

## Wideband tetraskelion dielectric resonator antenna

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### ABSTRACT

In this paper, a wideband tetraskelion dielectric resonator antenna with a low profile and high gain for the upcoming fifth generation (5G) communication applications is presented. The proposed DR antenna has been designed at the operating frequency of 26 GHz. The designed antenna is etched on Rogers RT/Duroid 5880 substrate of dielectric constant  $\epsilon_r=2.2$ , with a thickness of 0.254mm. The DR material having a relative dielectric constant ( $\epsilon_r$ ) of 10 is used for a proposed design. The antenna was fed by using a 50-ohm microstrip line with slot coupling. The simulation and optimization have been performed by using the commercial software CST Microwave studio. The proposed structure exhibits a wide impedance bandwidth of 19.6% for  $|S_{11}| < -10$  dB from 24.5 to 29.6 GHz and peak gain of 9 dBi with the efficiency of 95% for complete bandwidth. The results show that an antenna is low profile and can be used for 5G wireless communication Applications

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## 1. INTRODUCTION

The rapid growth of wireless communication systems leads the researchers and antenna designers to design new and better antennas with a low profile, highly efficient, small size and wide bandwidth that can satisfy the demands of the constant growth of wireless devices. In recent years, dielectric resonator antenna (DRA) is most widely used in the modern wireless communication applications because of their various advantages of a lightweight, low profile, low loss, inexpensive, large bandwidth, and ease of fabrication [1-7]. Also, DRAs have high radiation efficiency, as they are not suffered from metallic losses or surface waves [8]. Moreover, DRA is feed by using various feeding techniques like microstrip feed line [9], coaxial probe feed [10, 11], aperture slot coupling [12, 13], and co-planar waveguide (CPW) [14]. Furthermore, DRA comes in various shapes of rectangular [15, 16], cylindrical [17, 18], hemispherical [19], and triangular [20]. The rectangular shape is the basic and most commonly used in the literature because of the salient features of design flexibility, simple in structure and ease of fabrication.

Since the last two decades, investigations have been focused on the enhancement of bandwidth of DRA, and thus, different methods have been used to improve the bandwidth of DRAs. These methods use fractal approach [21], stacking DRAs [22, 23], or various other DR geometries such as H-shaped [24], T-shaped [25], L-shaped [26], Z-shaped [27] and so on. By using these techniques, compactness and wideband is achieved. In this paper, tetraskelion geometry based dielectric resonator antenna excited by aperture coupled feeding is investigated and designed. The tetraskelion DRA produces a wide bandwidth of 19.6% (5.1 GHz) from 24.5 GHz to 29.6 GHz. This paper is organized into the following sections: Section 2 presents the tetraskelion DRA design configuration. Section 3 describes the results and discussion in details. Finally, a conclusion is presented in Section 4.

2. ANTENNA CONFIGURATION

The resonant frequency ( $f_o$ ) of rectangular dielectric resonator antenna is given by [28]:

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

Where ' $f_o$ ' is the resonant frequency of RDRA, ' $\epsilon_r$ ' is the relative permittivity of DRA, 'c' is the speed of light. The proposed DR structure is made of ECCOCK HiK TEK dielectric material. The dielectric constant ( $\epsilon_r$ ) of material is 10 and dissipation factor ( $\tan\delta$ ) of 0.002 is chosen for the proposed antenna design. The proposed structure of the DRA is depicted in Figure 1. The DRA is placed on the square-shaped ground plane with dimensions of  $L \times W = 11\text{mm} \times 11\text{mm}$ . The proposed tetraskelion DRA is fed by microstrip feed line with narrow aperture slot in the ground plane. The feed line is placed on the bottom side of the substrate and the slot is etched in the ground plane. Rogers substrate having dimensions of  $L_s \times W_s = 11\text{mm} \times 11\text{mm}$  with a dielectric constant of 2.2, and substrate thickness of  $h_s = 0.254\text{mm}$ . The antenna is designed at the operating frequency of 26 GHz. The optimized dimensions of the tetraskelion DRA are given in Table 1.

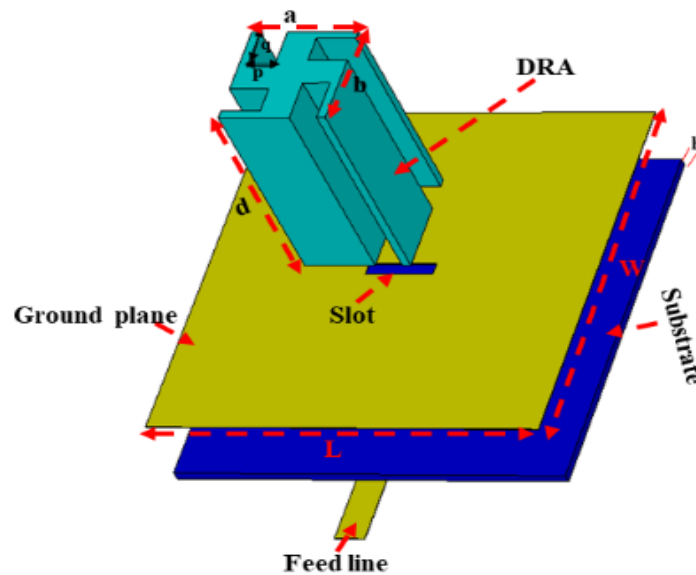


Figure 1. The geometry of the proposed tetraskelion DRA

Table 1. Optimized dimensions of the proposed antenna design

| Antenna Parts                     | Parameters      | Description                              | Dimensions(mm) |
|-----------------------------------|-----------------|--|----------------|
| Ground Plane                      | $L$             | Length of ground                         | 11             |
|                                   | $W$             | Width of ground                          | 11             |
|                                   | $h_g$           | Thickness of ground                      | 0.0154         |
| Substrate (Rogers RT/Duroid 5880) | $L_s$           | Length of substrate                      | 11             |
|                                   | $W_s$           | Width of substrate                       | 11             |
|                                   | $h_s$           | Height of substrate                      | 0.254          |
|                                   | $\epsilon_{rs}$ | The dielectric constant of the substrate | 2.2            |
|                                   | $\tan \delta$   | Loss tangent                             | 0.0009         |
|                                   | DRA             | $a$                                      | Length of DRA  |
| $b$                               |                 | Width of DRA                             | 2.98           |
| $d$                               |                 | Thickness of DRA                         | 6.26           |
| $\epsilon_{rd}$                   |                 | The dielectric constant of DRA           | 10             |
| Feed line                         | $\tan \delta$   | Loss tangent                             | 0.002          |
|                                   | $L_f$           | Length of feed                           | 6.65           |
|                                   | $W_f$           | Width of feed                            | 0.85           |
| Slot                              | $L_{slot}$      | Length of slot                           | 1.9            |
|                                   | $W_{slot}$      | Width of slot                            | 0.36           |
| Stub                              | $l_{stub}$      | Length of stub                           | 1              |

### 3. RESULTS AND DISCUSSIONS

The tetraskelion DRA fed by microstrip line through an aperture is designed at 26 GHz. The proposed antenna structure is simulated and optimized by using the CST Microwave Studio software. The square-shaped DRA is modified by introducing the air gap slots to achieve the tetraskelion shaped DRA. The insertion of air gap slots reduces the Q-factor and thus, improves the bandwidth of proposed DRA. The bandwidth and Q-factor are inversely proportional to each other. Figure 2 shows the reflection coefficient versus frequency of the tetraskelion DRA. The simulated results show that the proposed DRA resonates at 26 GHz, offering a wide impedance bandwidth of 5.1 GHz (19.6%) for  $|S_{11}| < -10$  dB from 24.5 GHz to 29.6 GHz. The simulated plot of gain versus frequency as well as radiation efficiency versus frequency is shown in Figure 3. The peak gain at 26 GHz frequency is 9 dBi. The peak radiation efficiency of 95% is achieved at 26 GHz. Figure 4 shows the VSWR versus frequency of the proposed DRA. It can be observed from the plot that the VSWR is less than 2 for the complete bandwidth. The simulated normalized radiation pattern (yz-plane and xz-plane) are shown in Figure 5. The simulated results are taken at 26 GHz. The results show that the proposed antenna radiates in the broadside direction. Table 2 shows the summarizing table of the simulated results. From the table, it can be seen that the proposed tetraskelion DRA not only achieved a wider impedance bandwidth but also high gain and high radiation efficiency.

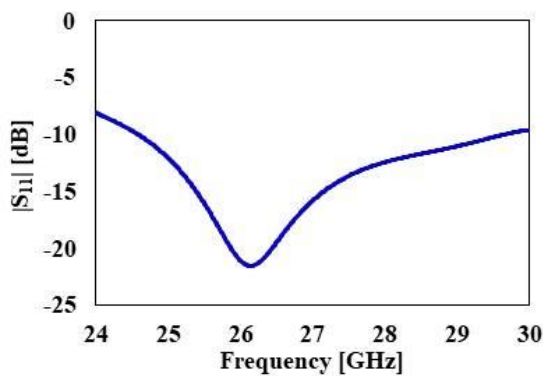


Figure 2. Simulated reflection coefficient of the proposed DRA

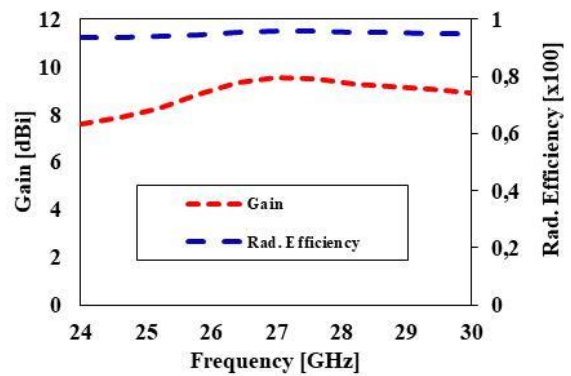


Figure 3. Simulated gain and efficiency versus frequency of the proposed DRA

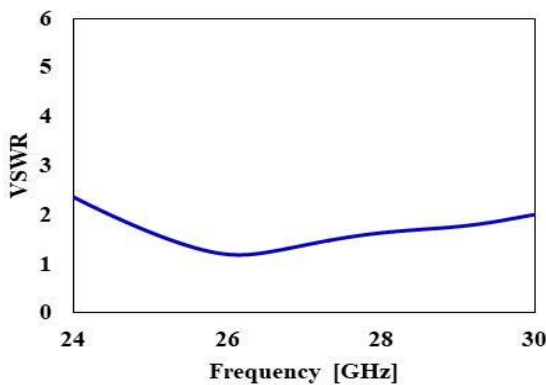


Figure 4. Simulated VSWR versus frequency of the proposed tetraskelion DRA

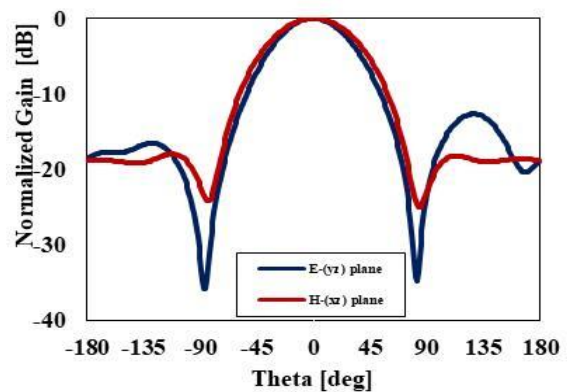


Figure 5. Simulated normalized radiation pattern in the E-plane and H-plane of the DRA at 26 GHz

Table 2. Summary of Simulated results of Proposed tetraskelion Structure DRA

| Antenna          | $f_o$ (GHz) | BW (%) | Gain (dBi) | Efficiency (%) |
|------------------|-------------|--------|------------|----------------|
| Tetraskelion DRA | 26          | 19.6   | 9          | 95             |

BW, bandwidth in percentage;  $f_o$ , resonant frequency in GHz

#### 4. CONCLUSION

In this paper, a wideband tetraskelion dielectric resonator antenna fed by microstrip strip line through slot coupling is proposed for the 5G communication applications. The DRA resonates at 26 GHz, and simulated results show that the proposed structure yields a wide impedance bandwidth of 5.1 GHz (19.6%), ranging from 24.5 GHz to 29.6 GHz. Furthermore, DRA has obtained a high gain of 9 dBi with a radiation efficiency of 95%. As a result, the proposed DRA structure is suitable and can be used for future 5G wireless communication applications.

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