequencies (2.104 – 2.9826) GHz, which covers the RFID applications at 2.45 GHz. By using a partial ground method and adding slots in patch and ground plane that present good antenna performance as well as suitable input impedance in the required band of frequencies. The antenna performance has been improved where the critical parameters of the designed antenna offer wide bandwidth, less return loss, minimum VSWR, and high directivity with a suitable amount of gain. To miniaturize the proposed antenna, the partial ground and slots are used, and the miniaturization in the proposed antenna is arrived to 64.5 %. The gain value of 2.47dB and directivity equals 2.84 dB lead to get good efficiency of 86.9 %. Therefore, it's capable to operate in most countries according to their standards, where the RFID system requires a compact size, good agreement performance with wide bands and low cost.

Table 2
Summary results of simulated parameters

Antenna's parameters	Value
Frequency range	2.104 – 2.9826 GHz
Resonance frequency (f_o)	2.45 GHz
Bandwidth	878.6 MHz
Return loss at f_o	-33.2 dB
VSWR at f_o	1.07
Real impedance	49.8 Ω
Imaginary impedance	0.25 Ω
Directivity	2.84 dB
Gain	2.47 dB

REFERENCES

[1] Xavier F, Hikage OK, de Paula Pessôa MS, Fleury AL. A View about RFID Technology in Brazil. in *PICMET 2010 Technology Management for Global Economic Growth*. 2010; pp. 1–9.

[2] Finkenzeller K. RFID handbook: fundamentals and applications in contactless smart cards, radio frequency identification and near-field communication. 3rd ed. Munich, Germany: John Wiley & sons; 2010.

[3] Chen WS, Huang YC. A Novel CP Antenna for UHF RFID Handheld Reader. *IEEE Antennas Propag. Mag*. 2013; 55(4): 128-137.

[4] Lim JH, Kang BS, Jwa JW, Kim HS, Yang DY. RFID Reader Antenna with Hilbert Curve Fractal Structure over Partially Grounded Plane. *J. Korea Contents Assoc*. 2007; 7(4): 30-38.

[5] Jin Y, Tak J, Choi J. Quadruple Band-notched Trapezoid UWB Antenna with Reduced Gains in Notch Bands. *Journal of Electromagn. Eng. Sci.* 2016; 16(1): 35-43.

[6] Chen ZN, Qing X. Asymmetric-circular Shaped Slotted Microstrip Antennas for Circular Polarization and RFID Applications. *IEEE Trans. Antennas Propag*. 2010; 58(12): 3821-3828.

[7] Cao R, Yu SC. Wideband Compact CPW-fed Circularly Polarized Antenna for Universal UHF RFID Reader. *IEEE Trans. Antennas Propag.* 2015; 63(9): 4148-4151.

[8] Yoon JH, Ha SJ, Rhee YC. A Novel Monopole Antenna with Two Arc-shaped Strips for WLAN/WiMAX Application. *J. Electromagn. Eng. Sci.* 2015; 15(1): 6-13.

[9] Lai XZ, Xie ZM, Xie QQ, Cen XL. A Dual Circularly Polarized RFID Reader Antenna with Wideband Isolation. *IEEE Antennas Wirel. Propag. Lett.* 2013; 12: 1630-1633.

[10] Kaur G, Singla G, Kaur S. Design of Wideband Micro strip Patch Antenna Using Defected Ground Structure for Wireless Applications. *Int. J. Adv. Res. Comput. Sci. Softw. Eng.* 2013; 3(10): 762-765.

[11] Patel JM, Patel SK, Thakkar FN. Comparative Analysis of S-shaped Multiband Microstrip Patch Antenna. *Int. J. Adv. Res. Electr. Electron. Instrum. Eng.* 2013; 2(7): 3273-3280.

[12] Sandeep BS, Kashyap SS. Design and Simulation of Microstrip Patch Array Antenna for Wireless Communications at 2.4 GHz. *Int. J. Sci. Eng. Res*. 2012; 3(11): 1-5.

[13] Ali SA, Rafique U, Ahmad U, Khan M. Multiband Microstrip Patch Antenna for Microwave Applications. *IOSR J. Electron. Commun. Eng.* 2012; 3(5): 43-48.

[14] Fang DG. Antenna Theory and Microstrip Antenna. 1st ed. United States of America: Taylor and Francis Group; 2010.

[15] Gautam AK, Agrawal N, Rambabu K. Design and Packaging of a Compact Circularly Polarised Planar Antenna for 2 . 45-GHz RFID Mobile Readers. 2019; 13(13): 2310-2314.

[16] Ojaroud Parchin N, et al. Dual-band Monopole Antenna for RFID Applications. *Futur. Internet.* 2019; 11 (2).

[17] Aziz MZA, et al. Printed Omnidirectional Antenna for RFID Applications. *IEEE Int. Conf. RFID-Technologies Appl. RFID-TA.* 2013, Sept. 4–5; Malaysia.

[18] Wu T, et al. A Compact and Broadband Microstrip Stacked Patch Antenna With Circular Polarization for 2.45-GHz Mobile RFID Reader. *IEEE Antennas and Wireless Propagation Letters* 2013; 12: 623-626.

[19] Kamil YEMA and Salh MK. Modified Sierpinski Gasket Patch Antenna for UMTS and 2.4/5.2 WLAN. *Tikrit Journal of Engineering Sciences*, 2013; 20(1): 42-50.

[20] Balanis CA. Antenna Theory Analysis and Design. 4th ed. United States of America: John Wiley & Sons; 2016.

[21] Niboriya BS, Choudhary C, Prabhakar G. S-shape Wideband Microstrip Patch Antenna with Enhanced Gain and Bandwidth for Wireless Communication. *Int. J. Comput. Appl.* 2013; 73(7): 975-8887.