Dual-Band Dipole Antenna for Sensing Applications in ISM Bands

Guy Ayissi Eyebe, Hatem El-Matbouly, Frédéric Domingue
Laboratoire de Microsystèmes et de Télécommunications
Université du Québec à Trois-Rivières
Trois-Rivières, Canada
guy.ayissi.eyebe@uqtr.ca, hatem.el.matbouly@uqtr.ca, frederic.domingue@uqtr.ca

***Abstract*—This paper presents a dipole antenna with dual-band operation designed for sensing applications in ISM bands. The proposed antenna has the advantages of being low profile, low cost, easy to fabricate with a flexible design based on the microstrip antennas. A prototype has been fabricated and tested. The measured results show good gain performance and omnidirectional radiation patterns for all the resonant modes. The proposed structure is suitable for integration with any wireless sensors in the ISM bands.**

Keywords : antenna; dual-band; ISM; wireless; sensors.

I. INTRODUCTION

The exponential growth of wireless communications technology has increased the need for highly integrated RF modules operating in multiple frequency bands. This expansion has been driving the development of dual-band and multiband antennas, in order to integrate numerous frequency bands within the same RF module. Some dual-band or multiband antennas performances reported recently allow achieving wireless applications taking advantage of the free license ISM bands. This includes radiofrequency identification (RFID), wireless local area network (WLAN), wireless sensor network (WSN), and sensing [1-4].

Multiband operation involving 434 MHz, 915 MHz, 2.45 GHz and 5.8 GHz ISM bands has been significantly investigated. The performances reported include dual-band antennas with only one resonant mode inside the ISM bands, and dual-band antennas with the two resonant modes inside the ISM bands. For dual-band antennas with the two ISM resonant modes, most of them operate at 915 MHz – 2.45 GHz, or 2.45 GHz – 5.8 GHz. As single or dual resonant mode, the 434 MHz band has been involved recently in medical applications and passive acoustic sensor, which represents an emerging technology for gas sensors [5]. But amongst the frequency bands listed above, 434 MHz resonant mode is not involved enough in dual-band operation with another ISM resonant mode. Yet, this mode together with the 915 MHz resonant mode can avoid the use of two distinct antennas [6, 7], integrate the UHF RFID function [8] and take advantage of the free license bands for these two functions and others. Dual-band antennas operating in 434 MHz – 915 MHz bands have been proposed in [1] and [2]. The antenna presented [1] consists of a metal plate of 335 mm x 155 mm x 1mm acting as RFID tag antenna while the antenna presented in [2] is a double loop patch antenna ensuring a bidirectional communication between sensors in a wireless sensors network. These antennas are not suitable for sensing applications since the RFID tag proposed in [1] suffers from non-compact configuration and metallic structure, while the double loop antenna proposed in [2] needs a matching network to operate properly.

This paper presents a dual-band dipole antenna with the two resonant modes at 434 MHz and 915 MHz within the ISM bands. The proposed antenna operates in the two free of charge ISM bands to improve sensing possibilities with the same device, and use the sensing application together with another function such as UHF RFID. This antenna has a compact configuration in regards to the resonant modes involved and is very suitable for integration with all the sensors bonded within any package. The proposed antenna structure has the advantages of having high gain with omnidirectional radiation patterns, adjustable design structure and low fabrication cost.

II. ANTENNA DESIGN

Figure 1 presents the picture of the proposed dual-band dipole antenna, fabricated on RO4300 Rogers laminated substrate. The parameters of the substrate are shown in Table I.

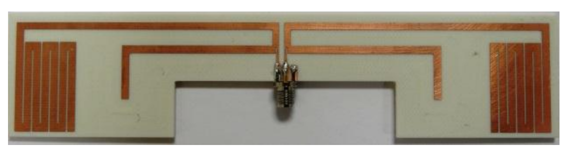


Figure 1. Photograph of antenna

TABLE I

PARAMETERS OF ROGERS RO4300 LAMINATED SUBSTRATE

Parameters	Values
Dielectric constant (ε_r)	3.55
Dissipation factor (tanδ)	0.0027
Dielectric thickness	1.524 mm
Upper layer cooper foil thickness	17 µm

 ISBN: 978-1-61208-297-4

As depicted in Figure 1, each half of the proposed dipole antenna has two arms, in order to achieve ISM dual-band operation.

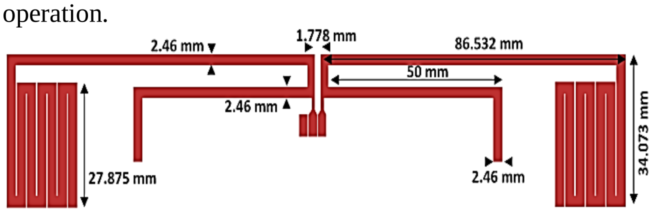


Figure 2. Layout of the proposed dual-band antenna

Given the fact that resonant frequency is inversely proportional to the arm's length, the shorter arm ensures the 915 MHz band operation, whereas the long arm ensures the 434 MHz operation. To achieve a compact configuration, the short arm has been folded down and the long arm has been meandered, so that the antenna is 17.34 x 3.4 x 1.541 (cm). These dimensions have been obtained while taking into consideration the trade-off between the performances of the antenna such as matching levels for each resonant mode, and the compactness of the antenna. Figure 2 shows the layout of dual-band dipole printed antenna with dimensions, designed for matching to a 50 Ω feed line.

III. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 3 shows the simulated and measured S_{11} parameters performed on the prototype shown in Figure 1.

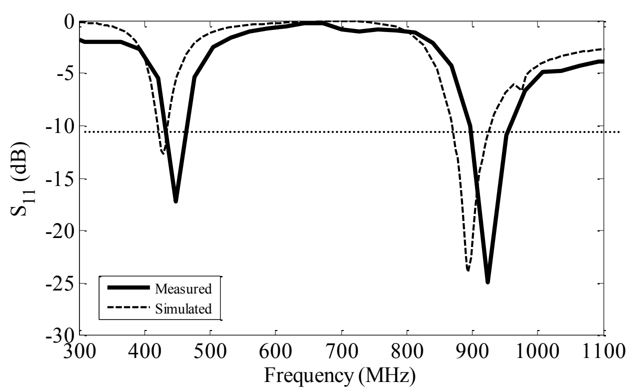


Figure 3. Simulated and measured return loss of the fabricated antenna

The results show a good agreement between simulated and measured results. There are only two distinct resonant modes in the frequency band (300 MHz - 1.1 GHz), the low-band resonant mode is at 448 MHz, and the high-band resonant mode is at 924.3 MHz. The measured return loss is less than -10 dB for (423 – 470 MHz) and for (896 – 956 MHz) bands, which covers the whole ISM bands. To evaluate the far-field behavior of the antenna, radiation patterns have been measured. The radiation patterns have been carried out with the antenna orientated as shown in Figure 4 in regards to the Cartesian axes (x, y, z). Figure 5 and Figure 6 show the cuts of the radiation patterns made in x-z plane, y-z plane and x-y plane at 433.3 MHz for the lower band and 916.6 MHz for the higher band, respectively.

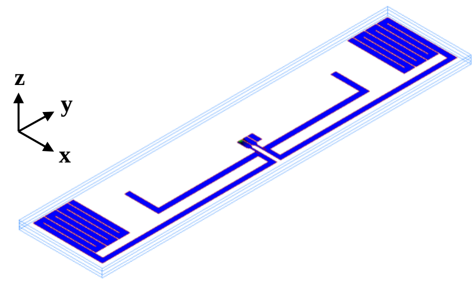
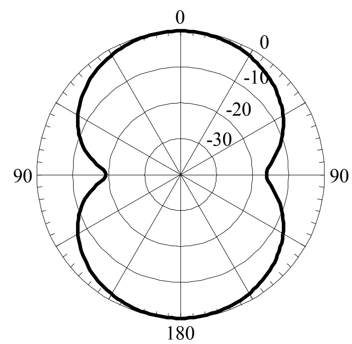
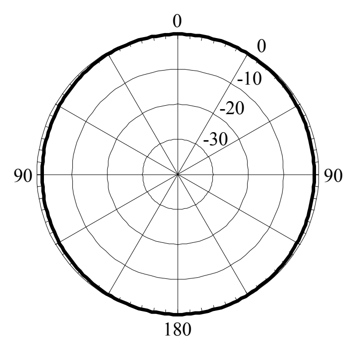


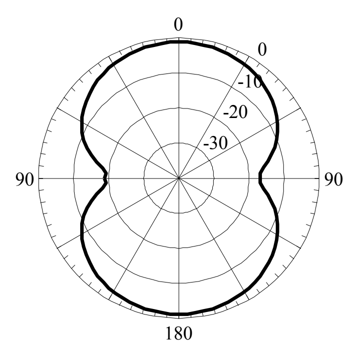
Figure 4. Orientation of antenna in regards to the cartesian axes



(a)

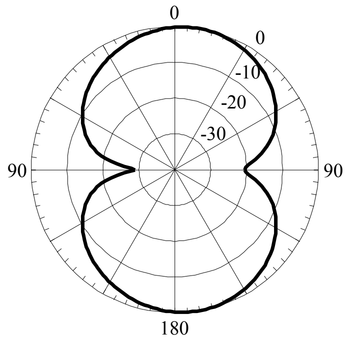


(b)

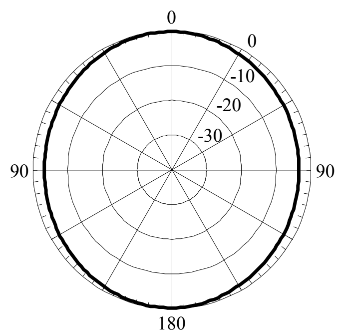


(c)

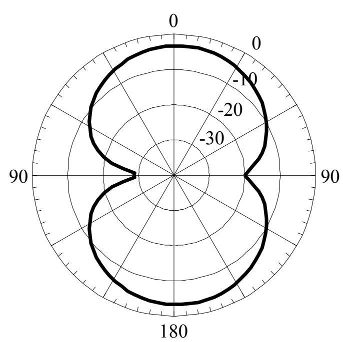
Figure 5. Measured radiation patterns of the proposed antenna at 433.3 MHz (a) x-z plane at 433.3 MHz, (b) y-z plane at 433.3 MHz and (c) x-z plane at 433.3 MHz



(a)



(b)



(c)

Figure 6. Measured radiation patterns of the proposed antenna at 916.6 MHz (a) x-z plane at 916.6 MHz, (b) y-z plane at 916.6 MHz and (c) x-z plane at 916.6 MHz

Figure 5 and Figure 6 show omnidirectional radiation patterns as expected with a dipole antenna. The simulated gain across the 434 MHz ISM band is shown in Figure 7 whereas the simulated gain across the 915 MHz band is shown in Figure 8. The proposed antenna exhibits 1.8 dBi of peak gain across the lower band and 2.07 dBi of peak gain across the higher band.

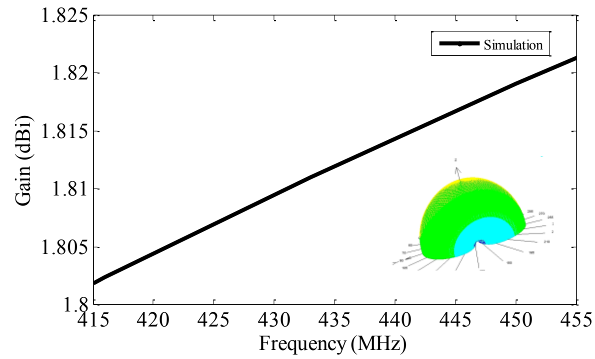


Figure 7. Measure peak antenna gain across the 434 MHz band

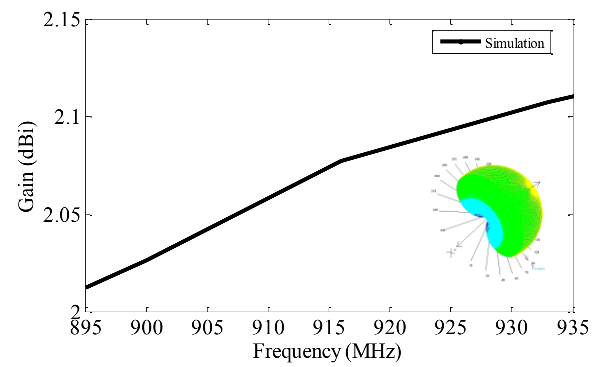


Figure 8. Measure peak antenna gain across the 915 MHz band

Table II summarizes the performances of the antenna for each resonant mode, including simulated peak gain, simulated directivity and simulated efficiency.

TABLE II

SUMMARY OF THE PERFORMANCE OF THE DIPOLE ANTENNA AT 433.3 MHZ AND 916.6 MHZ

Parameter	@433.3 MHz	@916.6 MHz
Gain (dBi)	1.8099	2.0724
Directivity (dBi)	1.9441	2.3719
Efficiency (%)	96.959	93.337

A comparison has been made between the present work and some previous references presenting 434 – 915 MHz dual operation. The results are shown in Table III.

TABLE III

COMPARISON OF PERFORMANCES REPORTED FOR DUAL-BAND OPERATION AT 434 MHZ AND 915 MHZ

Réf.	Types	Dimensions (cm)	Applications
[1]	Metal plate	55.3 x 15.5 x 1	UHF RFID
[2]	Double loop	8 x 3.2 x 0.16	WSN
This work	Dipole	17.3 x 3.4 x 0.15	Sensing UHF RFID

From this comparison, this work proposed a compact configuration in regards to the dimensions of the metal plate antenna reported in [1]. Moreover, the metallic structure is very limited to implement sensing applications and compromises the integration of the antenna proposed in [1] together with a sensor inside the same device. The antenna proposed in [2] is a patch antenna like the one proposed in this paper. It can be easily integrated with any sensor bonded within a package that can be welded on PCB. The antenna reported in [2] has a compact design compared to the antenna proposed in this work but is devoted to bidirectional communication inside a WSN. Thus, it needs a matching network to operate properly, which is an additional constraint in the context of achieving sensing applications with passive devices. The antenna proposed in this work does not need any matching network and can be directly connected to the sensor on a printed circuit board to achieve wireless applications. Like the antenna reported in [1], the proposed antenna can used the 915 MHz band to achieve UHF RFID applications.

IV. CONCLUSION

Dual-band operation with a novel dipole patch antenna has been investigated and a prototype to operate in the 434 and 915 MHz ISM bands has been constructed. The results with the fabricated prototype show good gain and omnidirectional radiation patterns in all the two frequency bands. The antenna is compact in regards to the resonant modes and suitable for sensing applications. The proposed antenna can take advantage of these two ISM bands to improve sensing possibilities with the same device and use the sensing application together with another application such as UHF RFID.

ACKNOWLEDGMENT

This research is partially supported by the Natural Sciences and Engineering Research Council of Canada (NSERC). The authors would also thank the Centre collégial de transfert de technnologie en telecommunications (C2T3) for their support.

REFERENCES

[1] P. Dea-Hwan and M. Kyeong-Sik, "Design for license plate RFID tag antenna with dual resonance to improve identification ratio," in Antennas and Propagation (EuCAP), 2010 Proceedings of the Fourth European Conference on, ed, 2010, pp. 1-4.

[2] S. Genovesi, S. Saponara and A. Monorchio, "Parametric Design of Compact Dual-Frequency Antennas for Wireless Sensor Networks," in Antennas and Propagation, IEEE Transactions on vol. 59, ed, 2011, pp. 2619-2627.

[3] D. Ahbe, S. Beer, T. Zwick, W. Yang and M. M. Tentzeris, "Dual-Band Antennas for Frequency-Doubler-Based Wireless Strain Sensing," in Antennas and Wireless Propagation Letters, IEEE vol. 11, ed, 2012, pp. 216-219.

[4] Z. Zhijun, M. F. Iskander, J. C. Langer and J. Mathews, "Wideband dipole antenna for WLAN," in Antennas and Propagation Society International Symposium, 2004. IEEE vol. 2, ed, 2004, pp. 1963-1966 Vol.2.

[5] I. Kerroum, H. El Matbouly and F. Domingue, "Survey of commercial sensors and emerging miniaturized technologies for safety applications in hydrogen vehicles," in Sensors Applications Symposium (SAS), 2012 IEEE, ed: IEEE, 2012, pp. 1-6.

[6] F. Iacopetti, S. Saponara and L. Fanucci, "Improving Power Efficiency and Reliability in RF Tire Pressure Monitoring Modules," in Electronics, Circuits and Systems, 2007. ICECS 2007. 14th IEEE International Conference on, ed, 2007, pp. 878-881.

[7] D.-S. Lee, Y.-H. Liu and C.-R. Lin, "A Wireless Sensor Enabled by Wireless Power," in Sensors vol. 12, ed, 2012, pp. 16116-16143.

[8] J. M. Boccard and L. M. Reindl, "Printed loop and ceramic antenna for wireless interrogation of SAW resonators on a clamp system," in Systems, Signals and Devices (SSD), 2012 9th International Multi-Conference on, ed, 2012, pp. 1-5.

 ISBN: 978-1-61208-297-4