A Dual-Band and Quadruple-Mode Circular Stacked Patch Antenna With Dual TM_{11} and TM_{12} Modes

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***Abstract*—This paper presents a novel wideband dual-band and quadruple-mode circular stacked patch antenna. The dual-band of the antenna comprises a low-frequency TM_{11} mode and a high-frequency TM_{12} mode, with both bands exhibited by dual resonant modes. A slot is opened in the upper patch at the position radiated by the TM_{11} mode, aiming to enable the TM_{11} mode to radiate from the gap. Fed directly through a coaxial line, the symmetric structure of the stacked antenna allows the antenna to generate two resonant points in both resonator bands.The gap in the upper patch excites both modes simultaneously Simulated results indicate that the antenna exhibits a TM_{11} mode impedance bandwidth of 18.6% from 4.72 GHz to 5.69 GHz and a TM_{12} mode impedance bandwidth of 11.8% from 6.38 GHz to 7.18 GHz.**

Keywords—dual band, dual mode, stacked patch antenna

I. INTRODUCTION

With the advancement of wireless communication, the division of spectrum resources continues to refine, indicating that wireless devices need the capability to operate across multiple frequency bands to access various services. However, spatial resources for wireless devices are limited. Therefore, compact antennas that support multiple frequency bands become crucial .[1][2] design multi-bands antennas using multi-patch structures. To avoid multipath effects and enhance communication quality, multi-band antennas are often designed with multi-polarization [3][4].

Another approach to designing multi-band antennas involves utilizing different modes of the antenna [5][6]. A single antenna can often excite multiple modes. By employing certain perturbation techniques to excite these modes within the desired frequency bands, multi-band antennas can be designed. This design approach often features a compact structure. Moreover, with different bands operating under different modes, interference between bands can be effectively minimized.

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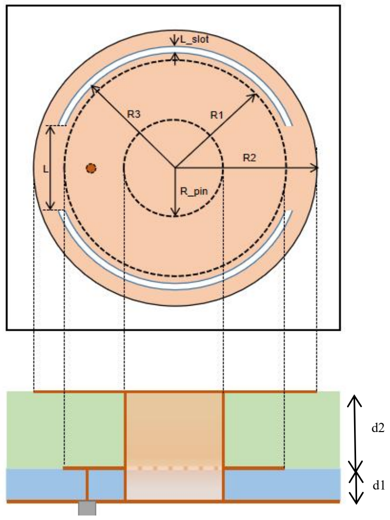

Fig. 1. *Top and side view of the proposed antenna*

II. ANTENNA DESIGN AND DISCUSSION

A. Antenna design

The top and side view of the proposed antenna structure are illustrated in Fig. 1. The antenna consists of two layers of circular patches with radius R1=9.4mm and R2=12mm, each printed on Rogers© 5880 material with a thickness of d1=0.87mm and dielectric constant ε=2.2 and Rogers© 3006 material with a thickness of d2=5.8mm and dielectric constant ε=6.15. In order to excite the TM_{11} mode of the antenna, a shorting post with a radius of R_pin=4.2mm is introduced.To simultaneously excite both the TM_{11} mode and the TM_{12} mode, two arc-slots are introduced with a width of L_slot=0.5mm, and an inner radius of R3=10.8mm. A 50-ohm coaxial feed line is connected directly to the bottom patch through a hole in the ground, allowing for convenient antenna processing and manufacturing. The optimal feeding point location can be determined through analysis.

B. perating Mechanism

In [7], a combination of two different dielectric constant materials is separately used for the lower and upper dielectric layers to design a stacked patch antenna with a wide band. By employing a substrate with a higher dielectric constant

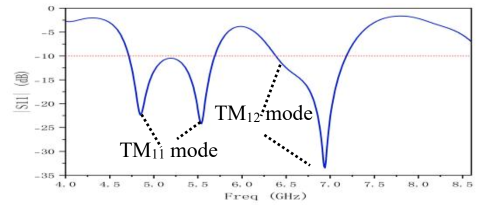

Fig. 2. *Simulated |S11| of the proposed antenna*

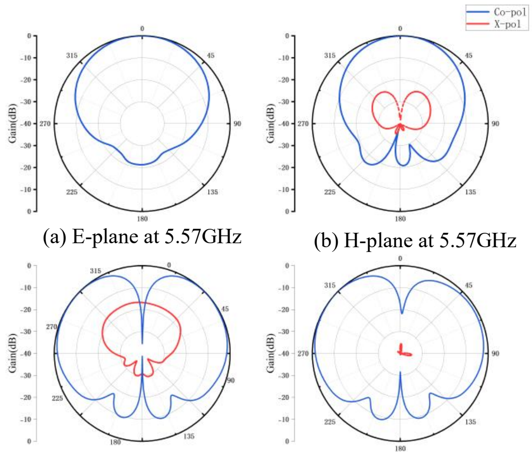

Fig. 3. *Simulated radiation patterns of the proposed antenna*

for the lower patch, over-coupling is achieved, while the upper patch utilizes a substrate with a lower dielectric constant, resulting in loose coupling between the upper and lower patches. In [8], a circular microstrip patch antenna with a coupling annular ring at the center feeding point is introduced. The coupling between the patch and the annular ring induces resonance frequencies, where varying the patch radius affects these frequencies. Drawing inspiration from this, the proposed structure also leverages similar principles. Experimental findings demonstrate that by adjusting the radius of the upper patch, different modes of resonance can be achieved. By slotting the upper patch, a ring structure is formed that couples with the patch, enabling the simultaneous excitation of the TM_{11} and TM_{12} modes on a single structure.

III. Results And Discussion

In the end, a dual-mode dual-band antenna has been designed. Fig. 2. displays the S11 parameter curve of the antenna. From the simulation results, it is evident that the antenna exhibits two resonant points in both upper and lower bands, with bandwidths of 18.6%(4.72GHz-5.69GHz) and 11.8%(6.38GHz-7.18GHz) respectively.Fig. 3. presents the radiation patterns of the antenna operating at 5.57GHz and 6.34GHz. Simulation results indicate that the TM_{11} mode exhibits broadside radiation characteristics, while the TM_{12} mode demonstrates higher directivity radiation properties. By examining the electric field distribution at 4.48GHz, 5.57GHz,6.34GHz and 7.04GHz, as shown in Fig. 4. ,it is observed that at 4.48GHz and 5.57GHz, the antenna resonates in the TM_{11} modes, while at 6.34GHz and 7.04GHz, the antenna operates in the TM_{12} modes.This indicates that the antenna structure can simultaneously excite the two modes of interest.

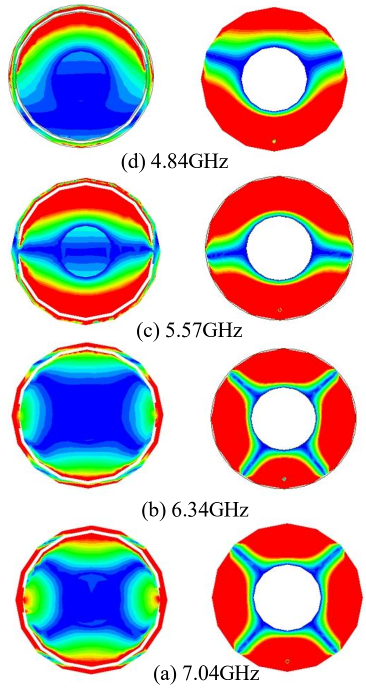

Fig. 4. *E-field distribution of the proposed antenna*

IV. Conclusion

This paper introduces a novel circular stacked patch antenna design that excites the TM_{11} and TM_{12} modes, exhibiting dual-band dual-mode characteristics at 4.72GHz-5.69GHz and 6.38GHz-7.18GHz. Additionally, there are two resonant points within each frequency band. The dual-frequency points within each band are generated by the upper and lower stacked patches individually, whereas the dual-mode excitation is achieved by introducing a slot structure in the upper patch.

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