Multilayer Structure Study of A Rectangle Ring Slot Aperture Coupled Antenna

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Abstract: In this paper, a novel rectangle ring slot aperture coupled antenna for 2.45 GHz wireless communication is presented. The aim is to show the effects what multilayer structure made to further study the influence of the change of the substrate height and the dielectric constant. Another Flame Retardent 4(FR-4) substrate antenna is studied compared with the original felt substrate antenna. Details of the results are presented.

1. Introduction

D.M Pozar first proposed an aperture coupled microstrip antenna, the feed line and the radiation patch can be isolated by use of a common ground plane, it also overcome the inductance effect caused by the traditional feeding mode and the parasitic radiation of the feed network[1]. However, the limited bandwidth is their major weakness for the application. After decades of hard efforts, a lot of methods were came out to increase the bandwidth of the aperture coupled antennas, such as the use of multiplayer structure, change the dielectric constant, the feed structure or the slot structure, etc[2-4].

In this letter, an aperture coupled antenna with a 50Ω U-shaped feed line and a rectangle ring slot for 2.4GHz application is presented. At the beginning, a parameter of W_2 has been studied to know the performance by changing the length of the slot. Then the designed aperture coupled antennas with the offer of different numbers of flexible felt layers are compared[5]. Furthermore, another antenna with layers of the FR4 substrate is proposed on the basis of this paper designed. The design and comparisons will be showed in detail. All simulations have been done by CST microwave studio software based on the method of finite integration technology(FIT).

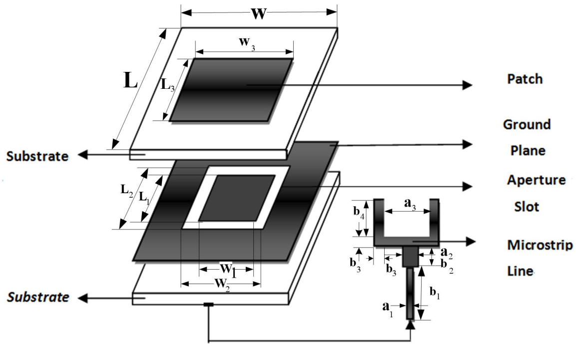


Figure 1: Structure and design parameters of antenna.

2. Description of Antenna Configuration

As shown in Figure 1, the geometry of the proposed antenna consists of three copper foil tape layers (CFT, 0.05 mm thickness) separated by two felt substrate layers with the relative permittivity of 1.2 (2 mm thickness). In the top is a CFT radiation patch, the middle CFT layer is the ground plane and a novel rectangle-ring slot is inserted ensuring electromagnetic coupling between the feed line and the radiation patch. A U-shaped feed line is located at the bottom of the overall substrate. The total size of the antenna is W×L. The width of the feed line is designed as a_1 to achieve 50Ω characteristic impedance. Figure 3 shows the cross-sectional view of the proposed antenna. All the parameters have been optimized to have an efficient design and listed in Table 1.

Table 1: Dimensions of the proposed felt substrate antenna. All dimensions are in millimeters.

Parameter	Value	Parameter	Value	Parameter	Value
W	60	b	20	L_2	33
L	60	b_2	5	L_3	40
a_1	1	b_3	2	W_1	12
a_2	2	b_4	8	W_2	23
$a_{3.}$	12	L_1	20	W_3	31

3. Parametric Study of Antenna

In this paper, an important parameter W_2 has been studied. By varying the length of the rectangle ring slot, it can be seen that the resonance frequency of the proposed antenna is displaced. Along with the increase of the slot length, the resonance frequency will shift to left toward the lower frequency and also, the bandwidth become wider, but the matching effect will be worse. After many parameter adjustments, it is clearly seen that the coupling can be successfully achieved for the case of W_2 =16.5mm. The simulated results are shown in Figure 2.

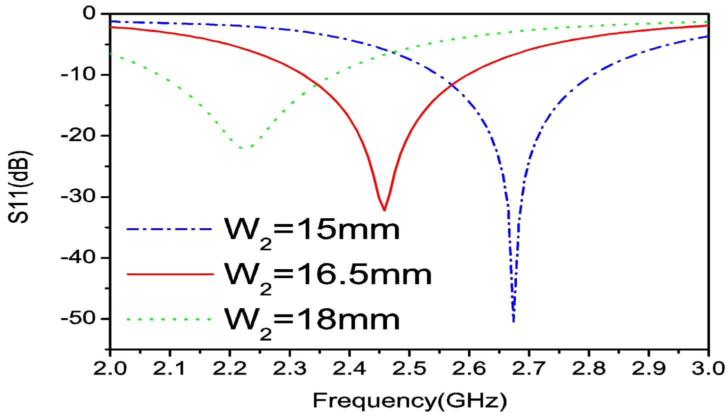


Figure 2: Effect of changing W_2 on return loss.

4. Multilayer Structure Research

It has been well known that thick substrates with low permittivity provide wider bandwidth and result in a larger antenna design. On the contrary, thin substrates with high dielectric constant lead to smaller bandwidth and dimension[6-7]. In this section, the structure of the antenna will be discussed. It can be seen from Figure 3 that three kinds of antenna structures are showed. The main difference is the numbers of 2mm thickness felt layers between the radiation patch and the ground plane. Such as in Figure 3(a), there is one felt layer and its height h_2 is 2mm, then the antenna structure in Figure 3(b) has two felt layers in the same place and a 4mm height, Figure 3(c) shows three felt layers.

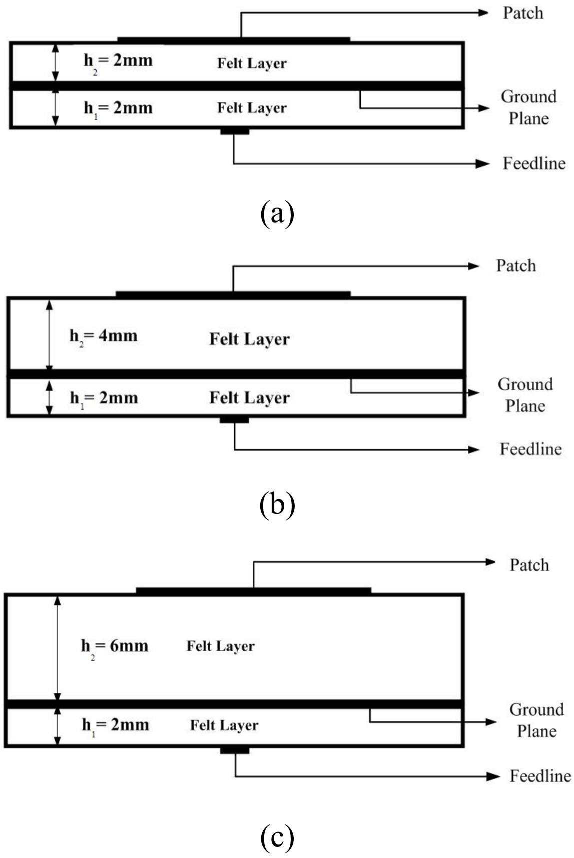


Figure 3: Cross-sectional views of structure with different h_2.

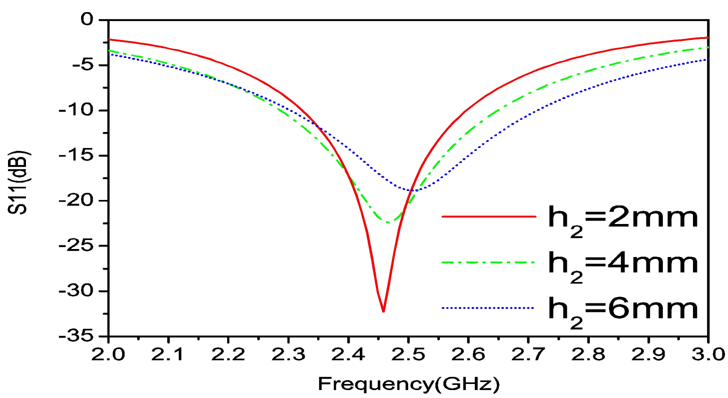
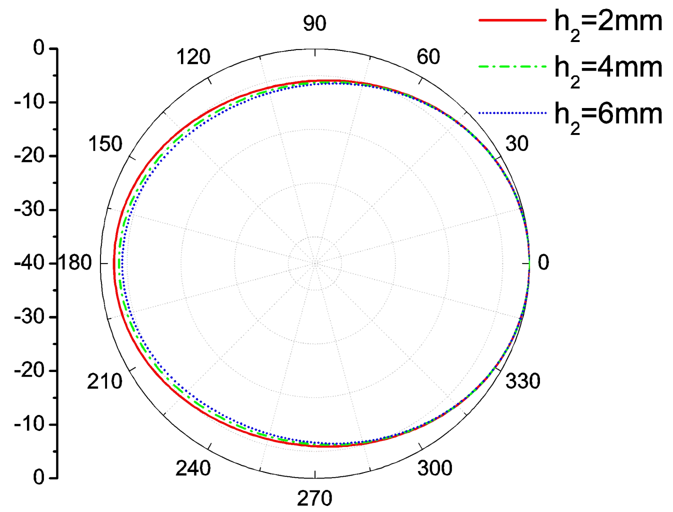
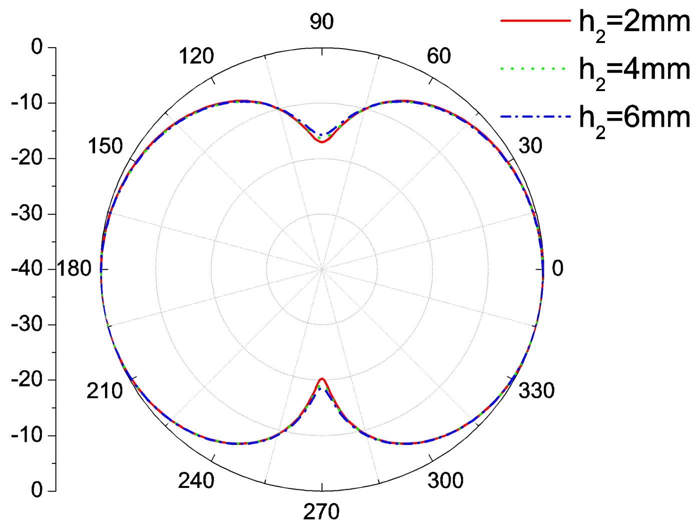


Figure 4: Variation of return loss for different h_2.

The variation of return loss for different h_2 is exhibited in Figure 4, it is shown that the bandwidth will broaden along with the growing height of h_2, but the impendence matching will be dramatically reduced. The proposed antenna radiation patterns in the x-z plane (H-plane) and x-y plane(E-plane) at 2.45 GHz in the case of h_2 is 2,4,6mm are plotted in Figure 5 respectively. Figure 5(a) shows the radiation patterns are approximately omni-directional in the x-y plane and they are similar to each other under the condition of different h_2 . Figure 6 shows the realized gain from 2 GHz to 3 GHz. From the observation of the result, a higher gain will be got when h_2 =6 mm, this match with the S_{11} performance. The gain increase when the slot is away from the patch.



(a)



(b)

Figure 5: Simulated radiation patterns at 2.45GHz in case of different h_2 . (a)x-z. (b)x-y.

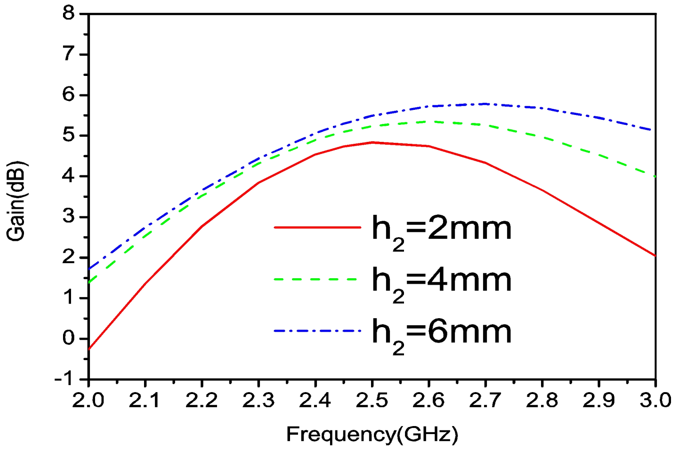


Figure 6: Simulated realized gain in case of different h_2.

In order to study the quality influence of different dielectric materials for the antenna, a substrate named FR4 with the relative dielectric constant of ε_r =2.78 and the thickness of h=0.8mm has been used to replace the felt substrate. The FR4 substrate antenna has the same structure as Fig.1, except the dimensions. Detailed dimensions are shown in Table 2.

5. Substrate Research

Table 1: Dimensions of the proposed FR4 substrate antenna.

Parameter	Value	Parameter	Value	Parameter	Value
W	30	b	10	L_2	20.2
L	30	b_2	2.5	L_3	20
a_1	0.5	b_3	1	W_1	6
a_2	1	b_4	6	W_2	10.5
$a_{3.}$	4	L_1	10	W_3	15

Figure 7. shows the compared return loss of the proposed antennas with the felt substrate and the FR4 substrate, both of them can obtain a good impedance matching, but most obviously the felt substrate has a much wider bandwidth. Figure 8 exhibits the radiation patterns in the x-y plane from two kinds of antennas. The patterns are still similar, only there is a little attenuation when the antenna is made up with FR4 substrate.

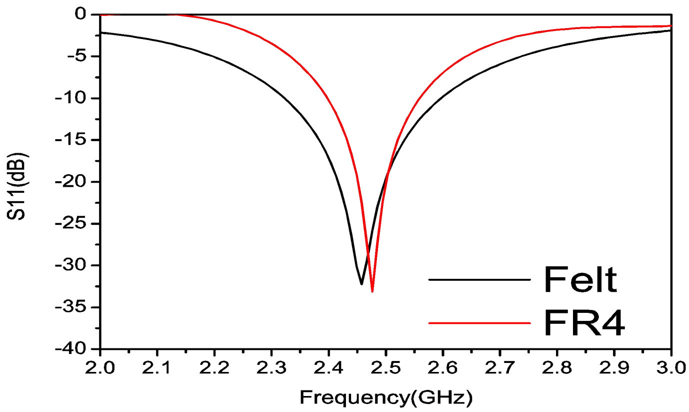


Figure 7: S_{11} of aperture coupled antenna on felt substrate and the antenna on FR4 substrate.

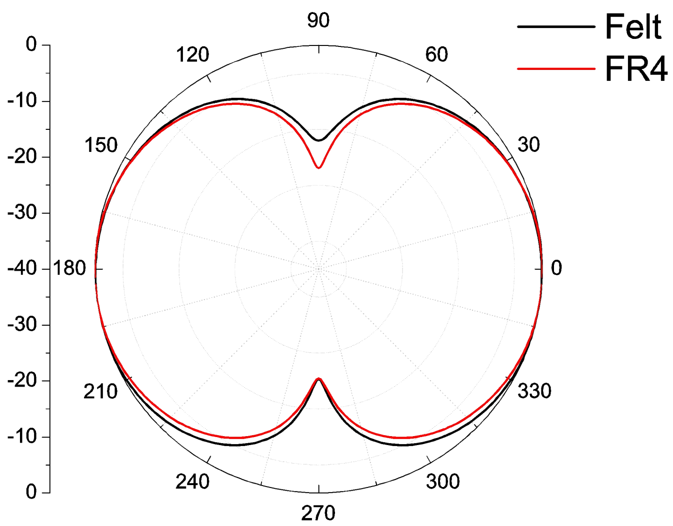


Figure 8: Radiation patterns in x-y plane of aperture coupled antenna on felt substrate and the antenna on FR4 substrate.

6. Conclusions

A rectangle ring slot aperture coupled antenna has been discussed to know its performances in different situations. From this paper, it can come to the conclusion that a multilayer structure will broaden the antenna bandwidth, but also need a larger design. FR4 substrate antenna has a higher dielectric constant and a smaller size as compared to felt substrate, however, its bandwidth seems narrower.

Acknowledgments

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