A Compact Printed Monopole Antenna for Dual-band RFID and WLAN Applications

Jyoti Ranjan PANDA, Aditya Sri Ram SALADI, Rakhesh Singh KSHETRIMAYUM

Dept. of Electronics and Electrical Engineering, IIT Guwahati, Assam, India

j.panda@iitg.ernet.in, aditya.s.ram@gmail.com, krs@iitg.ernet.in

Abstract. *Design of a simple and compact microstrip-fed printed monopole antenna (PMA) for applications in wireless local area network (WLAN) and radio frequency identification (RFID) is presented. The dual-band operation is achieved from the 9-shaped folded antenna which is printed on a non-conductor backed dielectric. Measured percentage impedance bandwidth of the PMA at the center frequencies of 2.43 GHz and 5.24 GHz are 33.13 (2.14 GHz to 2.99 GHz) and 36.43 (4.40 GHz to 6.36 GHz) respectively. Consistent omnidirectional radiation patterns have been observed in both the frequency bands from the experimental results. The proposed antenna is simple in design and compact in size. It exhibits broadband impedance matching, consistent omnidirectional radiation patterns and appropriate gain characteristics (>2.5 dBi) in the RFID and WLAN frequency regions.*

Keywords

9-shaped monopole antenna, RFID, WLAN.

1. Introduction

Compact printed monopole antennas are indispensable candidates for applications in WLAN, UWB and RFID. Along with the small size, the antenna should preferably be low cost, light weight, less fragile and low profile. Besides, the fabrication methodology should be simple. Many compact printed monopole antennas are reported in the literature for wireless applications. Notable structures among them are: CPW-fed dual frequency monopole antenna [1], dual band CPW-fed strip-sleeve monopole antenna [2], CPW fed L-shaped slot planar monopole antenna for triple band operation [3], internal planar monopole antenna for mobile phones [4], dual-band planar branched monopole antenna [5], etc. Similarly, many compact printed antennas for RFID application at 5800 MHz are available in the literature such as CPW-fed folded slot [6], T-shaped folded slot monopole antenna [7], F-shaped CPW-fed monopole antenna [8], CPW-fed dual folded strip [9], semi circular CPW fed folded slot antenna [10], CPW-fed U-shaped folded slot monopole antenna [11], etc. In [12], a dual band monopole antenna with stagger-tuned arm was proposed, where the antenna resonates at 2.45 GHz and 5.8 GHz, which was solely meant for the application in WLAN domain. Our intention here is to design a compact monopole antenna, which can be used simultaneously for WLAN as well as RFID systems.

In this paper, a new compact, 9-shaped and dual-band printed monopole antenna is presented for RFID and WLAN. This antenna simultaneously resonates at 2.51 GHz and 5.18 GHz, which are the operating frequency bands for RFID and WLAN systems respectively. It allows us to use a single antenna for both the RFID and WLAN systems. The antenna is constructed on a non-conductor backed dielectric. 9-shaped strip is printed on one side of it, which is fed by a microstrip line. The dual-band performance can be easily obtained for this type of antenna by fine-tuning the lengths of the 9-shaped strip.

2. Antenna Design

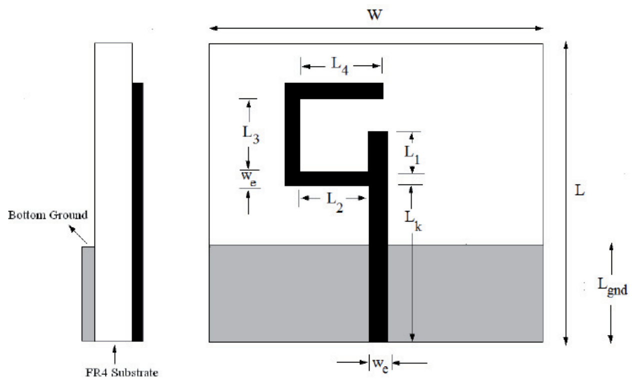

Fig. 1. Geometry of the proposed antenna.

Fig. 1 shows the geometry of the proposed 9-shaped printed monopole antenna for RFID and WLAN applications. The shape of the radiating element of the proposed monopole antenna looks like an English number "Nine". That's why the name of the proposed antenna is "9-shaped antenna". The 9-shaped monopole antenna is printed on a FR4 substrate of relative permittivity 4.4 and thickness 1.6 mm as shown in Fig. 1. A 50-Ohm microstrip line is used for the excitation. The strip width of the 9-shaped monopole antenna is 3.06 mm, same as that of the width of the microstrip feed line. The proposed antenna has 9-

shaped resonating element which is responsible for the two resonances around 2.51 GHz and 5.18 GHz respectively. The proposed 9-shaped monopole antenna was simulated by using the IE3D full wave simulator [13].

For a printed monopole antenna, the resonant frequency can be approximately calculated by equating its area (in this case a folded 9-shaped printed monopole) to that of an equivalent cylindrical monopole antenna[14] of equivalent height L_c and equivalent radius r_c as follows:

$$f_1 = \left(\frac{7.2}{L_c + r_c + p} \right) \text{GHz} \tag{1}$$

where

$$L_c = \{L_2 + L_3 + L_4 + 2w_e\}, \tag{2}$$

$$r_c = \frac{w_e\{L_1 + L_2 + L_3 + L_4 + 4w_e\}}{2\pi\{L_2 + L_3 + L_4 + 2w_e\}}, \tag{3}$$

$$p = (L_k - L_{gnd}). \tag{4}$$

The first resonance frequency f_1 of the printed monopole antenna is chosen to be of 2.45 GHz. The second resonant frequency f_2 is a multiple of the first resonant frequency. Without the element of length L_1, the radiating element is found to be giving the second resonant frequency at 5 GHz, whereas by including this L_1 in the radiating element, the second resonant frequency is obtained at 5.18 GHz. Thus this small length L_1 is shifting the second resonant frequency from 5 GHz to 5.18 GHz. By properly varying the dimensions of the antenna, we can fix the antenna resonance at 2.51 GHz and 5.18 GHz respectively. The overall adjustments of the geometrical parameters are done for the improvement of impedance bandwidth in the 2.45 GHz and 5.2 GHz band. The final optimized dimensions of the antenna through EM simulations are L_1=1 mm, L_2 = 5.4 mm, L_3 = 10 mm, L_4 = 7 mm, w_e = 3.06 mm, L_k = 14 mm and L_{gnd} = 12 mm. The dimensions (WxL) of the substrate are 30 mm and 38 mm respectively.

3. Results and Discussion

Fig. 2 shows the photograph of the fabricated prototype of the proposed 9-shaped monopole antenna for 2.45 GHz (WLAN) and 5.2 GHz (RFID) applications. Fig. 3 shows the comparison of the simulated return loss ($|S_{11}|$) and the measured return loss. The return loss measurement was done using the Rohde and Schwarz ZVA24 vector network analyzer. From the graph, it is quite clear that there is reasonably good agreement between the measured and the simulated return losses. The first simulated resonance frequency (f_1) occurs at 2.54 GHz at the return loss value of -15.02 dB with the percentage bandwidth of 29.35 (2.18 GHz to 2.93 GHz). The second simulated resonance frequency (f_2) occurs at 5.13 GHz at the return loss value of -24.87 dB with the percentage bandwidth of 34.20 (4.46 GHz to 6.30 GHz). Similarly the first resonance (f_1) occurs at 2.46 GHz having a measured return loss value of -24.57 dB with percentage bandwidth of 15.56 (2.31 GHz to 2.70 GHz) and the second resonance (f_2) occurs at 5.22 GHz having a measured return loss value of -14.08 dB with percentage bandwidth of 42.27 (4.03 GHz to 6.19 GHz). The summary of simulated and measured return loss values are tabulated in Tab. 1 shown below. Hence, from the experimental results, it is clear that the fabricated prototype antenna can be used for the dual band RFID (2.45 GHz) and WLAN (5.2 GHz) applications.

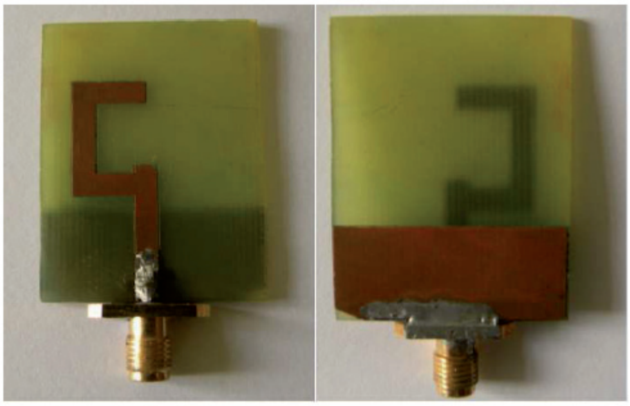

Fig. 2. Fabricated prototype of the 9-shaped monopole antenna for RFID and WLAN application. (a) Top View. (b) Bottom View.

	f_1 [GHz]	f_2 [GHz]	Return loss value (dB at f_1, dB at f_2)	% Bandwidth at f_1	% Bandwidth at f_2
Simulation	2.54	5.13	(-15.02, -24.87)	29.35 (2.18 to2.93 GHz)	34.20 (4.46 to 6.30 GHz)
Measured	2.46	5.22	(-24.57, -14.08)	15.56 (2.31 to 2.70 GHz)	42.27 (4.03 to 6.19 GHz)

Tab.1. Comparison of measured and simulated return loss and percentage bandwidth in the tabular form.

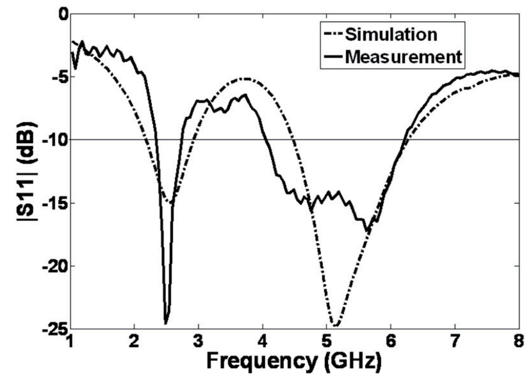

Fig. 3. Comparison of the simulated and measured return loss ($|S_{11}|$) of the proposed 9-shaped monopole antenna for RFID and WLAN application.

The gain is observed to increase smoothly with the frequency. The gain at 2.51 GHz is 2.76 dBi and the gain at 5.2 GHz is 3.29 dBi. The proposed antenna provides appropriate gain characteristics required for the operation in the RFID and WLAN frequency bands.

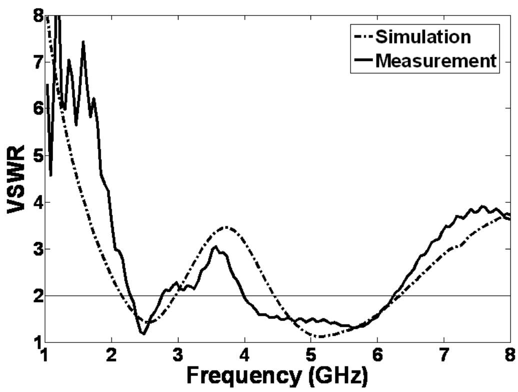

Fig. 4. Comparison of the simulated and measured VSWR of the proposed 9-shaped monopole antenna for RFID and WLAN application.

The measured normalized co-polarized and cross-polarized E-plane and H-plane radiation patterns of the 9-shaped monopole antenna at 2.45 GHz and 5.2 GHz are shown in Fig. 5 and Fig. 6 respectively. It can be observed that the co-polar E-plane radiation pattern is of the shape of "8" at 2.45 GHz and 5.2 GHz. At 2.45 GHz, the E-plane cross-polar radiation pattern is in between -10 and -20 dB. At 5.2 GHz the shape of the co-polar E-plane radiation pattern is slightly distorted in the bottom right hand side portion. The co-polar H-plane radiation pattern on the other hand is purely omni-directional at the two frequencies i.e. at 2.45 GHz and 5.2 GHz. Unlike at 2.45 GHz, the H-plane cross-polar radiation pattern is approximately at around -10 dB or more precisely the H-plane cross polarization level is in between -10 and -20 dB at 5.2 GHz. Hence, this 9-shaped monopole antenna demonstrates a consistent radiation pattern in the desired band of frequencies.

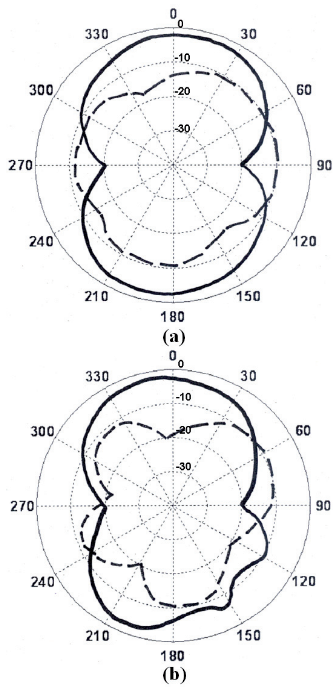

Fig. 5. Measured E-plane (Co-pol(solid line) and Cross pol(dotted line)) radiation patterns at (a) 2.45 GHz and (b) 5.2 GHz.

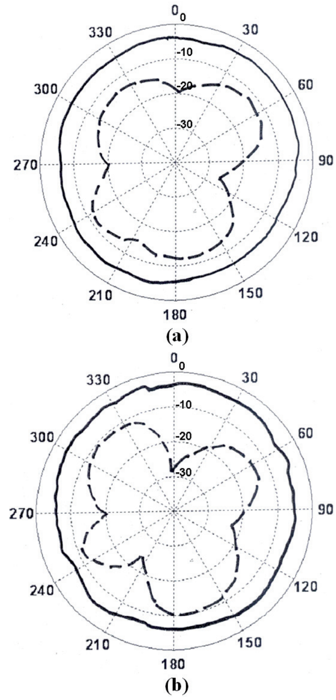

Fig. 6. Measured H-plane (Co-pol(solid line) and Cross pol(dotted line)) radiation patterns at (a) 2.45 GHz and (b) 5.2 GHz.

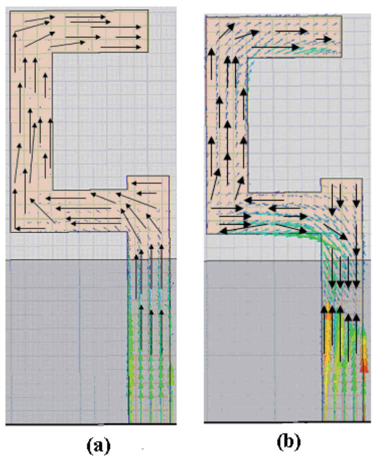

Fig. 7. Surface current distribution (A/m) of the proposed 9-shaped monopole antenna (a) at 2.45 GHz and (b) at 5.2 GHz.

At 2.45 GHz, the direction of current is forward moving nature on the L_4 element and L_3 element. In other words the current in L_4 element is moving in right side direction. More clearly, in the L_3 element, the current is moving upward and in the L_2 element, the current is moving left side direction. Hence in the element L_2 and L_4, the current is moving in opposite direction. At the corner junction of element L_3 and width w_e, the current is moving in the same direction and a current addition situation arises which is shown in Fig 7(a). Similarly at 5.2 GHz, the current in the L_1 element is moving downward. But in the L_c element, the movement and direction of current are very much peculiar to watch. At the top of the L_c element, the current is moving forward, but at the left hand corner i.e. at the width w_e, the current is reflected backward and creating a opposition to the upward moving current in L_k element along with the reflected current from the L_1 element. Hence at L_k element, the current from both the direction met each other and a cancellation situation arises which is depicted in Fig 7(b). In Fig. 7 the black arrows are the overall direction of the current in the entire 9-shaped radiating element. As known, the electromagnetic coupling effect controlled the two excited resonant frequencies at 2.45 GHz and 5.2 GHz between the (L_c+L_k) element and (L_1+L_k) element.

4. Conclusion

A compact 9-shaped printed monopole antenna for RFID and WLAN operations has been presented. Satisfactory dual-band operation for WLAN and RFID applications is easily achieved by the 9-shaped configuration. The proposed antenna is simple to design and compact in size. It provides broadband impedance matching, consistent radiation patterns and appropriate gain characteristics in the RFID and WLAN frequency range. Hence the proposed antenna may be a suitable candidate for the dual-band operation in RFID and WLAN applications.

Acknowledgements

The authors would like to thank U. K. Sarma & D. Goswami of IIT Guwahati, G. Hemanth & Hemalatha IISc Bangalore for their assistance in the fabrication and measurement of the proposed antenna. 3rd author is grateful to Dr. K. J. Vinoy for allowing the 1st author to use the Anechoic chamber radiation pattern measurement facilities at the Microwave Laboratory, IISc Bangalore. Authors are also very grateful to anonymous expert reviewers for pointing out discrepancies in some of the results.

References

[1] CHEN, H. D., CHEN, H. T. A CPW-fed dual-frequency monopole antenna. *IEEE Trans. Antennas Propagat.*, 2004, vol. 52, no. 4, p. 978-982.

[2] CHENG, C. H., LV, W. J., CHEN, Y., ZHU, H. B. A dual-band strip-sleeve monopole antenna fed by CPW. *Microwave Opt. Technol. Lett.*, 2004, vol. 42, no.1, p. 70-73.

[3] LIU, W. C., HUANG, C. C. A CPW-fed L-shaped slot planar monopole antenna for triple-band operations. *Microwave Opt. Technol. Lett.*, 2005, vol. 44, no. 6, p. 510-512.

[4] SHEN, C. A., LIN, K. H. A broadband internal planar monopole antenna for mobile phone. *Microwave Opt. Technol. Lett.*, 2006, vol. 48, no. 4, p. 768-769.

[5] SUMA, M. N., RAJ, R. K., JOSEPH, M., BYBI, P. C., MOHANAN, P. Compact dual band planar branched monopole antenna for DCS/2.4- GHz WLAN applications. *IEEE Microw. Wireless Comp. Lett.*, 2006, vol. 16, no. 5, p. 275-277.

[6] CHEN, S. Y., HSU, P. CPW-fed folded-slot antenna for 5.8 GHz RFID tags. *Electron. Lett.*, 2004, vol. 40, no. 24, p. 1516-1517.

[7] LIU, W. C., HU, P. K. Broadband CPW-fed folded-slot monopole antenna for RFID application. *Electron. Lett.*, 2005, vol. 41, no. 17, pp. 937-939.

[8] LIU, W. C., WU, C. M. CPW-fed shorted F-shaped monopole antenna for 5.8-GHz RFID applications. *Microwave Opt. Technol. Lett.*, 2006, vol. 48, no. 3, p. 573-575.

[9] LIU, W. C., KAO, P. C. Compact CPW-fed dual folded-strip monopole antenna for 5.8-GHz RFID application. *Microwave Opt. Technol. Lett* , 2006, vol. 48, no. 8, p. 1614-1615.

[10] MA, D., ZHANG, W. X. Broadband CPW-fed RFID antenna at 5.8 GHz. *Electron. Lett.*, 2006, vol. 42, no. 22, p. 1258-1259.

[11] LIU, W. C. A coplanar waveguide-fed folded-slot monopole antenna for 5.8 GHz radio frequency identification application. *Microwave Opt. Technol. Lett* , 2007, vol. 49, no. 1, p. 71-74.

[12] AMMANN, J. C., FARRELL, R. Dual-band monopole antenna with stagger-tuned arms for broadbanding. In *IEEE International Workshop on Antenna Technology: Small Antennas and Novel Metamaterials (IWAT-2005)*. 2005, p. 278-281.

[13] IE3D version 10.2, Zeland Corp., Freemont, CA, USA.

[14] KUMAR, G., RAY, K. P. *Broadband Microstrip Antennas.* Artech House 2003, p. 362-363.

About Authors

Jyoti Ranjan PANDA received the B.Tech degree in Electrical Engineering from the College of Engineering and Technology, Bhubaneswar in 1999, M. E. degree in Communication Engineering from BITS, Pilani, Rajasthan in 2001. He is currently pursuing Ph.D in Dept. of Electronics and Electrical Engineering (EEE) in IIT Guwahati. His current research interest is in planar antennas for wireless, UWB and RFID systems.

Aditya Sri Ram SALADI received the B.E. degree in Electronics and Communication Engineering from Andhra University, Visakhapatnam in 2008, and M.Tech. degree from the Dept. of EEE, IIT Guwahati in 2010. Since 2010, he is an Assistant Professor at the School of Electronics Engineering, Vellore Inst. of Technology University, Vellore. His research interests include Broadband, Multiband and UWB Antennas.

Rakhesh Singh KSHETRIMAYUM received the BTech degree in Electrical Engineering from the IIT Bombay, India in 2000 and Ph.D. degree from the School of Electrical and Electronic Engineering, NTU Singapore in 2005. During 2000-5, he worked as a Software Engineer at the MphasiS Architecting Value, Pune, India, Teaching Assistant in the NTU Singapore, Research Associate at the IISc Bangalore, India, Postdoctoral Scholar at the PSU, University Park, USA. Since 2005, he is a faculty member with the IIT Guwahati and presently he is an Associate Professor. His research interests are in microwaves, antennas and electromagnetics. He has published 75 journal and conference papers. He has been involved in the organization of 60 international conferences. He serves in the editorial /review board of 10 international journals. He is the recipient of State Merit Scholarship, NTU Singapore PhD Research Scholarship, Dept. of Science and Technology Young Scientist Award under Fastrack Scheme.