Design of Stable High-Gain Multiband Circular Microstrip Antenna

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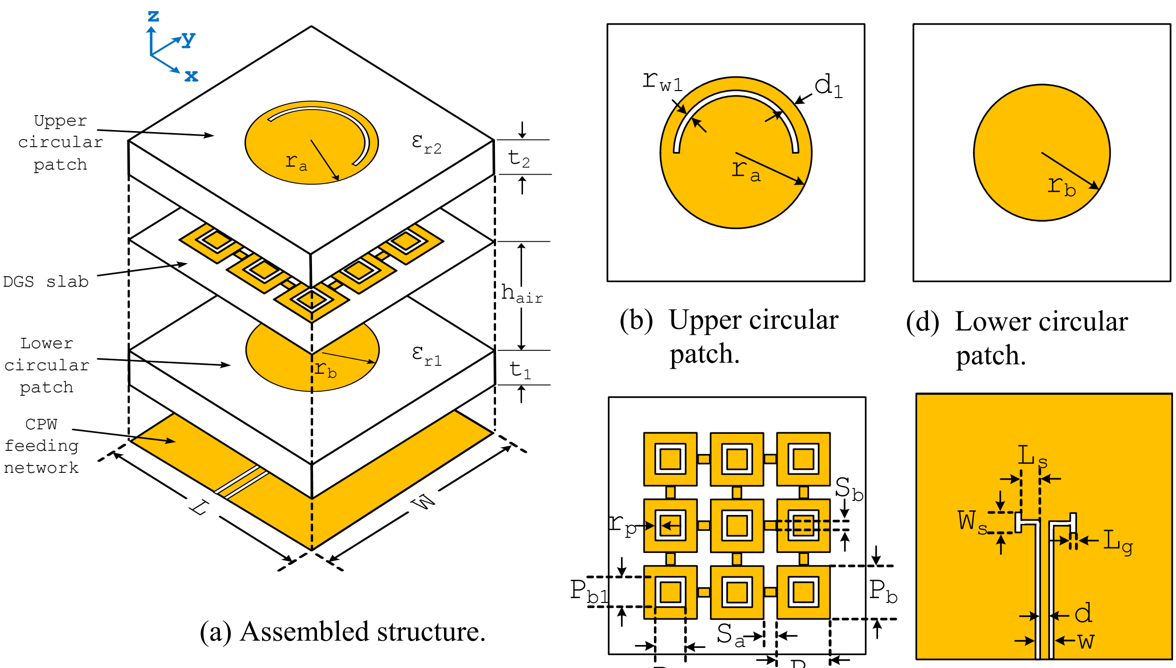
1. Introduction

Some recent investigations on multiband microstrip antennas have been focused upon obtaining the frequencies of interest, however, much less attention is paid to obtain a relatively stable high-gain [1], [2]. A single-layer circular microstrip antenna with 2-D defected ground structure (DGS) was reported to obtain the stable gain [3]. However, it might be difficult to increase the gain of this antenna because the gain is much dependent upon the material constants such as a dielectric of the substrate and a conductivity of the metal surfaces. It is also quite difficult to control the material constants effects [4]. Otherwise, one can design a high radiation efficiency antenna. Once it can be realized, the afterward problem is that the reflection loss should be minimized. This method is less difficult than the previous method [3] since there are some available methods that have been reported to obtain a good impedance matching. The stacked microstrip antenna configuration has been recognized as an effective method to enhance the antenna bandwidth with a relatively high-gain. A stacked rectangular microstrip antenna excited by coplanar waveguide (CPW) was reported to realize the bandwidth of approximately 23% (VSWR<2) [5]. The antenna gains reach around 8.0 dBi with a stable performance over the bandwidth.



(a) Assembled structure.

(b) Upper circular patch.

(c) DGS slab.

(d) Lower circular patch.

(e) CPW feeding network.

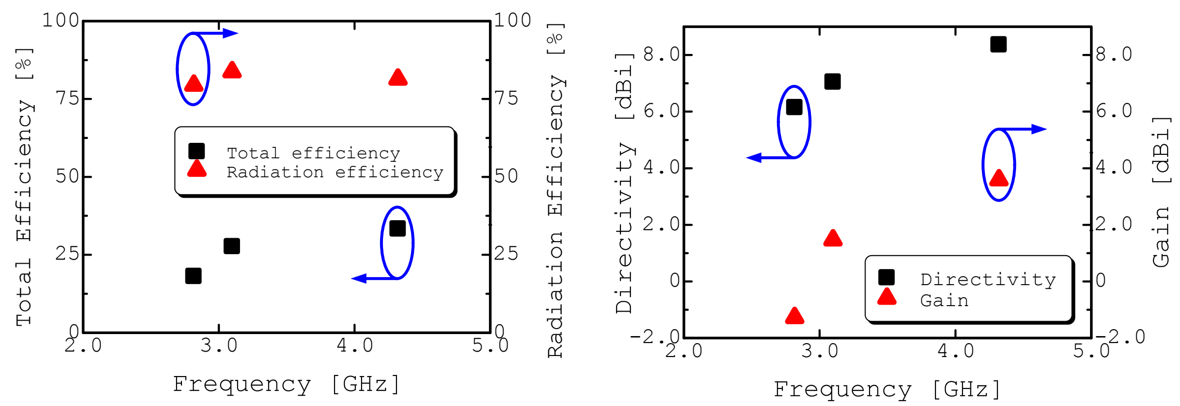
[r_a = 11.10, r_b = 10.0, h_{air} = 5.0, L_s = 5.35, W_s = 5.0, L_g = 2.0, w = 3.40, d = 1.40, r_{w1} = 0.75, d_1 = 0.50, P_a = P_b = 10.0, P_{a1} = P_{b1} = 5.0, r_p = 0.50, S_a = 1.0, S_b = 2.0, L = W = 60.0, t_1 = t_2 = 1.2, [unit : mm], ε_{r1} = ε_{r2} = 2.6]

Figure 1: Circular microstrip antenna with one half-ring slot.

This paper presents novel multiband stacked circular microstrip antennas with one half-ring slot and with two half-ring slots. The objective of this paper is reducing the reflection loss to realize a stable high-gain performance of the multiband circular microstrip antenna. The 2-D defected ground structure (DGS) slab is introduced to reduce the reflection loss and hence, increasing the antenna gains. The circular microstrip antenna with one half-ring slot is demonstrated to realize triple frequency bands. Moreover, the circular microstrip antenna with two half-ring slots is presented to verify that the stable high-gain of around 8.0 dBi can still be obtained at the new excited frequency. Experiments were conducted to verify the estimated results obtained by IE3D. Good agreements between the measured and simulated results are confirmed. Thus, the proposed antennas are promising candidates for multiband microstrip antenna applications.

2. Circular Microstrip Antenna with One Half-Ring Slot

Structure of the circular microstrip antenna with one half-ring slot is shown in Figure 1. The antenna is composed of two PTFE substrates with $\varepsilon_r = 2.6$, $\tan\delta = 0.0018$, and 1.2 mm thickness. An air gap h_{air} of 5.0 mm separates these two substrates. The air gap has a strong influence on controlling the coupling between the upper and lower patches. The circular microstrip antenna with a radius r_a has one embedded half-ring slot and is printed on the topside of the upper layer. In addition, the circular microstrip antenna with a radius r_b and a CPW feeding network are printed on the top and bottom side of the lower layer, respectively. Figure 2 shows the total efficiency, the radiation efficiency, directivity, and gain of the circular microstrip antenna with one half-ring slot without DGS slab. Figure 2 (a) reveals that the conduction loss and dielectric loss are relatively low at the frequencies of interest. However, the total efficiency is only around 25% in average. Figure 2 (b) shows that there is no severe problem in Half-Power Beamwidth (HPBW) of the antenna. These facts conclude that the antenna gain is much dependent upon the reflection loss of the antenna. To reduce the reflection loss, the 2-D defected ground structure (DGS) slab is inserted between the two circular patches and is printed on the bottom side of the upper layer, as shown in Figure 1 (a).



(a) Total and radiation efficiencies (sim.).

(b) Directivity and gain (sim.).

Figure 2: Total efficiency, radiation efficiency, directivity, and gain of the circular microstrip antenna with one half-ring slot without DGS slab.

As a result, the total efficiency is increased to be around 85% in average. Thus, the antenna gain is increased to be around 8.0 dBi at each of the excited frequencies, as shown in Figure 3. The return loss characteristic of the proposed antenna is shown in Figure 4. Triple frequencies of 2.8, 3.09, and 4.32 GHz are obtained. The current distributions of the upper circular patch at the 1st and 3rd modes are observed to have a similar behaviour as the reported circular microstrip antennas [6]. On the other hand, the current distribution of the 2nd mode behaves almost like it observed for the 1st mode. The 3rd mode can be tuned by adjusting the distance d_1 properly. A broadside radiation pattern is also obtained at each of the frequencies of interest. Good agreement between the measured and simulated results is confirmed.

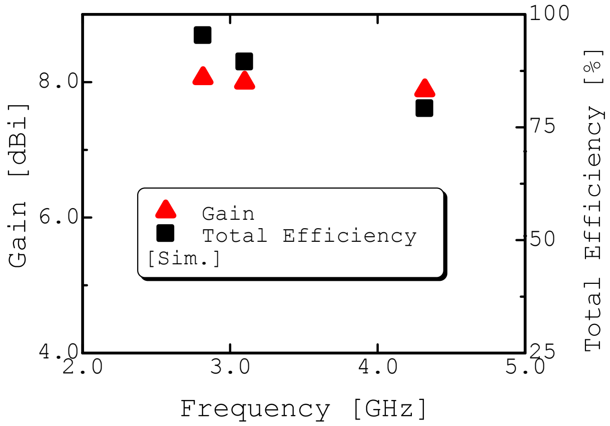


Figure 3: Antenna gain and total efficiency (sim.).

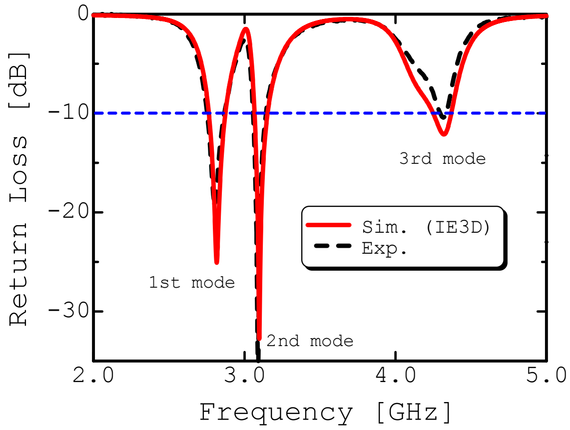


Figure 4: Return loss characteristic.

3. Circular Microstrip Antenna with Two Half-Ring Slots

Circular microstrip antenna with two half-ring slots is presented in this section to verify that the stable high-gain of around 8.0 dBi can still be obtained at the new excited frequency. It could be possible that the new frequency has the high-gain if the reflection loss is successfully reduced. The configuration of the proposed antenna is the same as the previous section of one half-ring slot. The additional slot has the width r_{w2} and is set to be the same as the slot width r_{w1} of the previous design. The structure and the dimensions of the proposed circular microstrip antenna with two half-ring slots are shown in Figure 5.

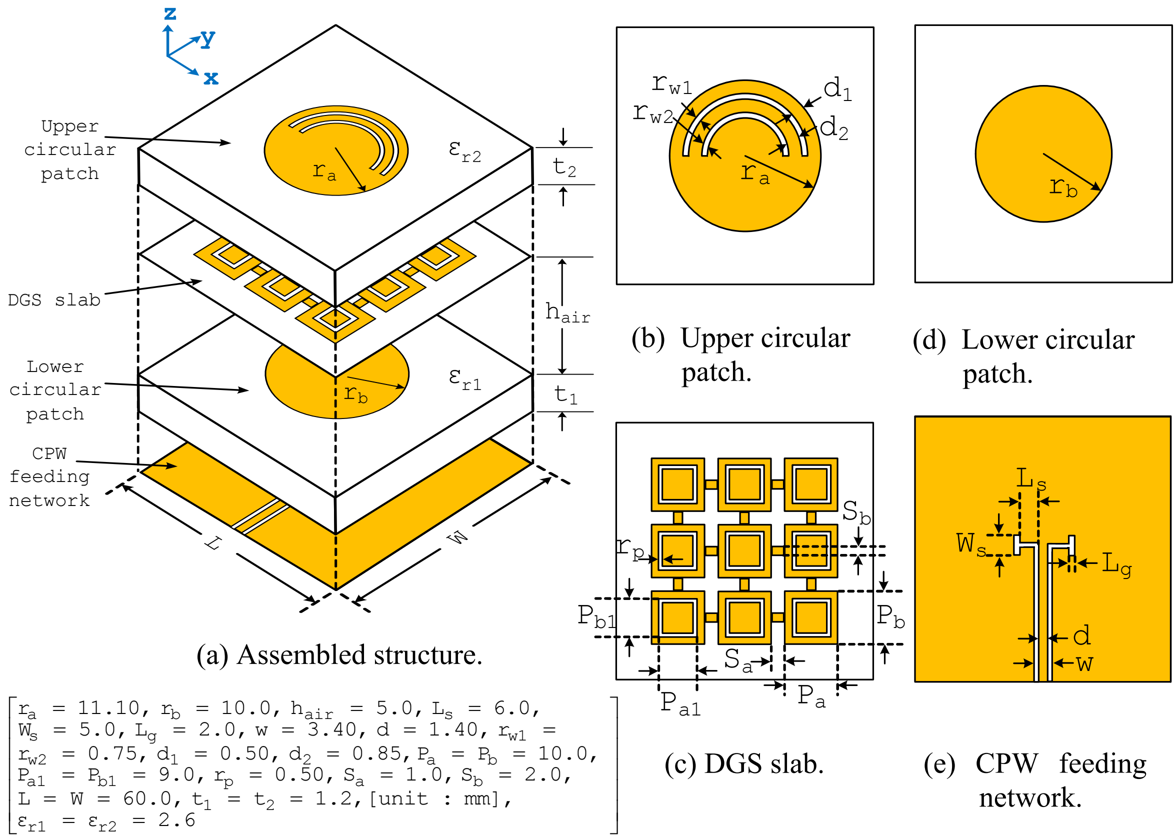


Figure 5: Circular microstrip antenna with two half-ring slots.

The return loss characteristic of the proposed circular microstrip antenna with two half-ring slots is shown in Figure 6. Four resonant frequencies are obtained in the range between 2.0 and 5.0 GHz. The current distributions observed for the 1st, 2nd, and 3rd modes have similar behaviour to those of the circular microstrip antenna with one-half-ring slot. The current distribution observed for the 4th mode is concentrated around the new embedded slot. The frequency of the 4th mode can be tuned by adjusting the distance d_2 properly. Good agreement between the measured and simulated results is confirmed. The total efficiency and gain are shown in Figure 7. The total efficiency reaches at least around 75%. Broadside radiation patterns are also obtained at the excited frequencies. The stable high-gain of around 8.0 dBi can also be obtained.

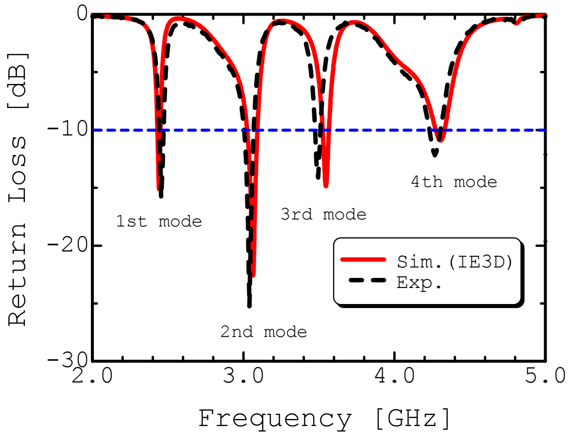


Figure 6: Return loss characteristic.

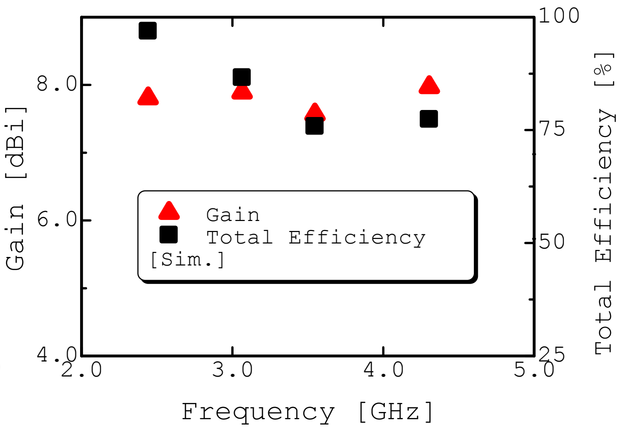


Figure 7: Antenna gain and total efficiency (sim.).

4. Conclusion

Novel stacked circular microstrip antennas with one and two half-ring slots for a stable high-gain multiband performance have been presented. The 2-D defected ground structure (DGS) slab is introduced to reduce the reflection loss. Thus, the stable high-gain of around 8.0 dBi can be obtained at each of the frequency of interest. Good agreement between the measured and simulated results is obtained. The proposed antennas can then be considered as promising candidates for multiband microstrip antenna applications.

References

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