A Novel Miniature Four-Band CPW-Fed Antenna Optimized Using ISPO Algorithm

Huihui Li[1], Xuanqin Mou[1], Zhen Ji[2,*], Hang Yu[2], Yan Li[2], and Lai Jiang[2]

[1] School of Electronics and Information Engineering,
Xi'an Jiaotong University, Xi'an 710049, China
[2] College of Computer Science and Software Engineering, Shenzhen University,
Shenzhen 518060, China, Shenzhen Key Laboratory of Embedded System Design,
Shenzhen, China
lihuihui80@gmail.com, xqmou@mail.xjtu.edu.cn,
{jizhen,liyan,yuhang}@szu.edu.cn

Abstract. A novel four-band CPW-fed antenna simultaneously satisfied the requirement for Radio Frequency Identification (RFID) tag and WiMAX /WLAN applications is reported in this paper. Limited to 30×30 mm^2 area on a PCBoard with ε_r=4.4, the antenna has four U-shaped, two F-shaped and eight L-shaped slots as additional resonators to achieve multi-band operation. Intelligent Single Particle Optimization (ISPO) algorithm is used to determine the optimized slot configuration for the best return loss at 0.96 GHz, 2.5 GHz, 3.76 GHz and 5.8 GHz simultaneously. The performance of the designed antenna was validated through simulations using both the Finite Element Method and the Method of Moment.

Keywords: RFID, Four-band Antenna, Optimization, ISPO.

1 Introduction

Wireless communication applications such as Radio Frequency Identification (RFID) [1], Worldwide Interoperability for Microwave Access (WiMAX), and Wireless Local Area Network (WLAN) technologies are widely used nowadays. However, these applications operate at various frequency bands. For example, 0.86-0.96 GHz, 2.45 GHz and 5.8 GHz bands are allocated to RFID related applications, 2.5/3.5/5.5 GHz bands are allocated for WiMAX application, and 2.4/5.2/5.8 GHz bands are allocated for WLAN applications [2]. Recently, the need for multi-band antenna has gained attention since it is more desirable for a single system to support multiple application standards simultaneously. However, most of the reported multi-band antennas, such as [3], [4] and [5], can either only operate at two frequency bands, or require relatively large areas. To the authors' best knowledge, few antenna design covers the frequency bands of RFID/WiMAX/WLAN applications.

* The corresponding author is Prof. Zhen Ji. The authors would like to thank the NSFC under grant No. 60901016, the project 10151806001000016 supported by Guangdong R/D Fund, the project JC201005280477A supported by Shenzhen city and the SRF for ROCS, SEM.

P. Ren et al. (Eds.): WICON 2011, LNICST 98, pp. 576–581, 2012.

In this paper, we report a miniature four-band CPW-fed antenna for 0.96/2.5/3.76/5.8 GHz applications. Limited to 30×30 mm^2 area on a PCBoard with ε_r=4.4, the antenna geometric configuration was optimized by Intelligent Single Particle Optimization (ISPO) algorithm [6]. The return loss and the radiation patterns of the finalized design are verified by Finite Element Method (FEM) and Method of Moment (MOM) simulations.

This paper is organized as follows. In Section 2, the design methodology of proposed antenna is described in detail. Simulation results including the return loss, radiation patterns and gains of the proposed antenna are shown in Section 3. The paper is concluded in Section 4.

2 Design Methodology

The antenna is implemented on a low-cost FR-4 substrate with dielectric constant ε_r=4.4, loss tangent tanδ=0.02 and thickness h=1.6 mm (Fig.1). A 50 Ω CPW transmission line is used for the antenna feed. The width of the feeding line is fixed as S=2.6 mm, and the gap between the feeding line and the ground plane is G=0.2 mm. In order to achieve multiband resonance, the antenna has four U-shaped, eight L-shaped and two F-shaped slots. The slots, including the eight symmetric L-, two symmetric F- and the two larger U-shaped branches (9×4 mm^2) are introduced to increase the antenna electrical length at the two lower frequency bands (0.96 GHz and 2.5 GHz), and the two smaller U-shaped branches (5×1.5 mm^2) are utilized as refiners to slightly adjust the antenna frequency response [7].

In order to optimize the antenna input impedance within the targeted frequency bands simultaneously, the geometric configurations of the slots are determined using the ISPO algorithm. The ISPO method is based on an analogy with models of the social behavior of groups of simple individuals, and it is a method specialized for solving complicated multidimensional problems. Detailed discussion of the ISPO algorithm can be found in [6].

Previous work [8] has used Particle Swarm Optimization (PSO) to design a multi-band CPW-fed monopole antenna. In this work, the ISPO algorithm is utilized for antenna optimization. The ISPO is a method specialized for solving complicated multimodal problems [6]. Using this algorithm, the complete position vector is partitioned into sub-vectors with smaller number of dimensions, and the sub-vectors are updated repeatedly in sequence. Based on the information generated during the updating process, the velocity vector required for updating the position vector is adjusted intelligently. For instance, the velocity of the particle will be increased if the fitness value is improved; the velocity will be slowed down when the particle skips over the optimum; when the fitness value is not improved after several iterations in the sub-vector updating process, the particle will increase the diversity of velocity in order to escape from the local optimum. Detailed discussion of the ISPO algorithm can be found in [6].

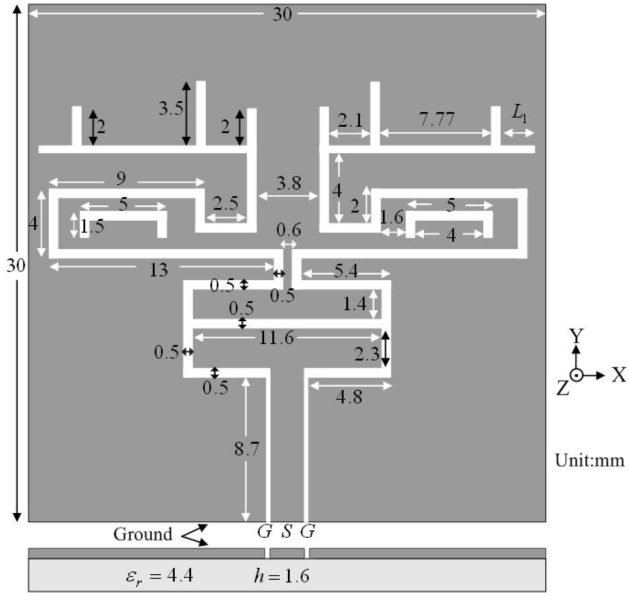

Fig. 1. Geometry of proposed four-band antenna

The target of the optimization process is set to achieve better-than- -10dB impedance matching at 0.96 GHz, 2.5 GHz, 3.76GHz and 5.8 GHz at the same time. For this purpose, totally nine physical dimensions (including L_1) of the antenna are defined as variables, which form the position vector described in the algorithm. To enhance the performance at 2.5 GHz, the weight right [9] of return loss at 2.5 GHz is a little larger than that at the other frequencies in the fitness function. The physical parameters of the finalized antenna are summarized in Fig.1. When L_1 equals to 1 mm, the antenna achieves the targeted frequency response.

3 Simulation Results

The ISPO-optimized multi-band antenna is verified using the FEM and MOM. As shown in Fig.2, the simulated return loss are -15.07 dB, -16.27 dB, -10.25 dB and -12.23 dB at the targeted frequency bands, all better than the design target. The bandwidth of the finalized antenna, which is defined as the frequency range within which the antenna achieves better than -10dB matching (VSWR$\leq$2), is 10 MHz at the 0.96 GHz band, 70 MHz at the 2.5 GHz band, 20 MHz at the 3.76 GHz band, and 480 MHz at the 5.8 GHz band. Calculated results obtained by two simulators are in a good agreement.

The radiation patterns of the antenna are also characterized, as shown in Fig.3 and Fig.4. It appears that the antenna radiates nearly omni-directionally in the xz plane, but the radiation patterns at all four bands show two nulls in the yz plane at $\theta=\pm90^{o}$. Note that the antenna has relatively strong cross-polarized radiation (~20dB below the co-polarized radiation at upper frequencies and ~10dB below the co-polarized radiation at lower frequency), which is advantageous for RFID applications since the tag-reader orientation is not strictly limited. The antenna gain (Fig.5) obtained by MOM is -19.8 dBi, -2.55 dBi, 0.93 dBi and 4.03 dBi at the targeted frequency bands, respectively.

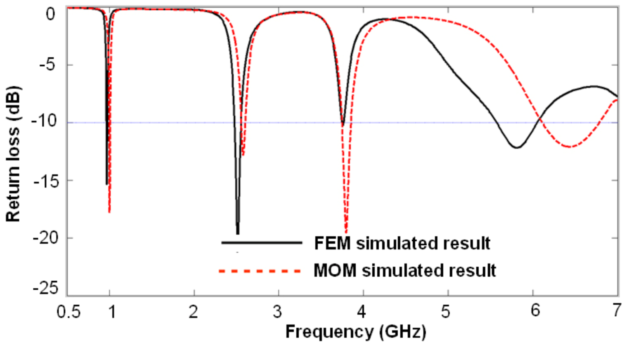

Fig. 2. Return loss of proposed four-band antenna obtained by FEM and MOM

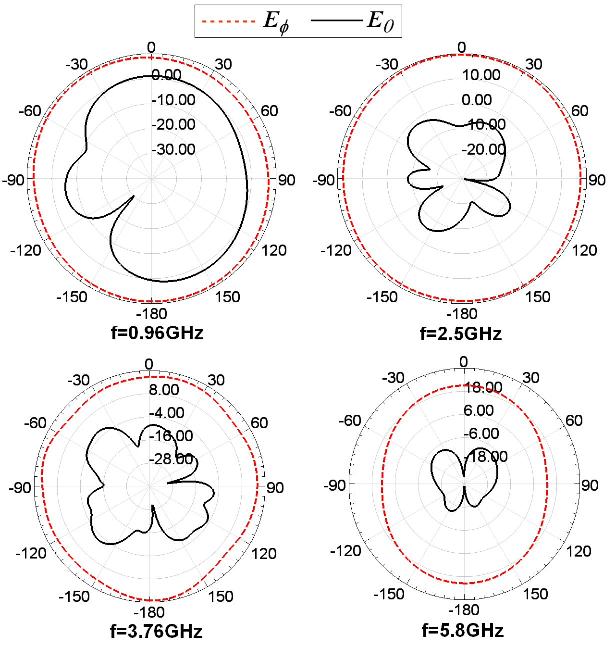

Fig. 3. Radiation patterns of proposed antenna in xz plane obtained by FEM

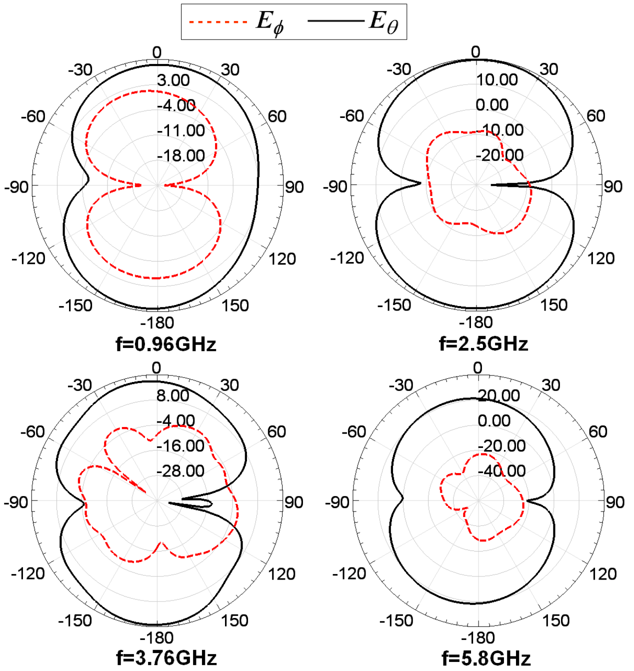

Fig. 4. Radiation patterns of proposed antenna in yz plane obtained by FEM

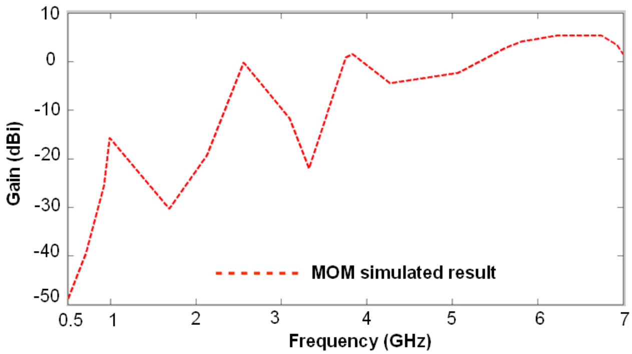

Fig. 5. Gain of proposed antenna obtained by MOM

4 Conclusion

A novel four-band antenna designed for RFID and WiMAX /WLAN applications is reported in the paper. Limited on a substrate of 30×30 mm^2 with ε_r=4.4, the antenna is resonated to multiple frequency bands by introducing four U-shaped, two F-shaped and eight L-shaped branches as additional resonators. To achieve impedance matching at 0.96 GHz, 2.5 GHz, 3.76GHz and 5.8 GHz simultaneously, the ISPO algorithm is utilized to help determine the slot geometric configurations. The performance of the ISPO-optimized antenna is characterized using the FEM method and the MOM method, and the simulation results show that the return loss within all the targeted frequency bands is better than -10dB.

Acknowledgments. The authors would like to thank the National Natural Science Foundation of China (NSFC) under grant numbers 60872125 and 60901016, Fok Ying-Tung Education Foundation, Guangdong Natural Science Foundation, Shenzhen City Foundation for Distinguished Young Scientists, SRF for ROCS, SEM and SZU R/D Fund.

References

1. Finkenzeller, K.: RFID Handbook: Fundamentals and Application in Contactless Smart Cards and Identification, 2nd edn. Wiley and Sons Inc., UK (2003)
2. Krishna, D.D., Gopikrishna, M., Aanandan, C.K.: A CPW-fed Triple Band Monopole Antenna for WiMAX/WLAN Applications. In: 38th European Microwave Conference, Amsterdam, The Netherlands, pp. 897–900 (2008)
3. You, B., Lin, B., Zhou, J., Xu, W.: Dual-frequency folded dipole antenna with PBG structure. Electronics Letters 45(12), 584–588 (2009)
4. Hu, S.M., Zhou, Y., Law, C.L., Dou, W.B.: Study of a Uniplanar Monopole Antenna for Passive Chipless UWB-RFID Localization System. IEEE Trans. Antennas and Propag. 58(2), 271–278 (2010)
5. Abu, M., Rahim, M.K.A., Suaidi, M.K., Ibrahim, I.M., Zhang, F.H.: A Meandered Triple-band Printed Dipole Antenna for RFID. In: Asia Pacific Microwave Conference, Singapore, pp. 1958–1961 (2009)
6. Ji, Z., Liao, H.L., Wang, Y.W., Wu, Q.H.: A Novel Intelligent Particle Optimizer for Global Optimization of Multimodel Functions. In: IEEE Congress on Evolutionary Computation, Singapore, pp. 3272–3275 (2007)
7. Wong, K.L.: Compact and Broadband Microstrip antennas. John Wiley and Sons Inc., New York (2002)
8. Liu, W.C.: Design of a Multiband CPW-fed Monopole Antenna Using a Particle Swarm Optimization Approach. IEEE Trans. Antennas and Propag. 53(10), 3273–3279 (2005)
9. Li, H.H., Mou, X.Q., Ji, Z., Yu, H., Li, Y., Jiang, L.: Miniature RFID Tri-band CPW-fed Antenna Optimised using ISPO Algorithm. Electronics Letters 47(3), 161–162 (2011)