Investigations on feeding techniques of dielectric resonator antenna at 26 GHz

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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.

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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.
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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 $d$ ($a \times b \times d = 4.3\, mm \times 4.3\, mm \times 2.7\, mm$) and dielectric constant $\varepsilon_r$ of 10 in each case of the designs. The Rogers RT/Duroid 5880 having a relative permittivity $\varepsilon_r$ 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]:

$$\sqrt{k_x^2 + k_y^2 + k_z^2} = \varepsilon_r k_0$$

$$k_x = \frac{\pi}{a}, \quad k_z = \frac{\pi}{d}$$

$$k_y \tan(k_y b) = (\varepsilon_r - 1)k_y^2 - k_y^2$$

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

$$f_o = \frac{c}{2 \pi \sqrt{\varepsilon_r}} \sqrt{\varepsilon_r k_0^2}$$

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 $k_0$ 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.

Table 1. Optimized parameters for MSA feeding

| Parameter | Dimension (mm) |
|-----------|----------------|
| Ground Plane | $L_a = 11, W_a = 12, H_a = 0.0175$ |
| Substrate | $L_z = 11, W_z = 12, H_z = 0.254$ |
| 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 ($L_f \times W_f = 5.6\, mm \times 1\, mm$). 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 1. The geometry of the DRA using MSA feed

Figure 2. The geometry of the DRA using ML feed
Figure 2. The configuration of the DRA with ML feed

Table 2. Optimized parameters for ML feeding

| Parameter    | Dimension (mm) |
|--------------|----------------|
| Ground Plane | $L_0 = 11, W_0 = 12. H_0 = 0.0175$ |
| Substrate    | $L_s = 11, W_s = 12. H_s = 0.254$ |
| DRA          | $a = 4.3, b = 6.3, d = 2.7$ |
| 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 performance of both feeding techniques is shown 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 $|S_{11}| < -10$ dB 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.
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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.

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