Indonesian Journal of Electrical Engineering and Computer Science
Vol. 19, No. 2, August 2020, pp. 864~869
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v19.i2.pp864-869

Investigations on feeding techniques of dielectric resonator antenna at 26 GHz

Irfan Ali, Mohd Haizal Jamaluddin, Abinash Gaya
Wireless Communication Centre, School of Electrical Engineering, Universiti Teknologi Malaysia, Malaysia

Article Info

Article history:

Received Jan 3, 2020
Revised Mar 6, 2020
Accepted Mar 22, 2020

Keywords:

5G communication
Dielectric resonator antenna
Microstrip line
Microstrip slot aperture
Millimetre wave frequency

Corresponding Author:

Mohd Haizal Jamaluddin,
Wireless Communication Centre,
School of Electrical Engineering,
Universiti Teknologi Malaysia,
Johor Bahru 81310, Malaysia.
Email: haizal@fke.utm.my

ABSTRACT

In this paper, Microstrip slot aperture and Microstrip line feeding techniques of dielectric resonator antenna are investigated and examined at 26 GHz for 5G applications. The dielectric resonator has a dielectric constant of 10 and etched on Rogers RT/Duroid 5880 substrate having a thickness of 0.254mm and relative permittivity of 2.2. The proposed structures are optimized and simulated using the commercial software CST Microwave studio. The effect of feeding techniques on the bandwidth, radiation efficiency, gain, VSWR and radiation pattern are also examined and analysed. The return loss, bandwidth, gain, radiation efficiency, VSWR and radiation pattern are presented and compared based on the excitation method employed for the studied DRA. The simulated results show that the microstrip slot aperture provides good performance and is suitable for 5G applications.

1. INTRODUCTION

The fast growth of wireless communication technology towards the future fifth generation (5G) communication systems requires compact size, wideband and high gain antennas to fulfil the needs of the constant growth of wireless devices. Dielectric resonator antennas (DRAs) have been studied and developed extensively in the last three decades. They have favourites among the antenna research community and have been used in the modern wireless communication applications. Dielectric resonator antennas (DRAs) enjoy many advantages compared to conventional and metallic antennas such as microstrip patch antennas (MSA), they are lightweight, low profile, relatively large bandwidth, ease of excitation, and 3-D design flexibility [1-8]. Additionally, DRA has high radiation efficiency due to the absence of surface wave and conductor losses [9]. These advantages make the DRA as an alternative of low gain metallic antennas and much more suitable candidate for the future 5G wireless communication applications. DRAs have different geometries like cylindrical [10-11], rectangular [12-13], triangular [14-15], hemispherical [16-17].

Due to various feeding techniques available to excite the DRA [18-24], a proper practice to select the best feeding method is required at millimetre wave frequencies for future 5G applications. In this paper, the performance of microstrip slot aperture and microstrip line feeding for DRA at 26 GHz is investigated and studied. The performance of the feeding techniques is analysed in terms of return loss, bandwidth, gain, radiation efficiency, VSWR and radiation pattern. The best feeding technique that is suitable for future 5G wireless communication analysed and compared.

2. ANTENNA DESIGN

The geometry of the dielectric resonator antenna using microstrip slot aperture and microstrip line feeding techniques are shown in Figure 1 and Figure 2, respectively. The square-shaped DRA having the same dimensions of length a, width b and height d ($a \times b \times d = 4.3\,mm \times\ 4.3mm\ \times 2.7\text{mm}$) and dielectric constant ε_r of 10 in each case of the designs. The Rogers RT/Duroid 5880 having a relative permittivity ε_r of 2.2 and thickness of 0.254mm is used in both structures of the DRA. The DRA is designed at the operating frequency of 26 GHz. The DRA is excited by using two different feeding techniques such as microstrip slot aperture and microstrip line. The resonant frequency (f_o) of the DRA is determined using the dielectric waveguide model (DWM) [25]:

$$\begin{gathered} k_x^2 + k_y^2 + k_z^2 = \varepsilon_r k_o^2 \\ k_x = \frac{\pi}{a}, k_z = \frac{\pi}{d} \\ k_y \tan\left(k_y \frac{b}{2}\right) = \sqrt{(\varepsilon_r - 1)k_o^2 - k_y^2} \\ f_o = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{k_x^2 + k_y^2 + k_z^2} \\ f_o = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{\varepsilon_r k_o^2} \end{gathered} \tag{1}$$

Where f_o is the resonant frequency in (GHz), c is the velocity of light (m/sec), and k_x, k_y, and k_z represents the wave number along the x, y and z directions, respectively and k_o is the free space wave number.

2.1. Microstrip slot aperture (MSA) feeding

The configuration of the proposed DRA structure using microstrip slot aperture feeding is shown in Figure 1. The optimized parameters of the designed antenna are depicted in Table 1.

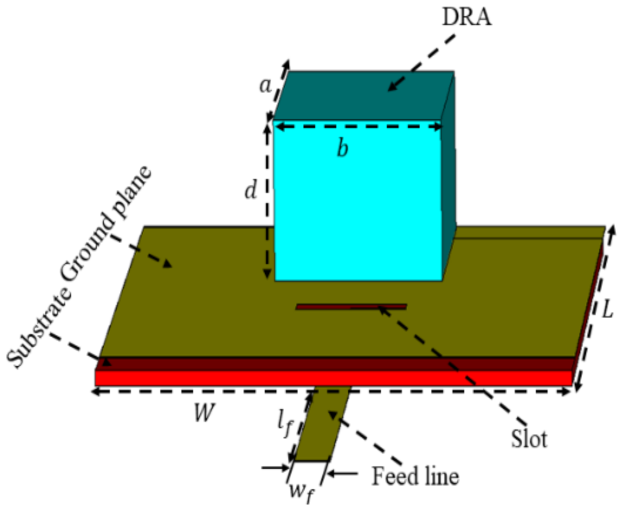

Figure 1. The geometry of the DRA using MSA feed

Table 1. Optimized parameters for MSA feeding

Parameter	Dimension (mm)
Ground Plane	$L_G = 11, W_G = 12, H_G = 0.0175$
Substrate	$L_S = 11, W_S = 12, H_S = 0.254$
DRA	$a = 4.3, b=4.3, d=2.7$
Feed line	$L_f = 6, W_f = 0.9$
Slot	$W_{slot} = 2.8, L_{slot} = 1.5$

2.2. Microstrip line (ML)

The configuration of the dielectric resonator antenna with microstrip line feeding is given in Figure 2. The microstrip line having length and width of feeding ($L_f \times W_f = 5.6mm \times 1mm$). The DRA is etched on the Rogers RT/Duroid substrate having relative permittivity of 2.2 and thickness of 0.254mm. The optimized parameters of the proposed DRA are tabulated in Table 2.

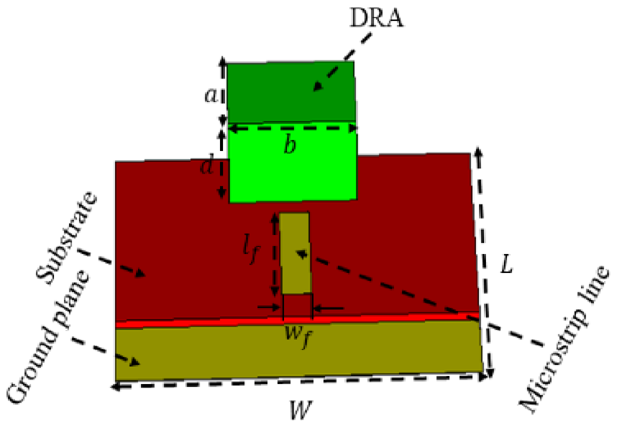

Figure 2. The configuration of the DRA with ML feed

Table 2. Optimized parameters for ML feeding

Parameter	Dimension (mm)
Ground Plane	$L_G = 11, W_G = 12, H_G = 0.0175$
Substrate	$L_S = 11, W_S = 12, H_S = 0.254$
DRA	$a = 4.3, b=4.3, d=2.7$
Microstrip line	$L_f = 5.6, W_f = 1$

3. RESULTS AND DISCUSSIONS

The DRA excited by MSA and ML feeding is simulated using the commercial software CST Microwave studio. The performance of both feeding techniques is examined at 26 GHz for future 5G applications. The comparison of the simulated return loss $|S_{11}|$ results of the rectangular DRA with microstrip slot aperture and microstrip line feeding techniques is presented in Figure 3. From the Figure 3, the return loss of the DRA with MSA feeding is -48 dB whereas DRA with ML feeding is -15 dB at 26 GHz. The simulated $|S_{11}|$<-10dB impedance bandwidth of 9.6% (24.9-27.4 GHz=2.5 GHz) and 11.2% (25-27.9 GHz=2.9 GHz) for the ML and MSA, respectively. The MSA feeding technique shows a good result of S_{11} compared to ML feeding. The simulated results of gain versus frequency for each design are shown in Figure 4. It can be seen from the Figure 4, the gain for MSA is 6.8 dBi while 4.7 dBi for the ML feeding. This shows that DRA with MSA feeding achieved higher gain compared to ML feeding technique at 26 GHz.

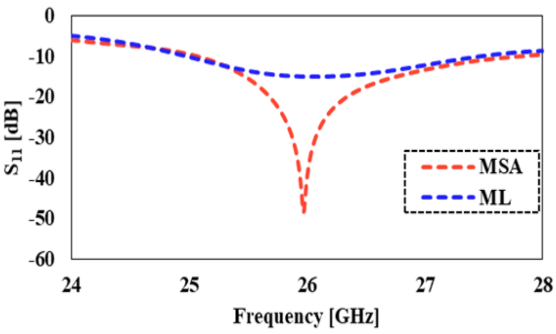

Figure 3. The reflection coefficient of the DRA with MSA and ML feeding

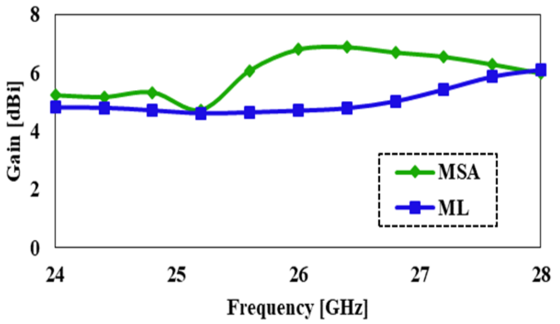

Figure 4. The gain versus frequency of the DRA with MSA and ML feeding

The radiation efficiency versus frequency plot for DRA with MSA and ML feeding at 26 GHz is presented in Figure 5. Concerning the Figure 5, the radiation efficiency of 94% and 95% for DRA with ML and MSA, respectively. Figure 6 shows the plot of the VSWR for the DRA with MSA and ML feeding. From the Figure 6, it can be observed that the VSWR for MSA is 1 and for ML is 1.45. The DRA with MSA feeding has good VSWR as compared to ML feeding. The normalized radiation pattern of the of DRA with MSA and ML feeding in the E-plane and H-plane at 26 GHz is presented in Figure 7. It can be seen from the results of the Figure 7, MSA and ML feeding techniques provide broadside direction radiation in the E-plane and H-plane.

The performance comparison of the microstrip slot aperture and microstrip line feeding of the DRA is given in Table 3. From the table; it is clear that the MSA feeding has better performance as compared to ML at 26 GHz. Results show that MSA feeding techniques have good performance at higher frequencies and is suitable for future 5G applications.

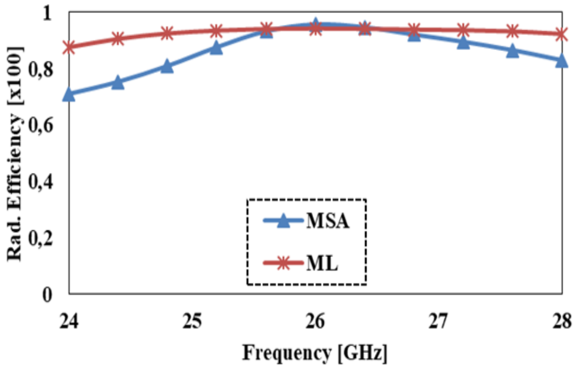

Figure 5. The radiation efficiency versus frequency of the DRA with MSA and ML feeding at 26 GHz

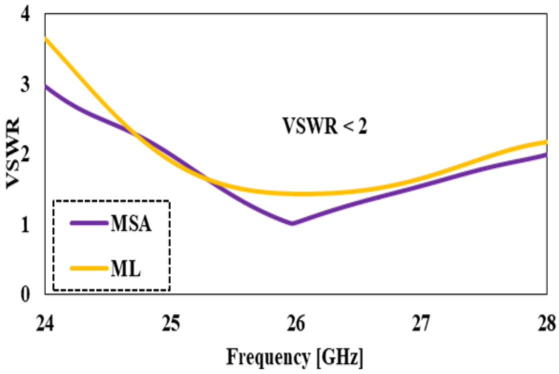

Figure 6. VSWR versus frequency of the DRA with MSA and ML at 26 GHz

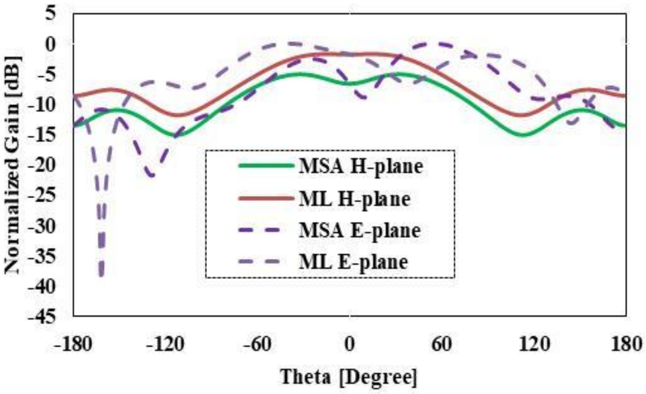

Figure 7. The normalized radiation pattern of the DRA with MSA and ML feeding in the E-plane and H-plane at 26 GHz

Table 3. Comparison between the MSA and ML feeding

Results	MSL	MSA
Frequency (GHz)	26	26
Bandwidth (%)	9.6%	11.2%
Return loss (dB)	-15	-48
VSWR	1.45	1
Gain (dBi)	4.7	6.8
Rad.Eff. (%)	94	95

4. CONCLUSION

This paper presents the performance analysis of the microstrip slot aperture and microstrip line of dielectric resonator antenna at 26 GHz frequency for 5G applications. The simulated results show that the microstrip slot aperture feeding has good results in terms of bandwidth, gain, and VSWR compared to microstrip line feeding technique. The MSA is considered as a potential feeding technique at millimetre wave frequencies for 5G applications.

ACKNOWLEDGEMENTS

The authors would like to thank the Universiti Teknologi Malaysia Grant HiCoE 4J415 and UTM Grant (TDR Grant 05G20 and GUP 19H56) for supporting this research work.

REFERENCES

[1] I. Ali, M. H. Jamaluddin, A. Gaya, and H. A. Rahim, “A Dielectric Resonator Antenna with Enhanced Gain and Bandwidth for 5G Applications,” *sensors*, vol. 20, no. 3, pp. 1–12, 2020.

[2] A. Iqbal, A. Smida, O. A. Saraereh, and Q. H. Alsafasfeh, “Cylindrical Dielectric Resonator Antenna-Based Sensors for Liquid Chemical Detection,” *sensors*, pp. 2–10, 2019.

[3] Sudipta Maity and Bhaskar Gupta, “Communication Approximate Theoretical Investigations on Isosceles Triangular Dielectric,” *IEEE Trans. ANTENNAS PROPAGATION,* vol. 66, no. 5, pp. 2640–2643, 2018.

[4] M. Mrnka, M. Cupal, Z. Raida, A. Pietrikova, and D. Kocur, “Millimetre-wave dielectric resonator antenna array based on directive LTCC elements,” *IET Microwaves, Antennas Propag.*, no. Lapc 2016, pp. 662–667, 2018.

[5] N. H. Shahadan and M. H. Jamaluddin, “Steerable Higher Order Mode Dielectric Resonator Antenna With Parasitic Elements for 5G Applications,” *IEEE access*, vol. 5, pp. 22234–22243, 2017.

[6] A. Petosa, *Dielectric Resonator Antenna Handbook*. Norwood, MA:Artech House, 2007.

[7] K.M.Luk and K.W.Leung, *Dielectric Resonator Antennas*. Bal dock, U.K.: Research Studies Press, 2003.

[8] I. Ali, M. H. Jamaluddin, M. R. Kamarudin, A. Gaya, and M. H. Dahri, “Gain enhancement of dielectric resonator antenna for millimeter wave applications’,” *TELKOMNIKA Telecommun. Comput. Electron. Control*, vol. 17, no. 4, pp. 1670–1673, 2019.

[9] I. Ali, M. H. Jamaluddin, M. R. Kamarudin, A. Gaya, and R. Selvaraju, “Wideband and high gain dielectric resonator antenna for 5G applications,” *Bull. Electr. Eng. Informatics*, vol. 8, no. 3, pp. 1–6, 2019.

[10] R. K. Mongia and A. Ittipiboon, “Theoretical and experimental investigations on rectangular dielectric resonator antennas,” *IEEE Trans. Antennas Propag.*, vol. 45, no. 9, pp. 1348–1356, 1997.

[11] N. K. Mishra, S. Das, and D. K. Vishwakarma, “Beam steered linear array of Cylindrical Dielectric Resonator Antenna,” *AEUE - Int. J. Electron. Commun.*, vol. 98, pp. 106–113, 2019.

[12] M.W. McAllister ; S.A. Long ; G.L. Conway, “Rectangular dielectric resonator antenna,” *Electron. Lett.*, vol. 19, no. 6, pp. 218–219, 1983.

[13] J. Iqbal, U. Illahi, M. I. Sulaiman, M. Najib, M. Yasin, and M. H. Jamaluddin, “Bandwidth Enhancement and Generation of CP by Using Parasitic Patch on Rectangular DRA for Wireless Applications,” *IEEE Access,* vol. 7, pp. 94365–94372, 2019.

[14] H. Y. Lo, K. W. Leung, K. M. Luk, and E. K. N. Yung, “Low profile equilateral-triangular dielectric resonator antenna of very high permittivity,” *Electron. Lett.*, vol. 35, no. 25, p. 2164, 1999.

[15] N. R. Nayak, D. R. Saini, R. K. Singh, D. Sankaranarayanan, D. V. Kiran, and B. Mukherjee, “Edge Grounding Perforated Triangular Dielectric Resonator Antenna,” *2016 URSI Asia-Pacific Radio Sci. Conf. URSI AP-RASC 2016*, pp. 1805–1807, 2016.

[16] B. Mukherjee, P. Patel, and J. Mukherjee, “A novel hemispherical dielectric resonator antenna with complementary split-ring-shaped slots and resonator for wideband and low cross-polar applications,” *IEEE Antennas Propag. Mag.*, vol. 57, no. 1, pp. 120–128, 2015.

[17] A. A. Kishk, G. Zhou, and A. W. Glisson, “Analysis of Dielectric-Resonator Antennas with Emphasis on Hemispherical Structures,” *IEEE Antennas Propag. Mag.*, vol. 36, no. 2, pp. 20–31, 1994.

[18] C. E. Zebiri *et al.*, “Offset Aperture-Coupled Double-Cylinder Dielectric Resonator Antenna with Extended Wideband,” *IEEE Trans. Antennas Propag.*, vol. 65, no. 10, pp. 5617–5622, 2017.

[19] Abinash Gaya, M.H. Jamaluddin and I. Ali, “Performance Analysis of a Dielectric Resonator Antenna with Different Feeding Technique for 5G Communication,” in *International Conference on Electrical Engineering and Informatics (ICon EEI)*, 2018, no. October, pp. 92–97.

[20] K. W. Leung, K. M. Luk, K. Y. A. Lai, and D. Lin, “Theory and experiment of an aperture-coupled hemispherical dielectric resonator antenna,” *IEEE Trans. Antennas Propag.*, vol. 43, no. 11, pp. 1192–1198, 1995.

[21] B. Ghosh, K. Ghosh, and C. S. Panda, “Coplanar waveguide feed to the hemispherical DRA,” *IEEE Trans. Antennas Propag.*, vol. 57, no. 5, pp. 1566–1570, 2009.

[22] A. A. Kishk, “Directive dielectric resonator antenna excited by probe or narrow slot,” in *Proceedings: IEEE Radio and Wireless Symposium, RWS 2012*, 2012, pp. 387–390.

[23] J. S. Wight, A. Petosa, R. K. Mongia, and A. Ittipiboon, “Design of microstrip-fed series array of dielectric resonator antennas,” *Electron. Lett.*, vol. 31, no. 16, pp. 1306–1307, 1995.

[24] I. Ali, M. H. Jamaluddin, M. R. Kamarudin, A. Gaya, and S. Raghuraman, “Perforated Dielectric Resonator Antenna Operating on Higher Order Mode,” *2018 IEEE Int. RF Microw. Conf.*, pp. 250–253, 2018.

[25] J. Legier, P. Kennis, S. Toutain, and J. Citerne, “Resonant frequencies of rectangular dielectric resonators,” *IEEE Trans. Microw. Theory Tech.*, no. 9, pp. 1031–1034, 1980.

BIOGRAPHIES OF AUTHORS

Irfan Ali received the B.E degree in Telecommunications from the Mehran University of Engineering and Technology (MUET), Pakistan, in 2010 and the master’s degree in Telecommunications Engineering from NED University of Engineering and Technology in 2014. He is currently pursuing the Ph.D. degree with the Wireless Communication Centre (WCC), Universiti Teknologi Malaysia (UTM). He is a student member in IEEE. His research interests include microstrip patch antennas, dielectric resonator antennas, MIMO antennas, mutual coupling analysis.

Mohd Haizal Jamaluddin received bachelor's and master's degrees in electrical engineering from Universiti Teknologi Malaysia, Malaysia, in 2003 and 2006, respectively, and the Ph.D. degree in signal processing and telecommunications from the Université de Rennes 1, France, in 2009, with a focus on microwave communication systems and specially antennas such as dielectric resonator and reflectarray and dielectric dome antennas. He is currently an Associate Professor with the Wireless Communication Centre, School of Electrical Engineering, Universiti Teknologi Malaysia. His research interests include dielectric resonator antennas, printed microstrip antennas, MIMO antennas and DRA reflectarray antennas. He has published more than 100 papers in reputed indexed journals and conference proceedings.

Abinash Gaya is a PhD Student at Wireless Communication Centre (WCC), UTM Johor Bahru. He has been involved in the Design and Development of Dielectric Resonator Antennas for 5G Communications at WCC. He is also working towards Design of Phased Array Antenna system for 5G Base Stations. He is a student member in IEEE.