ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-WEPRB052

DESIGN OF TWO TYPES OF X-BAND HIGH POWER DIRECTIONAL COUPLER*

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Abstract

Special attention has been payed to the development of new type of directional coupler for different applications. We designed two types of directional coupler working at 11.424 GHz with high power handling capacity, stable coupling degree and high directivity. One is the H-plane directional coupler consists of two parallel R100 rectangular waveguides and the coupling degree is 49.9dB and the directivity is 54.5dB. The other is circular-rectangle waveguide directional coupler. The coupling degree of this coupler is 50.14dB and the directivity is 37.93dB. The bandwidth of the coupler is about 800MHz. The fabrication and measurement of these two directional couplers are in progress.

INTRODUCTION

The directional coupler is one of the most widely used components in many microwave systems, which is used to distribute the power of the input microwave signal according to a desired ratio. Directional coupler may be a three-port component or a four-port component with certain specification such as frequencies, bandwidth and structure. The basic working form of four-port directional coupler is that the power input to the port1 is coupled to the port3 by the coupling degree while the rest of input power is delivered to the port2 and there is no power deliver to the port4 in the ideal case [1].

In recent years the technique of substrate integrated waveguide (SIW) is applied in designing directional couplers integrating with mostly planar circuits [1]. Planar structures make the cost lower and the coupler space-saving but big uncertainties of the dielectric constant of the filling materials may cause the directivity and coupling degree change a lot. The common vacuum waveguide directional coupler has better high power capacity.

The commonly used coupling methods include circular eyelet coupling, elliptical eyelet coupling, cross-hole coupling and some irregular-hole coupling. Although the coupling theory is mature and is applied to develop various directional coupler to measure and distribute power, there are also some problems needed to be considered in designing coupler at high power operation such as RF breakdown, measurement accuracy, bandwidth, etc.

The H-plane directional coupler [2] proposed at the frequency of 11.9924GHz by IHEP is compact and easy to fabricate. This coupler has a high directivity and a low reflection of microwave.

The other new circular-rectangle waveguide directional coupler at 9.4GHz [3] uses a circular main waveguide to transport the basic TM01 mode. High power handling capacity and wide bandwidth are the advantages of this directional coupler. The structure of this directional coupler has been fabricated and tested on a long pulse high power microwave source.

We plan to design two different directional couplers working at 11.424GHz frequency with the coupling degree at 50±2dB and the directivity better than 30dB at 200MW peak power. The couplers designed mainly based on circular eyelet coupling theory are discussed in this paper.

H-PLANE DIRECTIONAL COUPLER

Structure Design

This directional coupler consists of two parallel rectangular waveguides with four holes drilled along the central line of the narrow-wall. Equal aperture distribution is employed in this coupler. The H-plane directional coupler in CST microwave studio is shown as Fig. 1. The SMA joint is a coaxial waveguide converter and commonly used to export small signals.

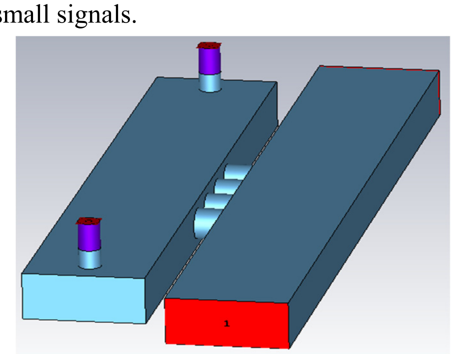

Figure 1: H-plane directional coupler in CST.

Simulation Results

All the calculations and optimizations are operated by CST-MWS. The distance between holes needs to be $\lambda_g/4$ according to equal aperture distribution while λ_g is the waveguide wavelength. The coupling degree and directivity are sensitive to the depth and radius of the coupling hole. The curves of coupling degree and directivity with respect to the depth and radius of the hole are shown in Fig. 2 and Fig. 3. Other parameters affecting the scattering

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properties are the positions and insertion depth of the SMA joint and the length of sub-waveguide, etc.

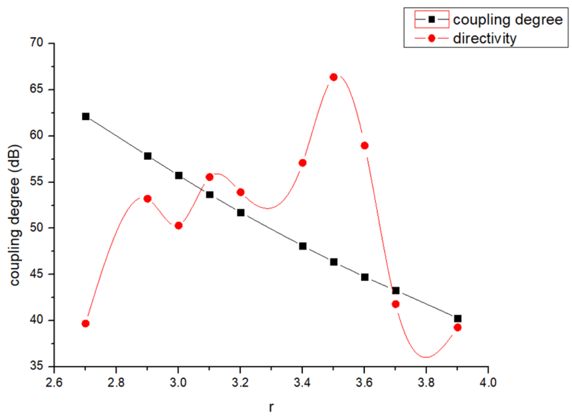

Figure 2: Curves of coupling degree and directivity with respect to the radius of the hole.

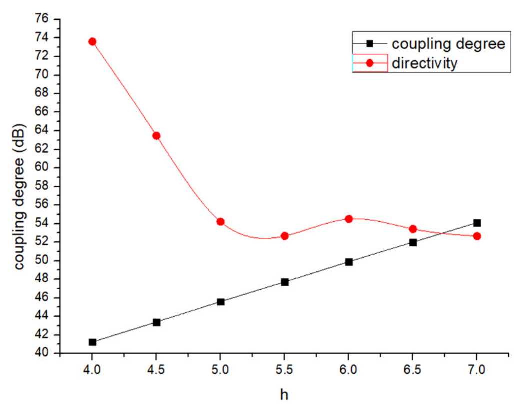

Figure 3: Curves of coupling degree and directivity with respect to the height of the hole.

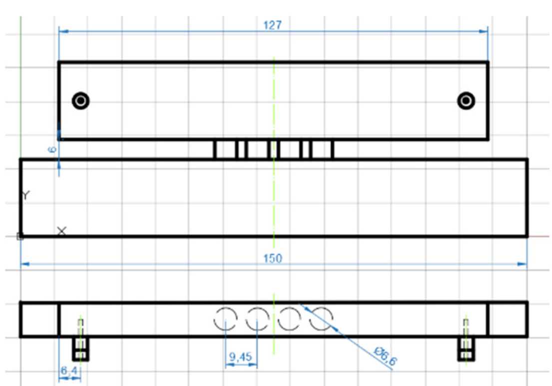

Figure 4: Main dimensions of H-plane directional coupler (units: mm).

The main optimized dimensions of the H-plane directional coupler are shown as Fig. 4. The electric field calculated by CST is shown as Fig. 5. The directivity and coupling degree are shown as Fig. 6 and Fig. 7. Simulation shows that the coupling degree of H-face directional coupler is 49.9 dB and the directivity is 54.5dB. The peak electric field is about 29MV/m while operating at 200 MW peak power. The bandwidth is about 100MHz. It can be seen that the coupling degree is stable in terms of frequency and the H-plane coupler has a good performance of directivity.

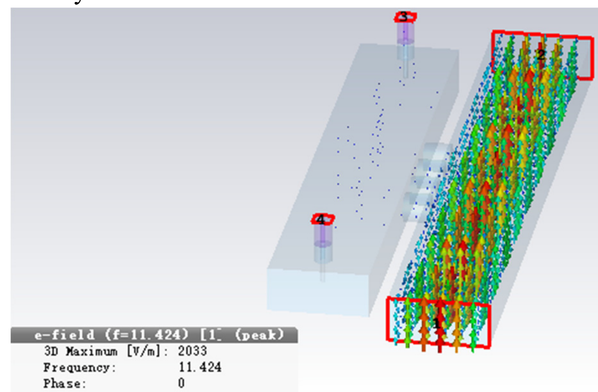

Figure 5: Electric field of H-plane directional coupler by CST.

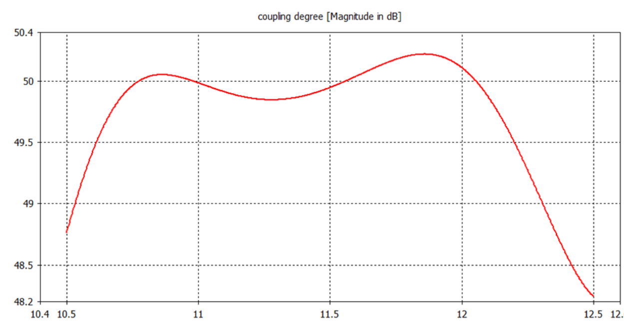

Figure 6: Coupling degree of H-plane directional coupler by CST.

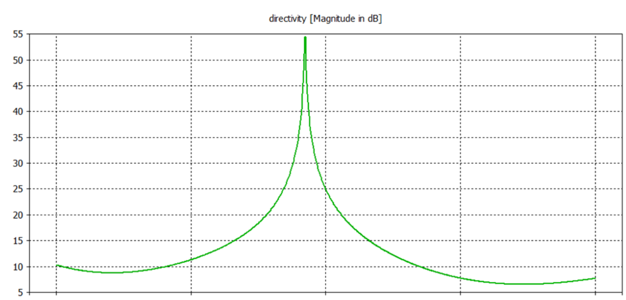

Figure 7: Directivity of H-plane directional coupler in CST.

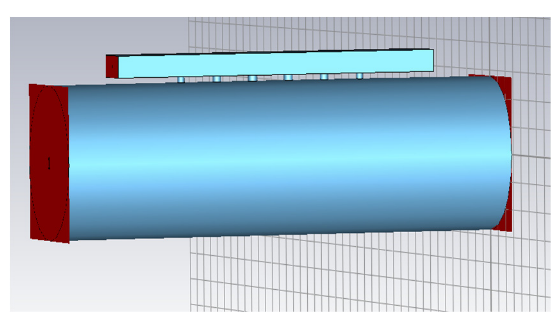

Figure 8: Circular-rectangle waveguide directional coupler in CST.

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CIRCULAR-RECTANGLE WAVEGUIDE DIRECTIONAL COUPLER

Structure Design

The circular-rectangle waveguide directional coupler consists of a circular main-waveguide transmitting TM01 mode and a rectangular sub-waveguide transmitting TE10 mode. These two waveguides are coupled by six holes. The Chebyshev distribution is employed in this coupler. The model is shown as Fig. 8.

Simulation Results

The radius of main-waveguide is 56mm and the rectangular waveguide model is R84. The parameters sweep conveys that the directivity is sensitive to the six holes' radiuses and the distance. The six holes are equally spaced and symmetric about the center line. The radiuses of holes from center to edge are 4.15mm, 3.80mm, 3.10mm respectively. The distance between each two holes is 34mm.

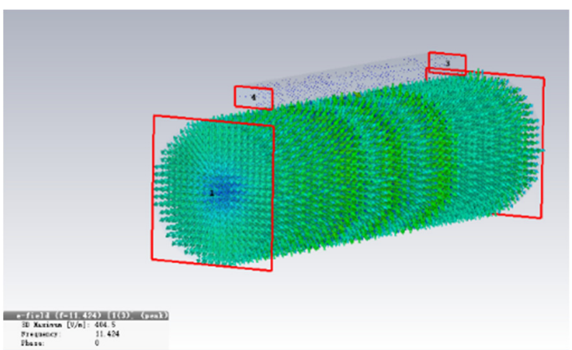

Figure 9: Electric field of circular-rectangle waveguide directional coupler by CST.

The electric field calculated is shown as Fig. 9 and the scattering properties are shown as Fig. 10 and Fig. 11. Simulation shows that the coupling degree of circular-rectangle waveguide directional coupler is 50.14 dB and the directivity is 37.93dB. Particularly the bandwidth is about 800MHz. The peak electric field is 5.72MV/m while operating at 200 MW peak power.

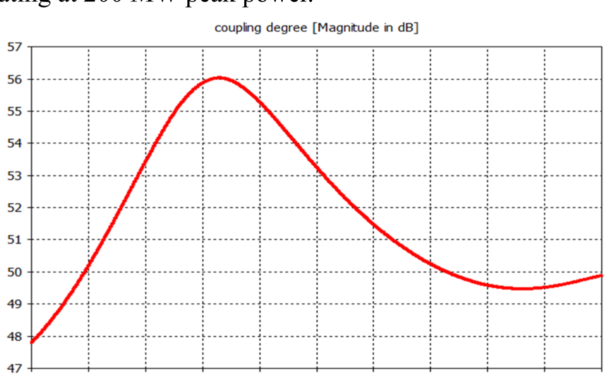

Figure 10: Coupling degree of circular-rectangle waveguide directional coupler by CST.

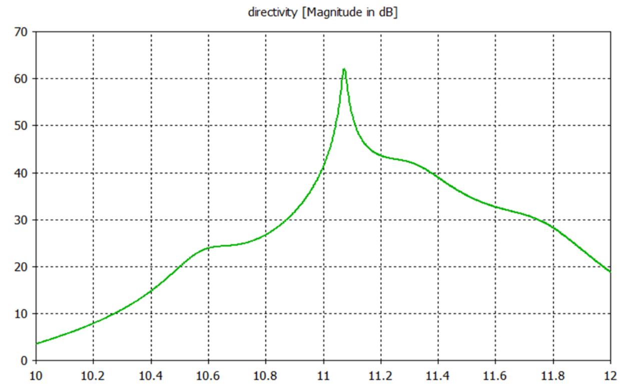

Figure 11: Directivity of circular-rectangle waveguide directional coupler by CST.

CONCLUSION

Comparing with the H-plane directional coupler, circular-rectangle waveguide directional coupler has a lower directivity, a lower peak electric field and a wider bandwidth. Low peak electric field can reduce the risk of RF breakdown and the Multipactor effect, which ensures the stable high power operation of the directional coupler.

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