A Compact Planar Diplexer Using Common Dual-Mode Rectangular Patch Resonators

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***Abstract*—In this paper, a third-order planar diplexer is proposed by using common dual-mode rectangular patch resonators. Compared with the traditional diplexer, there is no any connection-oriented junction network, which leads to a small size of the diplexer. There are two orthogonal resonant modes for each resonator. One mode is used as channel I, the other is used as channel II. The coupling coefficient of other channel is analysis. The desired external quality factor can be obtained by selecting the appropriate location of the input port. In addition, a pair of perpendicular slots are at the center of each resonator in order to reduce the insertion loss. For channel I, the measured insertion loss at a center frequency of 2.65 GHz is about 1.6 dB with a fractional bandwidth of 9.3%. For channel II, the measured insertion loss at a center frequency of 2.13 GHz is about 1.9 dB with a fractional bandwidth of 8.6%.**

***Index Terms*—dual-mode rectangular patch resonator, planar diplexer.**

I. Introduction

With the development of wireless communication systems, diplexers play an important role in the RF front-end module. More and more diplexers have been applied in the base station of wireless communication, especially cavity diplexers. But cavity diplexers are heavy and not suitable for integration. For the convenience of integration, various planar diplexers have emerged. Among these planar diplexers, a connection-oriented junction network is used, e.g. a T-junction or a Y-junction at the common port, which leads to a large size of diplexer [1]-[3]. Later, using a dual-mode resonator as a common port has become popular for a more compact size [4], [5]. In [4], by increasing the strength of disturbing, the resonant frequencies of two modes are split far away from each other in order to form up two channels. Moreover, the diplexer uses vertical stacking technology to further reduce the size, but the complexity increases. In [5], the substrate integrated waveguide diplexer is achieved by sharing a dual-mode (TE_{101} and TE_{201}) resonator for miniaturization. In [4] and [5], there are two separated filter channels to achieve diplex, which increases the size of the diplexer. As we all know, the disadvantage of using a patch resonator to form a filter is the large radiation loss. In [6] and [7], a pair of crossed slots are etched on the patch resonator, which can reduce the size and radiation loss.

In this paper, in order to further reduce the size, a third-order planar diplexer by using common dual-mode rectangular patch resonators is proposed. Each resonator exists two resonant modes. One mode is used as channel I, and the other is used as channel II. The two channels share a resonator for miniaturization, which reduces the number of resonator. Moreover, a pair of crossed slots on each resonator is used to reduce radiation loss.

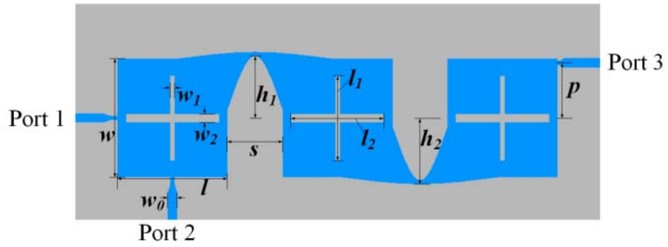

Fig. 1. Geometrical structure of the proposed planar diplexer. w = 28, l = 26, w_0 = 2.2, w_1 = 1, w_2 = 2, l_1=20, l_2=22, h_1=14.7, h_2=15.6, p=13, s=13. All in mm.

II. Geometry, Analysis and Design

Figure 1 shows the geometry of the proposed planar diplexer consisting of three dual-mode rectangular patch resonators. Each resonator has two resonant modes, which are used to form up two channels. Mode 1 with the resonant frequency of f_1 is used to form up upper channel, and mode 2 with the resonant frequency of f_2 is used to form up lower channel. In Fig.1, l and w indicate the length and width of a rectangular patch, respectively. Moreover, f_1 and f_2 are determined by l and w respectively. Adjacent resonators are appropriately coupled by using an arc structure in order to obtain the required coupling coefficient. As shown in figure 1, h_1 and h_2 represent the vertical distance from the lowest and highest point of the arc-shaped coupling structure to the center of the resonator, respectively. By changing the values of h_1 and h_2, a suitable coupling coefficient can be obtained between adjacent resonators. P represents the vertical distance from the center of the input port to the center of the resonator in Fig. 1. As the value of p changes, the external quality factor of both channels of the diplexer also changes. In addition, in order to reduce the radiation loss of the resonator, each resonator has a pair of mutually perpendicular slots. W_i and l_i (i =1, 2) respectively represent the width and length of the slot. When the length and width of the resonator are fixed, the resonant frequency of the two modes can be independently controlled by the length of the slot. In Fig. 2, it

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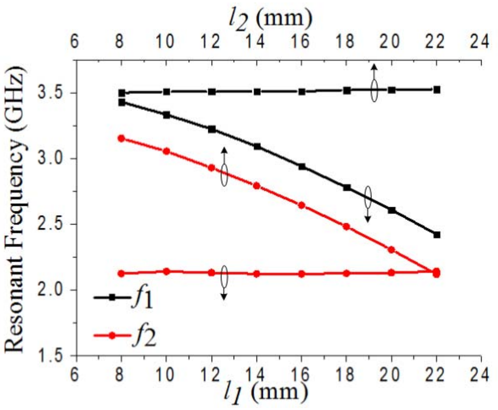


Fig. 2. Resonant frequency as a function of l_i (i=1, 2).

can be seen that as the value of l_1 (l_2) increases, the resonant frequency of f_1 (f_2) decreases but the resonant frequency of the orthogonal mode f_2 (f_1) keeps almost constant. Therefore, the size of the resonator with slots can be smaller than those without slots at the same operating frequency.

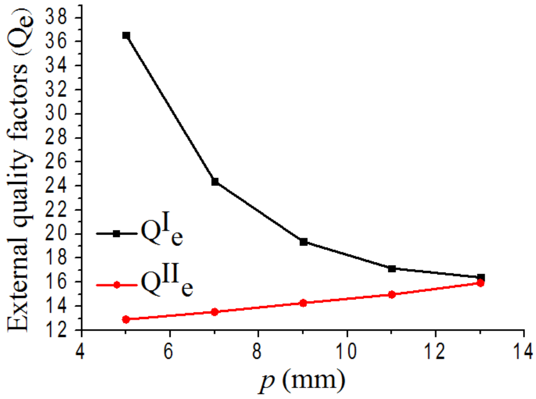
The operating frequencies of the diplexer are f_1=2.65 GHz and f_2=2.13GHz. Each filter channel of the diplexer is synthesized with the third-order Butterworth prototype. The element values of the Butterworth low-pass filter prototype can be found in [8]. Fig. 3 shows the change of external quality factor for different ports, and Fig. 4 depicts the variation of coupling coefficient (k) with different h_i (i=1, 2). The superscripts I and II in Figure 3 and Figure 4 represent the upper channel and the lower channel, respectively. In Fig. 3(a), it can be seen that as the value of p increases, Q^{I}_e decreases greatly but Q^{II}_e increases. When the value of p is approximately equal to 13 mm, the external quality factors of the two channels are approximately the same. In Fig. 3(b) and Fig. 3(c), it can be seen that as the values of l_i and w_i (i=1, 2) increase, Q^{I}_e and Q^{II}_e both decrease. It can be seen from the curves in Fig. 4 that as the value of h_2 increases, k^{I} and k^{II} both increase, but as the value of h_1 increases, k^{I} and k^{II} both decrease. When the fractional bandwidth (FBW) of the two channels are given, the theoretical k and Q_e of each channel can be calculated by

$$k^i{}_{12} = \frac{\mathrm{FBW}^i}{\sqrt{g^i{}_1 g^i{}_2}}, \; i = 1, 2. \qquad (1)$$

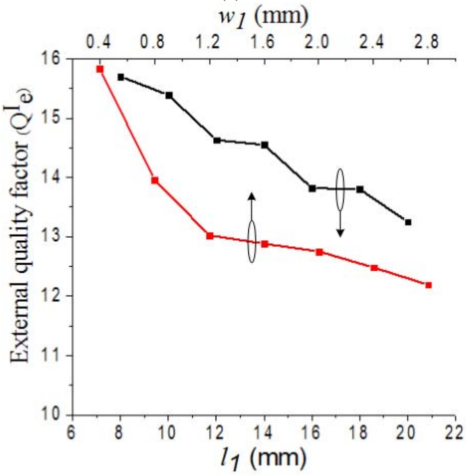
$$k^i{}_{23} = \frac{\mathrm{FBW}^i}{\sqrt{g^i{}_2 g^i{}_3}}, \; i = 1, 2. \qquad (2)$$

$$Q^i{}_e = \frac{g^i{}_0 g^i{}_1}{\mathrm{FBW}^i}, \; i = 1, 2. \qquad (3)$$

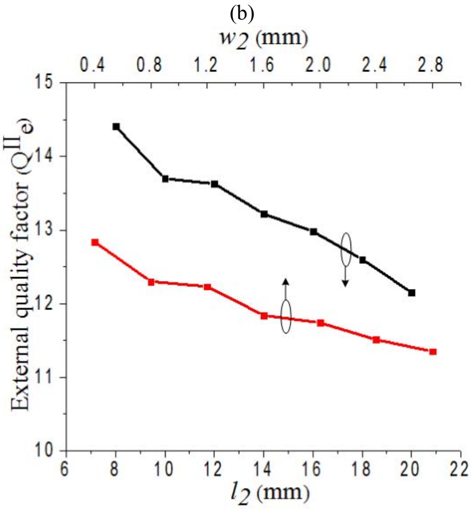
where k_{12} (k_{23}) represents the coupling coefficient between the first (second) resonator and the second (third) resonator. According to [8], g_1 is equal to g_3, so k_{12} is equal to k_{23}. The corresponding physical dimensions can be obtained through the design curves in Figure 3 and Figure 4.



(a)



(b)



(c)

Fig. 3. Variation of Q_e for different ports. (a) Port 3, (b) Port 1, (c) Port 2.

III. Simulated and Measured Results

Based on above theoretical analysis, a third-order planar diplexer with the operating frequencies of 2.65 GHz and 2.13 GHz is designed. First of all, the diplexer with slots is simulated by using electromagnetic simulation software CST. Fig. 5 shows the electric field distribution of the diplexer with slots. Finally, as shows in Fig. 6, the proposed diplexer with slots is

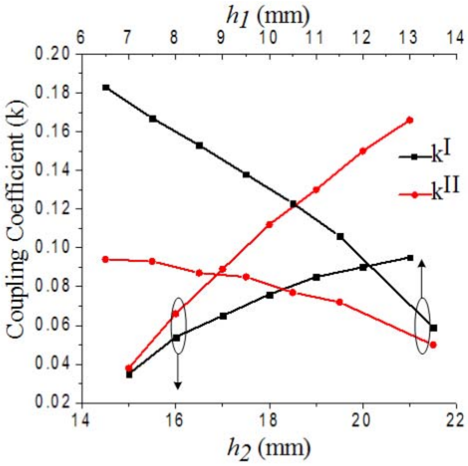
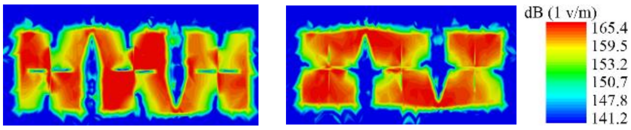


Fig. 4. Variation of *k* under different h_i (i=1, 2).



(a) (b)

Fig. 5. Electric field distribution of the diplexer with slots. (a) The operating frequency (f_1) of 2.65 GHz, (b) the operating frequency (f_2) of 2.13 GHz.

fabricated on the substrate with a relative permittivity of 2.55, a loss tangent of 0.0029, and a thickness of 0.8 mm. The optimized parameters are given: w = 28, l = 26, w_0 = 2.2, w_1 = 1, w_2 = 2, l_1=20, l_2=22, h_1=14.7, h_2=15.6, p=13, s=13, (all in mm). Fig. 7 shows the simulated and the measured results. For channel I, at the center frequency of 2.65 GHz, the measured insertion loss is about 1.6 dB with the fractional bandwidth of 9.3%. For channel II, at the center frequency of 2.13 GHz, the measured insertion loss is about 1.9 dB with the fractional bandwidth of 8.6%. For both channels, the measured return loss are more than 10 dB. The measured results agree with the simulated results.

IV. Conclusion

In this paper, a compact third-order planar diplexer by using common dual-mode rectangular patch resonators is proposed. This diplexer has no any additional connection-oriented junction network, which greatly reduces the size of the diplexer. Each resonator has two resonant modes which are used to form up channel I and channel II. By using proper coupling structure and adjusting the position of input port, the desired coupling factor and external quality factor can be obtained, respectively. In addition, each resonator has a pair of orthogonal slots at its center in order to reduce the insertion loss. The measured results are in good agreement with the simulated results.

Acknowledgment

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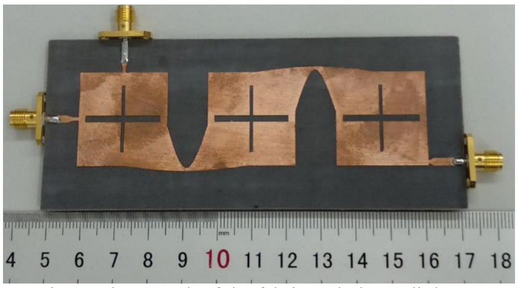

Fig. 6. Photograph of the fabricated planar diplexer.

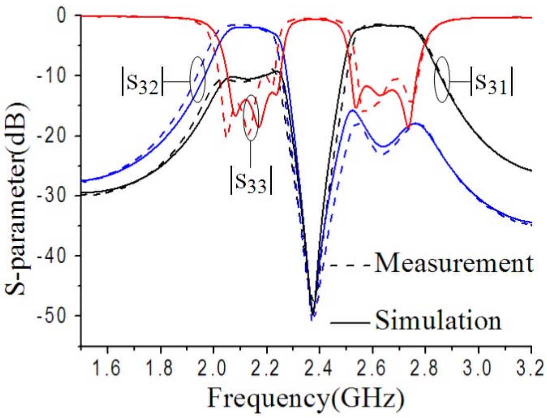

Fig.7. Simulated and measured results of the proposed diplexer.

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