

## Extremely Low-Profile Circular Patch-Ring Antenna with A Shorting Via for Impedance Matching Improvement

Zhang, Shuai; Syrytsin, Igor A.; Sørensen, Morten; Pedersen, Gert F.

*Published in:*

2017 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC)

*DOI (link to publication from Publisher):*

[10.1109/APWC.2017.8062285](https://doi.org/10.1109/APWC.2017.8062285)

*Publication date:*

2017

*Document Version*

Accepted author manuscript, peer reviewed version

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*

Zhang, S., Syrytsin, I. A., Sørensen, M., & Pedersen, G. F. (2017). Extremely Low-Profile Circular Patch-Ring Antenna with A Shorting Via for Impedance Matching Improvement. In *2017 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC)* (pp. 221 - 224). IEEE (Institute of Electrical and Electronics Engineers). <https://doi.org/10.1109/APWC.2017.8062285>

### General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

### Take down policy

If you believe that this document breaches copyright please contact us at [vbn@aub.aau.dk](mailto:vbn@aub.aau.dk) providing details, and we will remove access to the work immediately and investigate your claim.



# Extremely Low-Profile Circular Patch-Ring Antenna with A Shorting Via for Impedance Matching Improvement

Shuai Zhang<sup>1,2</sup>, Igor Syrytsin<sup>1</sup>, Morten Sørensen<sup>1,2</sup>, Gert Frølund Pedersen<sup>1</sup>

**Abstract**—An extremely low-profile circular patch-ring antenna with omnidirectional radiation patterns is proposed in this paper. By simply introducing a shorting via, the impedance matching of the antenna is improved, where both  $TM_{31}$  mode and  $TM_{32}$  mode are excited efficiently to realize a dual resonance behavior. The designed antenna covers the Wi-Fi band of 2.4–2.48 GHz with the realized gain of over 1.5 dBi and the thickness of  $0.005 \lambda$  ( $\lambda$  is the wavelength of the lowest operating frequency in free space). Since the antenna is not sensitive to size of ground plane, it is suitable to be mounted on different metallic platforms.

## 1 INTRODUCTION

Recently, there is higher and higher demand for low-profile antennas with omnidirectional radiation patterns. These antennas can be widely utilized on the large metallic platforms of aircrafts, unmanned vehicles, wind turbine blade deflection sensing systems with carbon coating [1] [2], and so on. In these applications, antennas are required to be extremely low-profile in order to reduce air dragging due to aerodynamics. Furthermore, nowadays, lots of electrical or electronic devices, e.g. loud speakers and TV, are designed to have full metallic bodies. It raises challenges for Wi-Fi or Bluetooth antennas to radiate signals out of the metallic covers. An extremely low-profile antenna with omni-directional radiation is one of the good choices, which can be integrated on the external metal surface with painting to make the antenna as “invisible” as possible.

Circular Patch-ring antenna has been proposed in [3] with the antenna thickness of  $0.029 \lambda$  ( $\lambda$  is the wavelength of the lowest operating frequency in free space). By introducing an annual ring, dual resonances of  $TM_{01}$  mode and  $TM_{02}$  mode have been excited simultaneously. To further broaden the impedance bandwidth of the antenna, two annular rings have been applied in [4] and triple resonance behavior has been achieved with the antenna thickness of  $0.027 \lambda$ . Another way of exciting both  $TM_{01}$  mode and  $TM_{02}$  mode has been given in [5] by shorting a circular patch antenna concentrically with a set of  $N$  conductive vias. By combining the method in [3] and [5], triple resonances have also been realized in [6] with the antenna thickness of  $0.016 \lambda$ . In [7],  $TM_{41}$  mode has been utilized to design an ultra-wideband antenna with the profile of  $0.07 \lambda$ . However, it is very challenging to efficiently excite the dual or triple modes simultaneously with the methods in [3]–[7] if the thickness of the antennas further decreases (e.g. to  $0.005 \lambda$ ).

In this paper, a circular patch-ring antenna with extremely low profile and omnidirectional radiation patterns is proposed.  $TM_{31}$  mode and  $TM_{32}$  mode are excited efficiently to realize a dual-resonance behavior by adding a shorting via. By tuning the distance between the shorting via and feeding, the impedance matching of dual resonances are significantly improved. The designed antenna covers the band of 2.4–2.5 GHz with the thickness of  $0.005 \lambda$ . The antenna could be mounted on different metallic platforms with the antenna performance nearly unchanged.

## 2 ANTENNA PERFORMANCE ANALYSIS

The configuration of the proposed circular patch-ring antenna with centrally fed is shown in Figure 1. In order to keep the antenna compact, the antenna is printed on a Rogers RO 3010 substrate with the thickness of 0.635 mm ( $0.005 \lambda$ ), the permittivity of 10.2, and the loss tangent of 0.0022. The proposed circular patch-ring antenna is similar to that in [3].

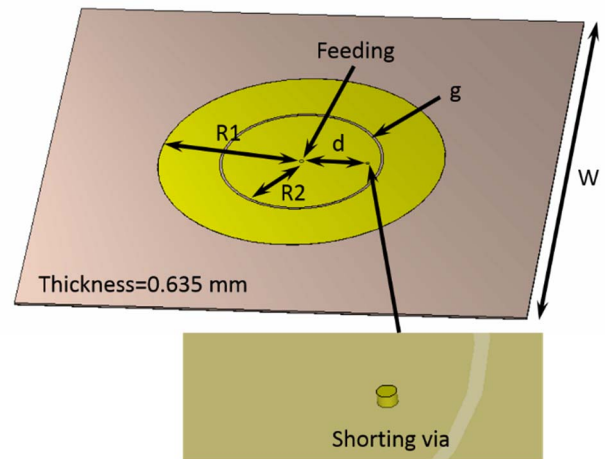


Figure 1. Antenna configurations.

Different from [3], one shorting via is introduced. By tuning the distance between the feeding and shorting via, both  $TM_{31}$  mode and  $TM_{32}$  mode can be efficiently excited with an extremely low antenna profile. The detailed dimensions of the antenna are listed in the following:  $R1 = 42.25$  mm,  $R2 = 23.42$  mm,  $d = 19.5$  mm, and  $g = 0.76$  mm.

<sup>1</sup> Department of Electronic Systems, Aalborg University, Aalborg, Denmark, e-mail: (sz@es.aau.dk, igs@es.aau.dk, gfp@es.aau.dk).

<sup>2</sup> Bang & Olufsen, Denamrk e-mail: mse@bang-olufsen.dk

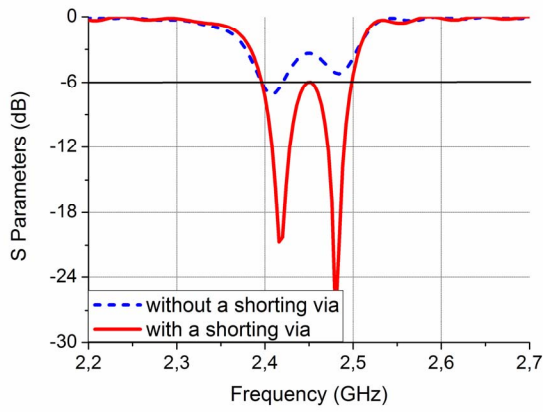
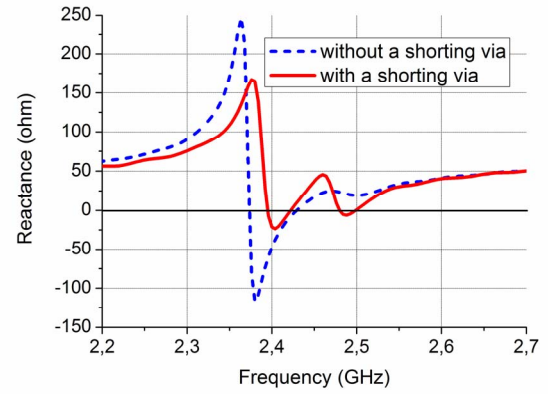


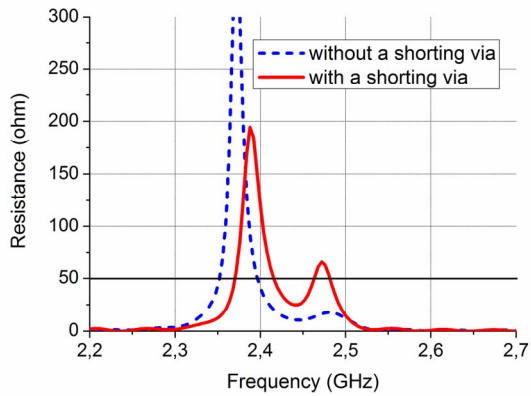
Figure 2. S parameters of the low-profile circular patch ring antenna with or without a shorting via.

In Figure 2, the S parameters of the low-profile circular patch ring antenna with or without a shorting via are shown. It can be clearly observed that the shorting via improves the impedance matching of the antenna significantly. The resonances at around 2.42 GHz and 2.48 GHz are  $TM_{01}$  mode and  $TM_{02}$  mode without a shorting via, respectively. With a shorting via, the resonances at around 2.42 GHz and 2.48 GHz have been changed to  $TM_{31}$  mode and  $TM_{32}$  mode. In addition, to better understand the mechanism, resistance and reactance of the designed antenna can be obtained in Figure 3 (a) and Figure 3 (b). The short via affects both the real and imaginary parts of the impedance.

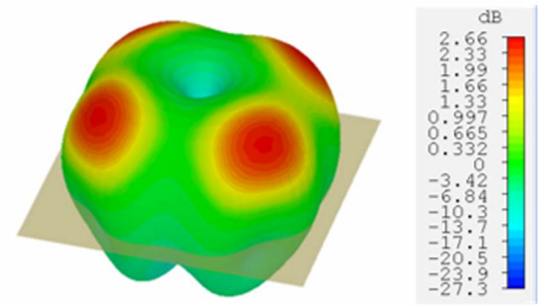


(b)

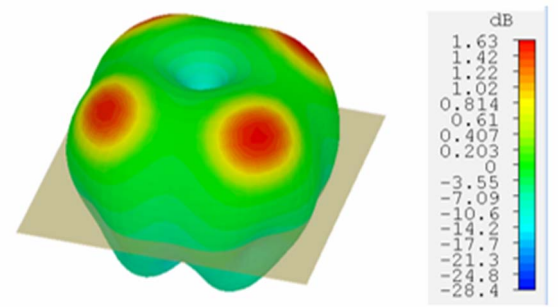
Figure 3. Impedance of the low-profile circular patch ring antenna with or without a shorting via: (a) resistance, and (b) reactance.



(a)



(a)



(b)

Figure 4. Radiation gain patterns of the low-profile circular patch ring antenna with a shorting via at: (a) 2.42 GHz, and (b) 2.48 GHz.

The radiation patterns of the designed antenna at 2.42 GHz and 2.48 GHz are shown in Figure 4. Both the  $TM_{31}$  mode and  $TM_{32}$  mode produce omnidirectional radiation patterns. It is also noticed that in the directions of ground plane corners the radiation is slightly stronger than the other directions. This is mainly because of the shape of the ground plane. Furthermore, the realized gain of the low-

profile antenna is given in Figure 5. The realized gain is from 1.5-3 dBi and the total efficiency is from 45% to 60 % within the Wi-Fi or Bluetooth band of 2.4-2.48 GHz, which is sufficient for Wi-Fi or Bluetooth applications.

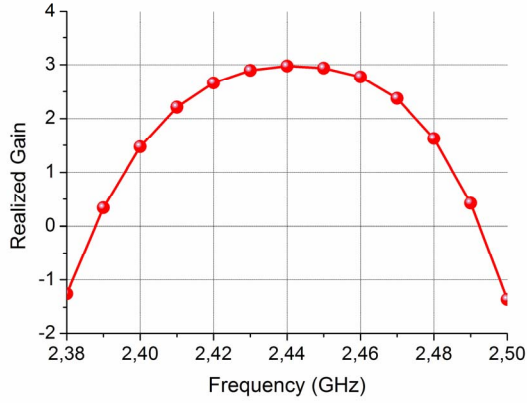
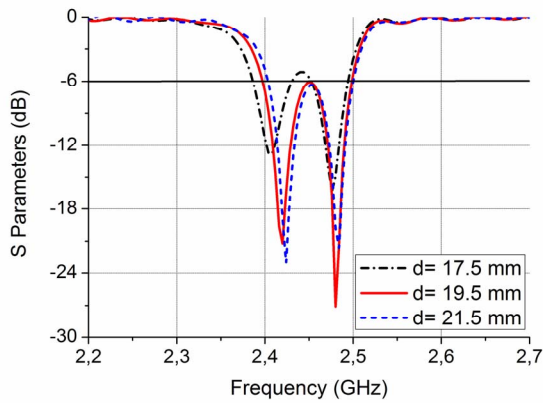
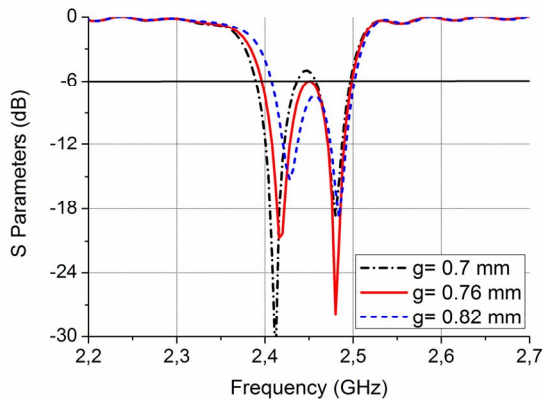


Figure 5. Realized gain of the proposed low-profile circular patch ring antenna.



(a)



(b)

Figure 6. Parametric studies of: (a) distance of d, and (b) gap of g.

To facilitate the application of the designed antenna, parametric studies of distance d and gap g have been carried out and shown in Figure 6 (a) and Figure 6 (b), respectively. By changing the distance d, the impedance matching of both  $TM_{31}$  mode and  $TM_{32}$  mode can be adjusted, while the gap g mainly affects the location and impedance matching of  $TM_{31}$  mode.

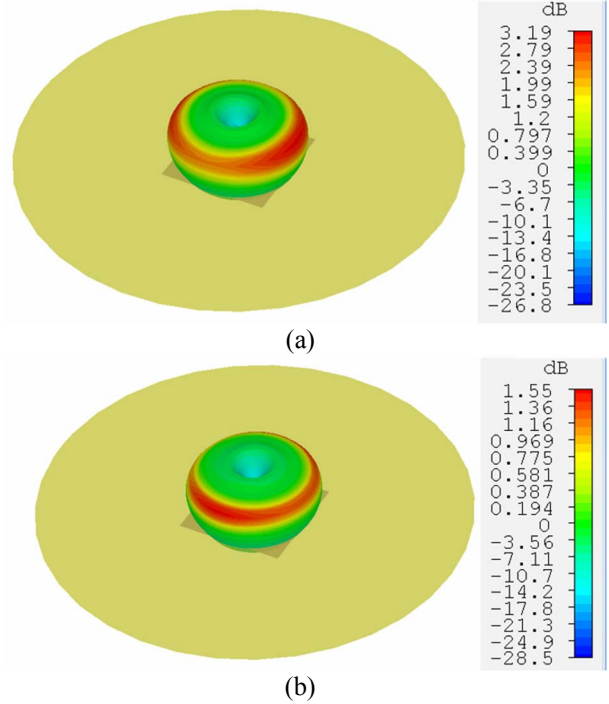


Figure 7. Radiation gain patterns of the designed antenna on a large ground plane at: (a) 2.42 GHz, and (b) 2.48 GHz.

To investigate the antenna performance on large metallic surface, the radiation gain patterns of the designed antenna on a large ground plane with the diameter of 600 mm at 2.42 GHz and 2.48 GHz are provided in Figure 7. Similar to Figure 4, omnidirectional radiation patterns can be observed clearly on the large ground plane, where the maximum realized gain slightly stronger than those in Figure 4.

## 2 CONCLUSIONS

In this paper, a circular patch-ring antenna with extremely low profile and omnidirectional radiation patterns has been introduced. By utilizing a shorting via,  $TM_{31}$  mode and  $TM_{32}$  mode have been excited efficiently to achieve a dual resonance behavior. The designed antenna has covered the band of 2.4-2.5 GHz with the thickness of  $0.005 \lambda$ . The realized gain within the Wi-Fi band is over 1.5 dBi. The sensitivity of antenna performance to a large ground plane has been

investigated, where the performance is nearly unchanged.

## References

- [1] S. Zhang, T. L. Jensen, K. Olesen, O. Franek, P. C. F. Eggers, C. Byskov and G. F. Pendersen, "UWB wind turbine blade deflection sensing for wind energy cost reduction," *Sensors*, vol. 15, no. 8, pp. 19768-19782, 2015.
- [2] S. Zhang, T. L. Jensen, O. Franek, P. C. F. Eggers, C. Byskov and G. F. Pendersen, "Investigation of a UWB wind turbine blade deflection sensing system with a tip antenna inside a blade," *IEEE Sensors Journal*, 2016. (accepted)
- [3] A. Al-Zoubi, F. Yang, and A. Kishk, "A broadband center-fed circular patch-ring antenna with a monopole like radiation pattern," *IEEE Trans. Antennas Propag.*, vol. 57, no. 3, pp. 789–792, Mar. 2009.
- [4] Y. Zhang, J. Liu, Z. Liang, and Y. Long, "A wide-bandwidth monopolar patch antenna with dual ring couplers," *Int. J. Antennas Propag.*, vol. 2014, 2014, Article ID 980120.
- [5] J. Liu, Q. Xue, H. Wong, H. Lai, and Y. Long, "Design and analysis of a low-profile and broadband microstrip monopolar patch antenna," *IEEE Trans. Antennas Propag.*, vol. 61, no. 1, pp. 11–18, Jan. 2013.
- [6] J. Liu, S. Zheng, Y. Li, and Y. Long, "Broadband monopolar microstrip patch antenna with shorting vias and coupled ring," *IEEE Antennas Wireless Propag. Lett.*, vol. 13, pp. 39–42, 2014.
- [7] W. Jeong, J. Tak, and J. Choi, "A low profile IR-UWB antenna with ring patch for WBAN applications," *IEEE Antennas Wireless. Propag. Lett.*, vol. 14, pp. 1447-1450, July 2015.