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An Irregular Rectangular Dielectric Resonator Filter Antenna with a Nested Structure

Yanze Kuai[1, a], Wusheng Ji[1, b], Junhai Cui[2, c], and Hanglin Du[1, d]

[1] School of Electronic Engineering, Tianjin University of Technology and Education, Tianjin 300222, China

[2] Shanghai SAINTENNA Wireless Technology Co., Ltd., Shanghai 200444, China

[a]kyz1232021@163.com, [b]wshji1326@sohu.com, [c]kevin.cui@saintenna.com, [d]duhanglin2022@163.com

Abstract

In this paper, an irregular rectangular dielectric resonator filter antenna with a nested structure is proposed, which consists of a rectangular dielectric resonator with a special structure, a metal ground plane, and a microstrip feeder. The stub-loaded slot line is etched on the ground plane to excite the dielectric resonator, and finally, two radiation nulls are generated under the combined influence of the feed structure and the special-structure dielectric resonator antenna, realizing the filtering effect. The impedance bandwidth of this antenna is about 7.6% (39.10-42.17GHz), the average gain is about 5dBi, and it is small in size and easy to integrate, and can work in the 5G millimeter wave frequency band.

Keywords

Dielectric Resonator Antenna; Millimeter Wave; Filtering Antenna; Radiation Nulls; Nested Structure.

1. Introduction

With the development of wireless communication technology, miniaturization, integration, multi-function, and low-cost hardware have become important development trends in current wireless communication systems [1]. The antenna and filter are two important components of the RF front-end. The former realizes the interconnection between chips and the latter plays the role of filtering. The filter antenna is designed with the filter and the antenna as a whole, so that it has radiation characteristics, filtering characteristics, and impedance matching functions at the same time [2].

Commonly used filter antenna design methods are: (1) replace the last resonator of the traditional bandpass filter with the antenna so that the antenna acts as the load impedance of the filter so that the size and loss can be partially reduced; (2) the parasitic band stop Structure is incorporated into the antenna design, which changes the antenna impedance and introduces a filtering response in the radiated performance. This method can eliminate the size of the filter and reduce the insertion loss; (3) use specific parasitic elements in the antenna, such as parasitic patches, slots, shorting pins and metal loops, etc., to generate radiation next to the operating passband Zero point, to realize the filtering function. In this way, no additional filter circuit is required, thereby reducing the insertion loss and achieving a more compact size; (4) Now the substrate integrated waveguide (SIW) technology is widely used in the millimeter wave field due to its low loss, low cost, and ease of integration. received extensive attention. A millimeter-wave filter antenna based on a substrate-integrated waveguide (SIW) filter with high filter response and good frequency selectivity[3-5].

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Millimeter waves have been widely used in various fields such as communications, radar, and medical care due to their wide bandwidth, narrow beam, and strong penetrating power. In millimeter-wave communication, the indispensable millimeter-wave antenna has received great attention. Commonly used millimeter-wave antennas include dielectric resonator antennas, microstrip antennas, and horn antennas [6].

DRA (Dielectric Resonator Antenna) is a new type of antenna that has appeared in recent years. It is widely used at home and abroad for its outstanding characteristics such as low loss, wide bandwidth, various feeding forms, easy adjustment of the pattern, high radiation efficiency, and small size[7]. DRA can be designed in different shapes such as rectangles, hemispheres, and cylinders. For a given resonant frequency and dielectric constant, rectangular DRAs offer greater flexibility in achieving desired profile and bandwidth characteristics. The microstrip line has the characteristics of easy processing and easy integration with the circuit and can be placed under or on the side of the DRA to directly feed it [8-10].

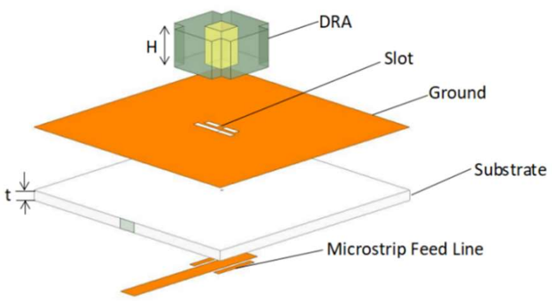
This paper proposes a dielectric resonator filter antenna that combines a filter antenna with a dielectric resonator antenna and feeds through a microstrip-slot line coupling. By changing the structure of the rectangular DRA, an irregular rectangular dielectric resonator filter antenna with a nested structure is designed. The antenna produces two radiation nulls at the out-of-band edge to realize the filtering effect.

2. Antenna Design

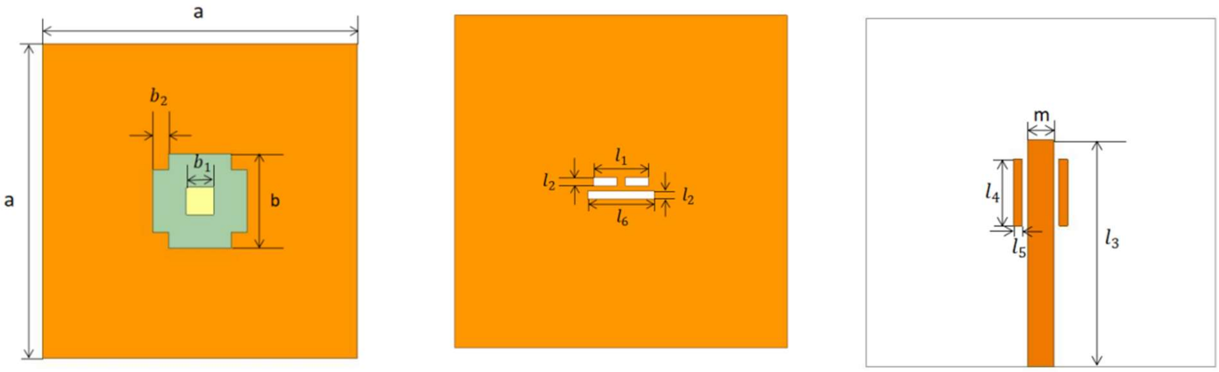
2.1 Antenna Configuration

Figure 1 shows the configuration of the proposed filter antenna. As shown in Fig. 1, the proposed antenna is composed of a special-structured rectangular dielectric resonator and a feed circuit. The dielectric resonator is fabricated at a thickness of t=0.813mm, size of a×a=20mm×20mm, and a dielectric Constant ε_{r1}= 3.38, on Arlon 25N dielectric substrate with loss tangent 0.0025. The material of the rectangular dielectric resonator is Arlon AD1000 with a dielectric constant ε_{r2}= 10.2, the size is b×b×H=6mm×6mm×3mm, the center of the dielectric resonator is a rectangular block of size, and the material is the dielectric constant of ε_{r3}= 6.15 Arlon AD600 fill, cut out four rectangular blocks of size around the rectangular resonator. The antenna is fed in the form of microstrip-slot line coupling.

As shown in Fig. 1(c), two slots with a length of (l_1-l_2)/2 and a width of l_2 are symmetrically located just below the dielectric resonator on the top layer of the substrate, and the interval between them aims to eliminate unwanted resonances in the lower stopband, increasing the level of rejection. Below the separation slots is a rectangular slot with a length of l_6 and width of l_2. As shown in Figure 1(d), the feeding structure is composed of a microstrip line with a length of m and width of l_3 and a pair of parasitic strips. The parasitic strips are located on both sides of the microstrip line, with a length of l_5 and width of l_4 . A shorting via with a radius of r_1 is introduced in the center of the substrate.



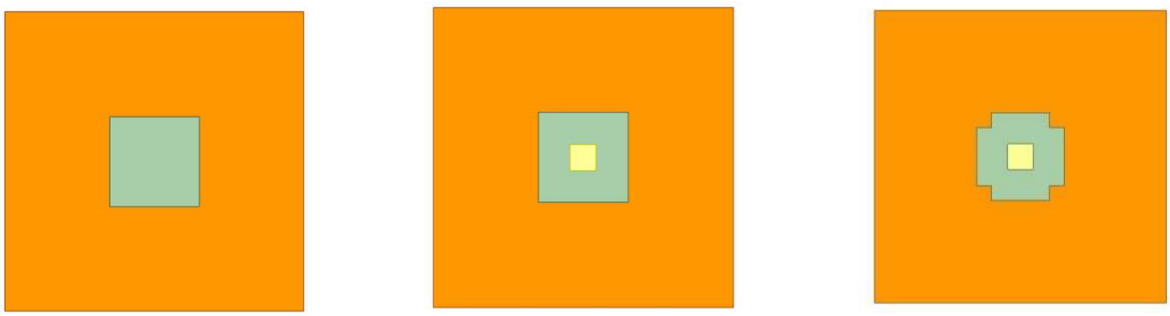
(a)



(b) (c) (d)

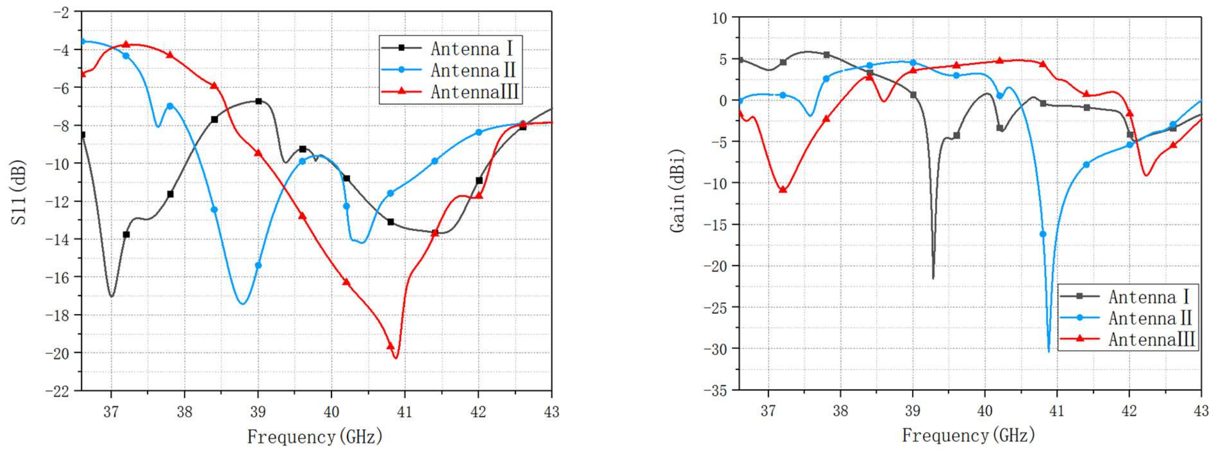
Figure 1. Antenna structure diagram (a) 3D diagram (b) top view (c) slot (d) microstrip feed line

2.2 Operating Principle



(a)AntennaI (b)AntennaII (c)AntennaIII

Figure 2. Reference Antenna and Recommended Antenna (a)AntennaI (b)AntennaII (c)AntennaIII



(a) (b)

Figure 3. Comparison of reflection coefficients and gains of three antennas Comparison of S11 (b) Comparison of gains

By comparing two reference antennas, the working principle of the dielectric resonator filter antenna is discussed. There are three antennas as shown in Figure 2, 1) the original antenna; 2) a rectangular DRA with a dielectric constant of 6.15 added in the center of the rectangular DRA; 3) the proposed

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antenna. Figure 3 shows the comparison of S11 and gains results of different antennas. It can be seen that the gain of the original antenna is about 0dBi between 39.5-42GHz. After adding the rectangular DRA in the middle, S11 is shifted to the left, and the gain is improved, but still lower than 5dBi. After cutting four rectangular blocks around the rectangular DRA to get the proposed antenna, the final gain is about 5dBi in the range of 39.10-42.17GHz. Compared with the first two antennas, its S11 is wider and there are two radiation nulls. It can be seen that the radiation null on the left is generated by the interaction of the microstrip line and the slots, and the radiation null on the right is generated under the influence of the DRA and the four cut corners of other materials added in the center.

3. Results

The electromagnetic simulation software ANSYS Electronics Desktop is used to simulate and analyze the antenna, and its performance is experimentally verified. The optimized parameters of the antenna are l_1=3.3mm, l_2=0.5mm, l_3=13mm, l_4=3.8mm, l_5=0.5mm, l_6 = 4mm, b_1=1.74mm, b_2=1mm, r_1=0.1mm, m=1.5mm. The reflection coefficient and realized gain are shown in Figure 4. The simulated impedance bandwidth for S11 <-10 dB is about 7.6% (39.10-42.17 GHz). Two radiation nulls are observed at the band edges, 37.19 and 42.27 GHz, which can lead to high selectivity. And it can be observed that the average value of the antenna gain in the passband is about 5dBi.

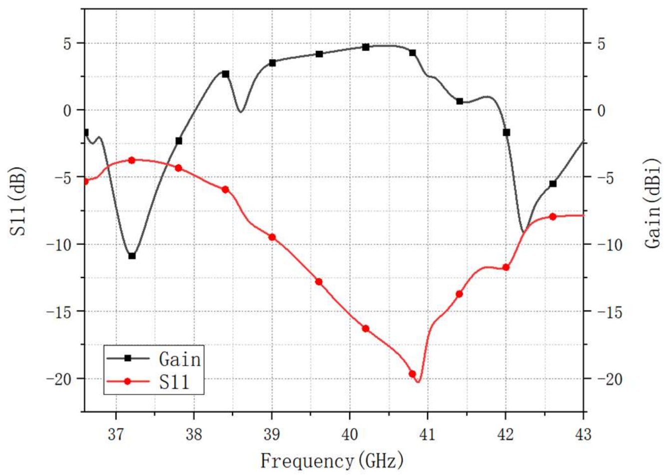

Figure 4. Simulation result diagram

4. Conclusion

In this paper, an irregular rectangular dielectric resonator filter antenna with a nested structure is proposed. By changing the structure of the rectangular DRA, the antenna generates two radiation nulls and realizes a dielectric resonator filter antenna with a -10dB impedance bandwidth of about 7.6% (39.10-42.17GHz) and an in-band gain of about 5dBi. The antenna is small in size, easy to integrate and process, and can be applied to the 5G mmWave frequency band.

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