

A Broadband Microstrip Antenna with a Strip-Slot Hybrid Structure

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Abstract: In order to solve the problem of narrow bandwidth of traditional microstrip antenna, a broadband patch antenna with Y-shaped microstrip feeder is proposed in this paper, which has the advantage of wider bandwidth and similar radiation pattern characteristics than the traditional microstrip slot antenna. Firstly, the Y-shaped microstrip line is used as the feed based on the straight microstrip line. Secondly, the strip-slot hybrid structure is used based on the square patch. Then the strip-slot hybrid structure is slotted. Finally, the impedance matching is achieved by optimizing the size of the antenna, which greatly widens the impedance bandwidth of the antenna. The full wave simulation software of high frequency structure simulator (HFSS) is used to simulate the proposed antenna structure. The simulation results show that when the reflection coefficient is less than -10dB, the relative bandwidth of the antenna is 22% (4.48-5.60GHz), and the maximum gain of the antenna is 10.72dB.

Keywords: Microstrip antenna, Broadband, Aperture coupling, Y-shaped feed.

1. Introduction

In recent years, microstrip antenna has been widely developed and applied in many fields of microwave engineering because of its small size, light weight, low cost, thin profile, easy conformal and other advantages. However, the development of microstrip antenna is limited by its narrow frequency band and surface wave defects. Many researchers have carried out in-depth research on it. In order to expand the bandwidth of microstrip antenna, many technologies and theories are used. For example, changing the shape of the antenna, slotting the patch, adding parasitic elements, and using substrate integrated waveguides [1-3].

Reference [4] proposed a single-layer C-band circular microstrip antenna with diamond shaped slot structure, with an impedance bandwidth of 16.93%. Reference [5] proposed a Y-shaped near coupled V-slot microstrip patch antenna with an impedance bandwidth of 21% (4.48-5.52GHz). Reference [6] proposed an ultra wideband high gain circularly polarized antenna fed by double Y-shaped slots, which achieved an impedance bandwidth of 71% (3.28 – 6.76 GHz). Reference [7] proposed a low profile aperture coupled microstrip patch antenna using TM₁₀ and TM₃₀ resonant modes to improve the impedance bandwidth, which achieved 15.2% (2.32-2.70GHz) wide impedance bandwidth. Reference [8] proposed a linearly polarized single fed double-layer dual band patch antenna with dual band performance through E-shaped and U-shaped slot patches. When the center frequency is 2.60 GHz and 3.50 GHz, the fundamental wave of the two frequency bands is TM₀₁ mode, and the impedance bandwidth is 26.9% and 7.1% respectively. Reference [9] proposed that four resonant modes with different frequencies are integrated in one structure, and a good matching is achieved by introducing folded walls, reaching an impedance bandwidth of 58% (2.84-5.17GHz). Reference [10] proposed a low profile microstrip antenna by exciting and coupling TM₁₀ mode and reverse TM₂₀ mode, which increased the impedance bandwidth to 41% and the low profile to 0.06 λ_0 (λ_0 is the working wavelength in free space).

Increasing the bandwidth of slot antenna plays a very

important role in meeting the growing communication demand. In this paper, a broadband microstrip antenna with slot hybrid structure is proposed. The antenna is composed of four strips separated by three narrow slots, and the middle two strips are slotted. The full wave simulation software of high frequency structure simulator (HFSS) is used to simulate the proposed slotted hybrid structure.

2. Antenna Design and Analysis

2.1. Antenna Design

Many researchers have made in-depth research on the approximate model for calculating the characteristic impedance of microstrip lines, and put forward many classical empirical formulas. These empirical formulas can guide us to design the size of microstrip line and optimize the antenna size to adapt to the characteristic impedance. When the substrate material and characteristic impedance are selected, the microstrip line structure (microstrip line width and dielectric plate thickness) can be obtained from the empirical formula.

When $w/h \leq 2$,

$$\frac{w}{h} = \frac{8e^A}{e^{2A} - 2} \quad (1)$$

The Coefficient A is,

$$A = 2\pi \frac{Z_0}{Z_f} \sqrt{\frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{\epsilon_r + 1} \left(0.23 + \frac{0.11}{\epsilon_r} \right)}$$

When $w/h \geq 2$,

$$\frac{w}{h} = \frac{2}{\pi} \left\{ \frac{B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left[\ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right]}{B - 1 - \ln(2B - 1) + \frac{\epsilon_r - 1}{2\epsilon_r} \left[\ln(B - 1) + 0.39 - \frac{0.61}{\epsilon_r} \right]} \right\} \quad (2)$$

The Coefficient $B = \frac{Z_f \pi}{2Z_0 \sqrt{\epsilon_r}}$. Where, $Z_f \approx 376.8\Omega$.

Z_f is the free space wave impedance. Z_0 is the characteristic impedance, and ϵ_r is the dielectric constant of the substrate.

2.2. Antenna Structure

In order to improve the bandwidth of the antenna, we improved the structure of the antenna on the basis of the traditional microstrip antenna. The Y-shaped microstrip line was fed on the basis of the straight microstrip line, and the slot hybrid structure was used on the basis of the square patch.

Finally, the slot structure was optimized to achieve impedance matching.

The whole antenna is $60mm \times 60mm \times 2.3mm$, and it is divided into five layers. The bottom layer is microstrip feeder, and the upper two layers are dielectric plates of the same material. The middle of the dielectric plates is separated by a slot ground plate, and the top layer is a patch etched on the dielectric plate. The dielectric plate is made of Nelco®NH9338 PTFE laminated board, and the excellent mechanical and electrical properties make the N9000 PTFE series laminated board system the preferred material for the lowest loss and high-frequency applications.

The geometric structure and design parameters of the antenna are shown in Figure 1:

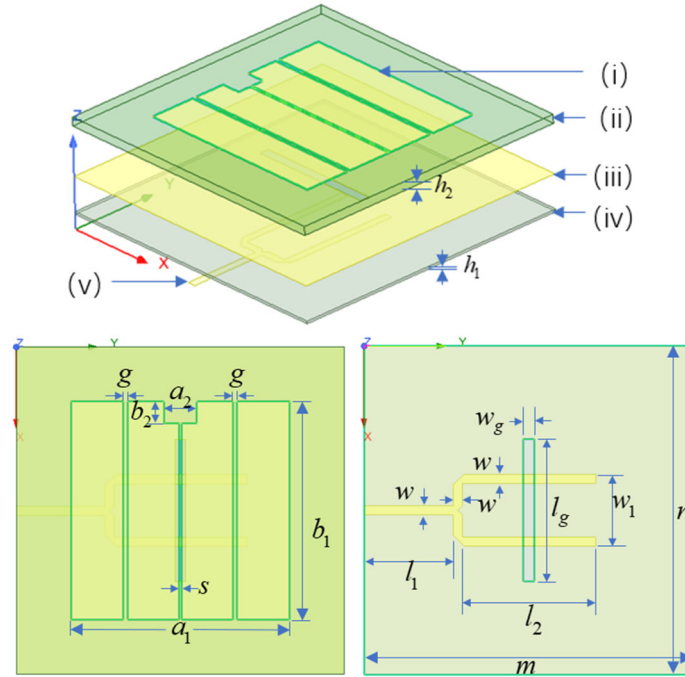


Figure 1. Antenna structure

patch:

(i)

$$a_1 = 40mm, b_1 = 40mm, a_2 = 6mm, b_2 = 4mm, g = 0.8mm, s = 0.5mm.$$

(ii) dielectric plate 2:

$$\epsilon_2 = 3.38, \tan \delta = 0.0027, h_2 = 1.8mm$$

(iii) ground

$$w_s = 2mm, l_s = 26mm, m = 60mm, n = 60mm.$$

(iv) dielectric plate 1:

$$\epsilon_1 = 3.38, \tan \delta = 0.0027, h_1 = 0.5mm$$

(v) Microstrip feed

$$w = 1.69mm, l_1 = 16.2mm, l_2 = 24.3mm, w_1 = 13.17mm.$$

2.3. Structural evolution

Microstrip slot antenna is developed from stripline slot

antenna. It adopts the combined structure of patch and slot, which can add an additional degree of freedom. The traditional microstrip slot antenna is composed of a straight microstrip line, a narrow slot ground plate and a square patch, as shown in figure 2- (Ant1). On this basis, the Y-shaped microstrip line is used for feeding, and the excitation of the strip slot hybrid structure is realized by optimizing the impedance matching. This improved feeding structure increases the optimized degree of freedom, as shown in figure 2- (Ant2). The square patch adopts a strip slot hybrid structure, which can excite and couple a variety of modes to improve the impedance bandwidth of the antenna. The structure is shown in figure 2- (Ant3). Finally, the middle strip of the slot structure is slotted to make the current path longer, change the Q value of the antenna, and improve the impedance matching of the proposed antenna, as shown in figure 2- (proposed antenna).

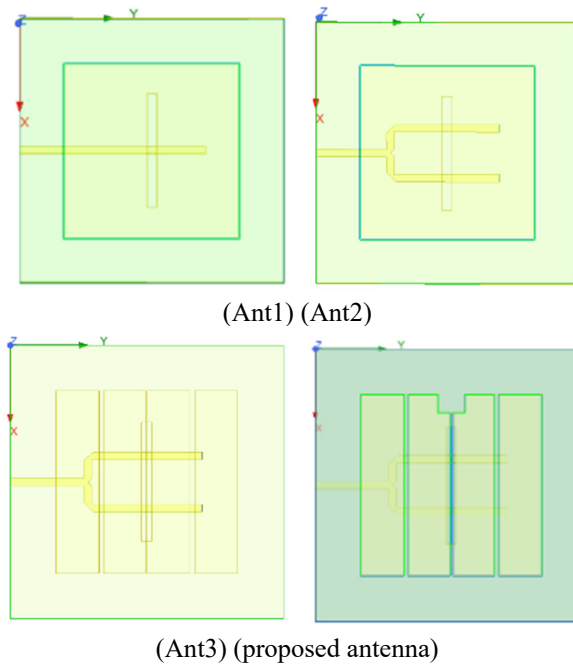


Figure 2. Structural evolution

Considering the discontinuity of the microstrip line, the elbow is chamfered, as shown in Figure 3.

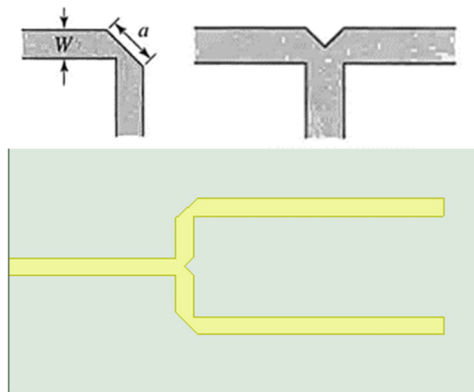


Figure 3. Right angle and T-shaped corner cutting treatment

2.4. Optimization analysis

The simulated reflection coefficient is shown in Figure 4. The coupling aperture and the size of microstrip feeder are optimized to achieve good impedance matching. As we can see, the bandwidth of the traditional microstrip slot antenna is very narrow. The bandwidth can reach 8% (5.48-5.88GHz) by

using Y-type feed. The bandwidth of the antenna can be greatly widened by using the slot hybrid structure, reaching 21.6% (4.64-5.72GHz). After the strip is optimized, for the proposed antenna, it achieves an impedance bandwidth of 4.48-5.60GHz, or 22.4% when the reflection coefficient is less than -10dB.

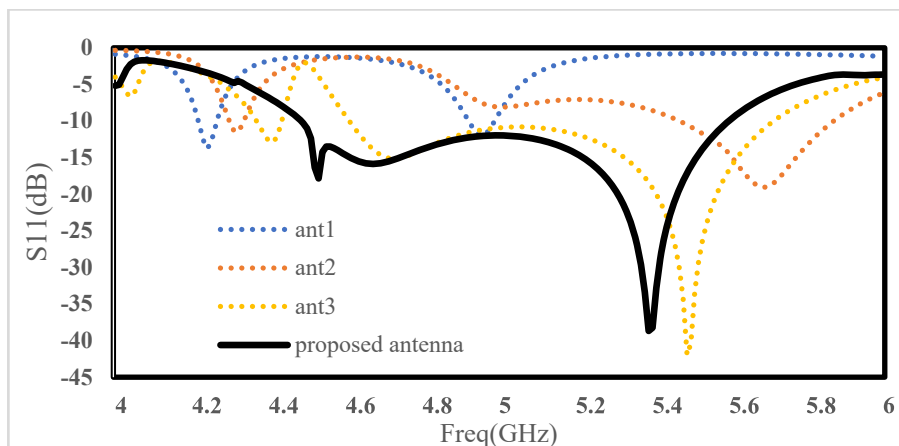


Figure 4. Reflection coefficient (S11)

3. Simulation Result

The optimized antenna model is simulated and analyzed in electronics desktop 2022 R1. The simulation results show that the gain is very high in the whole frequency band. As shown

in Figure 5, in the operating frequency band (4.48~5.60GHz), the gain range is 6.17~10.72dB. The gain is 6.0dB at 4.6GHz, 8.0dB at 5.0GHz and 10dB at 5.4GHz.

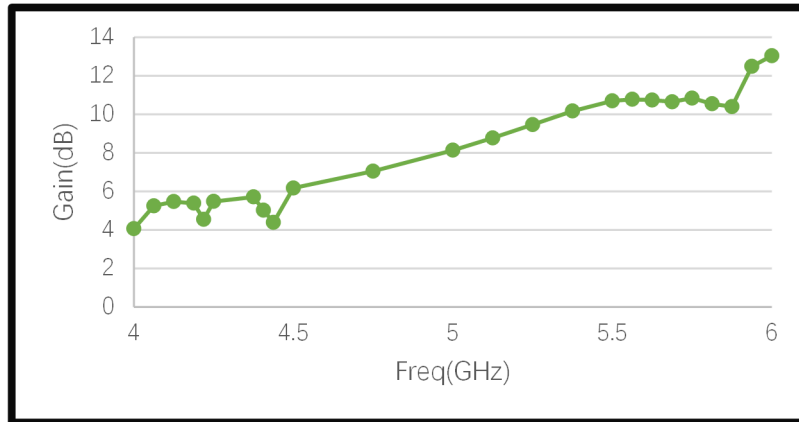


Figure 5. Radiation far field gain diagram

Figure 6 shows the far-field patterns of XZ plane and YZ plane simulated radiation of the proposed antenna at 4.6GHz, 5.0GHz and 5.4GHz operating frequencies. The results in figure 6 show that the maximum gain is obtained when theta

angle is 0 degrees. The measured radiation far-field pattern shows good radiation performance and remains stable in the whole working bandwidth.

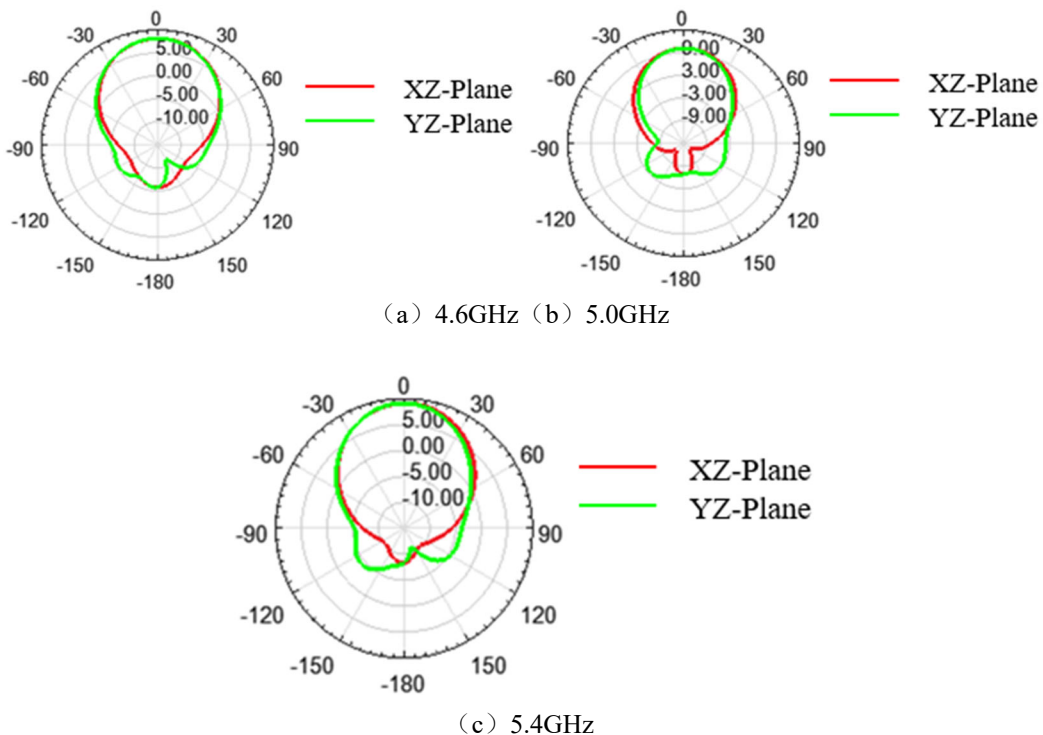


Figure 6. Radiation far field pattern

4. Conclusion

In this paper, a broadband low profile microstrip antenna with mixed slot structure is proposed. The bandwidth is increased to 22.4% (4.48GHz-5.60GHz). The antenna is composed of four strips separated by three narrow slots, and the middle two strips are specially slotted. The feed structure adopts aperture coupled Y-shaped microstrip line, and the excitation of the strip slot hybrid structure is realized by

optimizing the impedance matching. By controlling the size of strips and slots, various modes are excited and coupled to increase the working bandwidth. Compared with similar antennas [11-13], the antenna proposed in Table 1 achieves wider bandwidth and better gain. Due to the characteristics of broadband and low profile, the antenna with slot hybrid structure can be applied in modern wireless communication system.

Table 1. Antenna performance comparison

Literature	Impedance Bandwidth (GHz)	Relative bandwidth (GHz)	Gain (dB)
[11]	2.84-5.17	30	6.5
[12]	5.65-6.78	18	11.5
[13]	8.0-8.4	16	8.5
proposed antenna	4.42-5.72	22.4	10.72

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