Bulletin of Electrical Engineering and Informatics
Vol. 9, No. 4, August 2020, pp. 1734~1738
ISSN: 2302-9285, DOI: 10.11591/eei.v9i5.2175

Higher order mode dielectric resonator antenna excited using microstrip line

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Article Info

Article history:

Received Dec 13, 2019
Revised Mar 3, 2020
Accepted Apr 4, 2020

Keywords:

5G communication
Dielectric resonator antenna
Higher order mode
Microstrip feed
Millimetre wave (mm-wave)

ABSTRACT

In this paper, the square-shaped dielectric resonator antenna (DRA) operating on higher order ($TE_{\delta 13}$) mode for the fifth generation (5G) communication applications is presented. The proposed DR antenna is excited by using a microstrip feed line and designed at the operating frequency of 28 GHz. The Rogers RT/Duroid 5880 material having a thickness of 0.254mm and a dielectric constant of 2.2 is used for the substrate. The commercial CST microwave studio (CST MWS) is used for the optimization and simulation of the antenna design. The reflection coefficient, antenna gain, radiation efficiency, VSWR and radiation pattern are studied. A -10dB bandwidth of 4.6% (1.3 GHz) for VSWR<2 with a gain of 5 dBi and radiation efficiency of 89%. The proposed antenna design is suitable for future 5G wireless communication applications.

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1. INTRODUCTION

Due to the fast revolution in the telecommunication industry, wireless technology has evolving from first generation (1G) to fifth generation (5G) [1]. In recent years, the increasing number of wireless devices and services have triggered the engineers, scientists, researchers in academia and industries to move on to the future generation (5G) communication technology, which is expected to be introduced by 2020 and beyond. It is an ultimate goal of all scientists and researchers to build a wireless world in which all devices are connected with one another wirelessly. In Today's modern wireless era, antennas with high radiation efficiency, compact size, high gain, and large bandwidth are required [2, 3]. Antennas are an essential part of any wireless communication systems. The two classes of antennas, named microstrip patch antennas (MSA) and dielectric resonator antennas (DRAs) are extensively used in the applications of modern communication. Recently, research antenna community is paying more attention to dielectric resonator antenna (DRA) due to its alluring features of higher radiation efficiency, relatively large impedance bandwidth, low profile, design flexibility, ease of excitation schemes and ease of fabrication [4-12]. In addition, DRA can be excited by different feeding methods like microstrip feed line [13], probe feeding [14, 15], aperture coupling [16, 17], and coplanar waveguide (CPW) [16]. DRA comes in various shapes such as cylindrical [18, 19], rectangular [20, 21], Hemi-spherical [22] and triangular [23, 24]. Thus, DRA is considered as alternative to low gain metallic conventional antennas and is best candidate for the 5G applications [25].

Several methods have been proposed in the literature to improve the bandwidth and gain of DRA antenna, including stacking DRAs [26, 27] and EBG structure [28, 29]. In this paper, dielectric resonator antenna (DRA) based on higher order $TE_{\delta 13}$ mode using microstrip feed line for gain and bandwidth improvement with high radiation efficiency at millimeter wave frequency (mm-wave) of 28 GHz is presented. A lot of work has been done previously on the fundamental mode at a lower frequency, but a limited work has been done on the higher order mode especially at millimeter wave frequencies. The excitation of higher order mode is simple in structure and does not increase complexity as compared to other techniques mentioned. This paper is organized as follows: The antenna geometry configuration and design process are described in section 2. The results and discussion part of the proposed structure are described in section 3. The conclusion of the paper is given in section 4.

2. ANTENNA GEOMETRY

The resonant frequency f_o of dielectric resonator antenna (DRA) is computed as follows [30]:

$$f_o = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{k_x^2 + k_y^2 + k_z^2} \quad (1)$$

Where ε_r is the relative permittivity of the DRA, c is the speed of light (in free space), k_x, k_y and k_z. Symbols denote the wave number in the x,y and z directions, respectively. The proposed antenna geometry is shown in Figure 1. The antenna is resonating at the operating frequency of 28 GHz. The squared DRA has length, width and height $(a \times b \times d)$ with a dielectric constant of ε_{rs}. The DRA is placed on the Rogers RT/Duroid 5880 substrate with a thickness of h_s and relative permittivity of ε_{rd}. The DRA is excited by using 50Ω microstrip feed line. Table 1 lists the optimized dimensions of the proposed antenna design.

Table 1. Optimized dimensions of the proposed DR antenna, all dimensions are in millimetres (mm)

Parameters	Description	Dimension
L_g	Ground length	20
W_g	Ground width	20
h_g	Ground height	0.0175
L_s	Substrate length	20
W_s	Substrate width	20
h_s	Substrate height	0.254
Substrate ε_r	Dielectric constant	2.2
a	DRA length	3.5
b	DRA width	3.5
d	DRA height	5.1
DRA ε_r	Dielectric constant	10
L_f	Feed length	9.78
W_f	Feed width	1.65

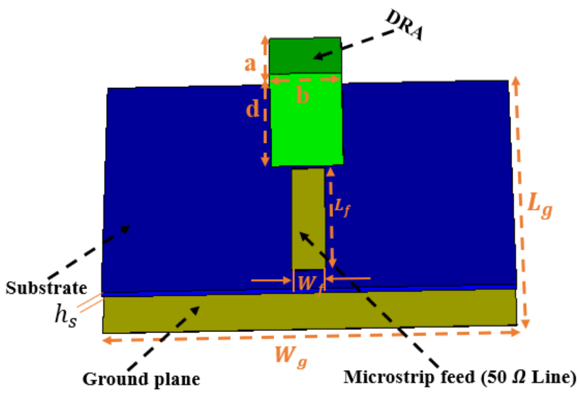

Figure 1. The geometry of the proposed higher-order mode DRA

3. RESULTS AND DISCUSSION

The proposed dielectric resonator antenna design is simulated by CST Microwave studio software. Figure 2 shows the S_{11} of the proposed DRA operating on higher order $(TE_{\delta 13})$ mode at the resonating frequency of 28 GHz. From the figure, the simulated -10 dB impedance bandwidth $S_{11} < -10dB$ of the antenna is 4.6% (27.3-28.8 GHz=1.3 GHz). The simulated gain and efficiency of an antenna are depicted in Figure 3. concerning the figure, the DRA shows a gain of 5dBi and high radiation efficiency of 89%. Figure 4 shows the simulated voltage standing wave ratio (VSWR) curve as a function of frequency. It is noted that the VSWR is less than 2 for the whole impedance bandwidth. The simulated normalized radiation pattern of the proposed DRA in the E-and H-plane at 28 GHz is shown in Figure 5. The antenna radiates in the broadside direction. Table 2 shows the results of the proposed DR antenna operating on $TE_{\delta 13}$ mode at 28 GHz.

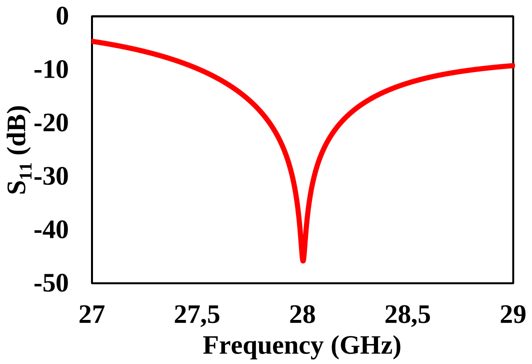

Figure 2. Simulated S_{11} of the proposed DRA

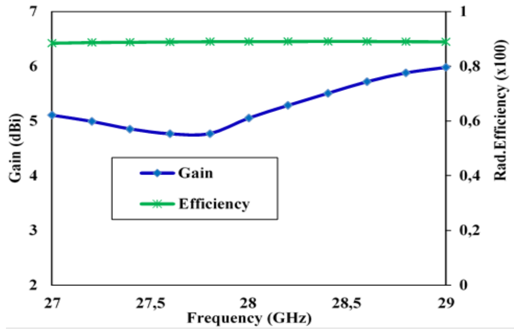

Figure 3. Simulated gain and radiation efficiency versus frequency of the proposed DRA

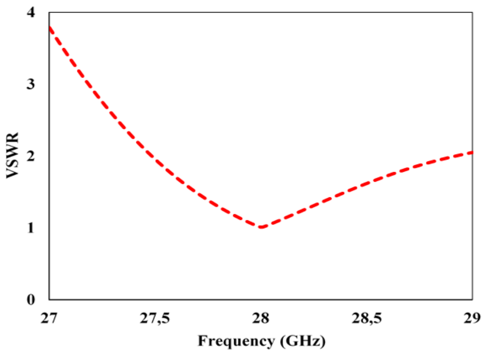

Figure 4. Simulated VSWR versus frequency of the DRA

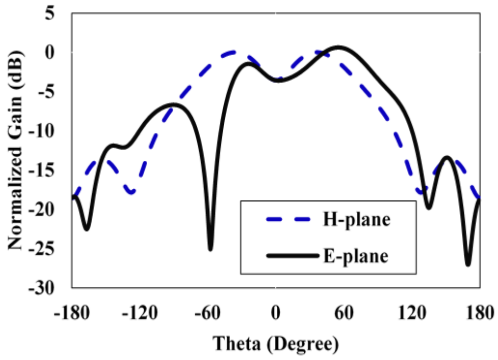

Figure 5. Simulated normalized radiation pattern in the E-plane and H-plane at 28 GHz

Table 2. Results of the proposed DRA based on higher order $TE_{\delta 13}$ mode at 28 GHz

Mode	f_o (GHz)	BW (%)	Gain (dBi)	Eff. (%)	VSWR
$TE_{\delta 13}$	28	4.6%	5	89	< 1.2

f_o −Resonant frequency in GHz, BW −Bandwidth in percentage, $Gain$ −Gain in dBi, $Eff.$−Efficiency in percentage (%), $VSWR$ −Voltage standing wave ratio.

4. CONCLUSION

Higher order mode dielectric resonator antenna excited using microstrip line is presented and investigated. The proposed antenna achieves an impedance bandwidth of 4.6%, for VSWR<2, covering the frequency range from 27.3GH to 28.8 GHz with a gain of 5dBi and high radiation efficiency of 89%. The proposed antenna is small in size and simple structure which can be used for fifth generation (5G) wireless communication 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.

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