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Ring Based Planar Crossover for Beamforming Networks

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Abstract

A crossover maintains signal integrity when transmission lines overlap. In this paper, a microstrip patch is used to design the overlapping region thus providing desired isolation and transmission between desired ports. Square and Circular patch configurations for crossovers are analysed using ANSYS HFSS. The basic microstrip patch is further modified by introducing fractals enhancing the electrical length and improving the crossover characteristics.

Keywords: crossover; isolation; fractals; microstrip patch

1. Introduction

Microwave crossovers are passive devices that helps in maintaining the signal purity when transmission lines overlap. Crossovers are traditionally designed using wire bond or air bridges which are difficult to fabricate [1, 2]. Planar crossovers are highly preferred when there is importance in packaging, multichip circuits, and other planar subsystems. Planar crossovers were designed using microstrip lines with ring resonators or patch resonators [3, 4].

A typical crossover when two transmission lines overlap is shown in Fig 1. For signal purity, the overlapped region has to be modified thus providing isolation between adjacent ports and transmission between opposite ports.

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A simple planar symmetric crossover with square patch is presented in [5]. This crossover can be designed using conventional patch antenna design. For improvement of characteristics Sierpinski gasket is found to enhance the crossover properties [6].

In this paper, the overlapped region is modified as microstrip patch. Both square and circular patches are analysed for crossover characteristics and is presented in following sections.

### 2. Design of Microstrip Patch Based Crossover

In the present study the overlapped region of the transmission lines is modified as microstrip patch - square and circular in geometry to provide desired isolation between the adjacent ports and transmission between opposite ports as shown in Fig. 2. The position of microstrip feed line decides the isolation provided by the patch based crossover. The feed location is selected in such a way that the adjacent ports transmit or receives orthogonal polarization, thus providing isolation between the ports. The opposite ports being in same polarization will transmit/receive the signal between them. The designed crossover is symmetric and reciprocal and the feed lines are designed for 50Ω. So transmission is observed as $S_{13} = S_{31}$ and $S_{24} = S_{42}$ while isolation is observed as $S_{12} = S_{21}$, $S_{14} = S_{41}$, $S_{23} = S_{32}$, $S_{34} = S_{43}$.

The patches are designed using standard equations in [7] on RT Durod 6010 with dielectric constant $\varepsilon_r=10.2$ and thickness, $h = 0.64$ mm. For square patch crossover, length, $L$ and for circular patch crossover, radius $R$ is designed for 2.45 GHz. The isolation obtained for both the designs presented in Fig 2 is -12 dB and -15 dB for square and circular patch respectively offering a transmission of 0.7 dB between opposite ports.

For further enhancement of isolation between adjacent ports, a ring shaped slot is introduced at the centre of the
patch as shown in Fig 3. The radius of the ring slot is \( r = \frac{R}{3} \) in both the patches. The operating frequency of the crossover is found to shift to lower side by 1 GHz for the square patch based crossover and to the higher side by 2 GHz for the circular patch based crossover on the introduction of the slot. The isolation observed is -14 dB and -25 dB respectively for square and circular crossovers respectively with transmission of 0.7 dB.

Fig. 3. Microstrip patch based crossover with ring shaped slot. (a) Ring shaped slot in square patch (b) Ring shaped slot in circular patch

Following the concept of fractals, ring shaped slots of radius \( r_1 = \frac{r}{3} \) is etched on the patches as shown in Fig. 4.

Fig. 4. Microstrip patch based crossover with ring shaped slot second iteration. (a) Square patch based (b) Circular patch based
These inclusions bring out further frequency shift of 4 GHz in square based crossovers and 3 GHz in circular based crossovers with respect to the conventional patch based crossover. This will help in designing crossovers at lower frequency with less area than the parent structure enabling area reduction. The second iterated crossovers gives an isolation of -22 dB in square base and -30 dB in circular based crossover with a transmission better than -1.2 dB in both cases.

For area reduction and enhancement of crossover characteristics, one more iteration is included in patches as shown in Fig. 5. The radius of the rings $r_2 = \frac{r_1}{3}$ in both the patches.

The crossover characteristics obtained are plotted in Fig 6 and Fig 7 for square and circle based crossover respectively. With third iteration, the frequency shift is found to be 1 GHz for square patch based crossover and 0.5 GHz for circular patch based crossover. Isolation is found to enhance further in the third iteration.

From the analysis of all the iterations, circular patch based crossovers are found to be more efficient in terms of isolation in comparison with square patch based crossovers due to, For a square patch to have efficient isolation TM10 mode and TM01 mode should be excited simultaneously. This means corner feeding for square patch which is difficult in fabrication. But a circular patch much ease in finding cross polarised points as feed locations.

Fig. 5. Microstrip patch based crossover with ring shaped slot third iteration.(a) Square patch based (b) Circular patch based
3. Conclusion

The planar Crossover using circular patch and square patch with sierpinski carpet method using circular rings is presented. From the study of three iteration, isolation was found to be better in the third iteration. An isolation as -25 dB for square patch crossover and -49 dB for circular patch crossover and maximum transmission of signal through the ports is obtained in third iteration. The fractal geometry is found to give better performance such as area reduction of patch, frequency shift to lower side and also maximum isolation characteristics. The proposed crossover can be used in Butler matrix for beamforming applications.
The consolidated characteristics of crossover for each iteration of the crossovers are present in Table 1.

Table 1. Optimized crossover characteristics

<table>
<thead>
<tr>
<th>Type of crossover</th>
<th>Isolation (dB)</th>
<th>Transmission (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square patch based</td>
<td>-12</td>
<td>-0.7</td>
</tr>
<tr>
<td>Square Patch with first iteration of ring slot</td>
<td>-14</td>
<td>-0.7</td>
</tr>
<tr>
<td>Square patch with second iteration of ring slots</td>
<td>-22</td>
<td>-1</td>
</tr>
<tr>
<td>Square patch with third iteration of ring slots</td>
<td>-24</td>
<td>-1</td>
</tr>
<tr>
<td>Circular patch based</td>
<td>-15</td>
<td>-0.7</td>
</tr>
<tr>
<td>Circular patch first iteration</td>
<td>-25</td>
<td>-1</td>
</tr>
<tr>
<td>Circular patch second iteration</td>
<td>-30</td>
<td>-0.7</td>
</tr>
<tr>
<td>Circular patch third Iteration</td>
<td>-49</td>
<td>-1</td>
</tr>
</tbody>
</table>

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References