Reflection Suppression in the Short-slot 2-plane Coupler by Step Structure

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Abstract – We discuss the reflection suppression in the short-slot 2-plane hybrid coupler by step structure. This structure suppresses the reflection around the design frequency of 22GHz. The reflections to the four input-side ports, S11 and S12 are suppressed to less than –20dB over 8.1% bandwidth, and S21 and S31 are less than –20dB over 12% bandwidth. However, the transmissions to the four output-side ports are deviated from –6dB at 22GHz. They are in a range from –6.9dB to –5.2dB.

Index Terms — short-slot 2-plane coupler, reflection suppression, hybrid junction

1. Introduction

The conventional one-plane coupler [1] is used as hybrid or cross coupler in the one-dimensional beam-switching Butler matrix [2] of waveguide structure. If two-dimensional beam-switching is required by conventional Butler matrices, the matrix beam-switching in the horizontal plane and that in the vertical plane should be cascaded [3]. The authors have proposed the one-body waveguide short-slot two-plane coupler as shown in Fig.1 for the key component of the two-dimensional beam-switching Butler matrix [4].

The bandwidth of the 2-plane coupler is narrower than that of the conventional 1-plane couplers. Because more modes are considered in the coupled region in the 2-plane coupler in comparison with the 1-plane coupler. This paper discusses the reflection suppression of the 2-plane hybrid coupler by introducing a step structure that is analogous for the 1-plane coupler [5].

2. Short-slot 2-plane Coupler

Fig. 1 shows the short-slot 2-plane coupler. It has 2x2 ports at each end of the coupled region. The cross section shape of the coupled region is changed from a rectangular. It has concaves at the center of the top and the bottom sides and at the corners to keep the symmetry in both the horizontal and the vertical directions. The modes considered in the coupled region are similar to TE_{10}, TE_{01}, TE_{20}, TM_{11}, TE_{11}, TM_{21}, TE_{21} and TE_{30} modes of the corresponding multimode rectangular waveguide as shown in Fig. 2.

The cross section shape of the coupled region should satisfy the following five conditions.

1. TE_{10}-like mode does not couple with the dominant mode of the ports.
2. TE_{21}-like and TE_{30}-like modes should be attenuated.
3. The propagation constants of TE_{20}-like, TM_{11}-like and TE_{11}-like modes should be equal. Because TM_{11}-like and TE_{11}-like modes can be dealt as one mode, it is called as TM/TE_{11}-like mode thereafter.
4. When the propagation constants of TE_{01}-like and TM_{21}-like modes are \( \beta_{10} \), \( \beta_{20} \) and \( \beta_{21} \), respectively, \( \beta_{20} = \frac{\beta_{10} + \beta_{21}}{2} \) should be satisfied.
5. The position and the dimensions of the ports should be determined so that TE_{10}-like, TE_{20}-like, TM/TE_{11}-like and TM_{21} modes should have equal coupling with the dominant modes of the ports.

The ideal operation of the hybrid is explained as follows.

For an incidence from Port 1 as an example, Ports 1-4 have 90-degree delay and Port 8 has 180-degree delay in comparison with Port 5. The length \( l \) of the coupled region should satisfy \( (\beta_{0} - \beta_{20}) \frac{l}{2} = \frac{\pi}{2} \) for the hybrid.

![Fig. 1. Short-slot 2-plane coupler](image)

![Fig. 2. Electric field in the coupled region](image)
3. Reflection suppression

Fig. 4 shows a step structure in the input side of the 2-plane coupler. The step structure in the output side is the same. The structure has two kinds of stepped regions. One is the horizontal stepped structure as shown in blue in Fig. 4, where the top two ports and the bottom two ports, respectively, are connected to one waveguide with a length of $d_o$. The other is the vertical stepped structure as shown in orange in Fig. 4, where the steps with a length of $d$ are removed from the coupled regions. The design frequency is 22GHz. The parameters of the proposed 2-plane coupler with the step structure are summarized in Table 1. Fig. 5 shows the frequency characteristics of the scattering matrix. Fig. 5(a) is the characteristics of the original structure without the step. In this coupler, the transmissions to the four output-side ports $S_{31}$-$S_{34}$ are within $-6 \pm 0.5$dB at 22.0GHz. The reflections to the four input-side ports $S_{11}$ and $S_{14}$ are $-21$dB, and $S_{21}$ and $S_{33}$ are $-25$dB. Fig. 5(b) shows the characteristics of the proposed structure with the step. The stepped structure acts well for the suppression of $S_{11}$ and $S_{14}$ but does not for $S_{21}$ and $S_{33}$. $S_{11}$ and $S_{14}$ are less than $-20$dB in 21.3-23.1GHz, and $S_{21}$ and $S_{33}$ are less than $-20$dB in 21.0-23.6GHz. However, the transmissions to the output-side ports are in a range from $-6.9$dB to $-5.2$dB.

![Horizontal stepped structure](image1)

![Vertical stepped structure](image2)

Fig. 4. Step structure in the short-slot 2-plane coupler.

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4. Conclusion

The stepped structure has been introduced in the coupled region to suppress the reflection in the short-slot 2-plane hybrid coupler. This model suppresses the reflections to the four input-side ports at the design frequency, however, the transmissions to the output-side ports are deviated from $-6$dB with a deviation of 0.9dB.

References