Mono-Grooved Circular Waveguide Polarizers

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ABSTRACT

This paper presents a unique type of polarizer that is composed of a circular waveguide with an only groove. The presented polarizer is suitable for realizing compact size and reducing degradation in performance due to manufacturing inaccuracy. An accurate design of the polarizer is performed using mode-matching techniques. A W-band polarizer has been designed, and the results of error analysis have verified the high efficiency of the presented polarizer.

INTRODUCTION

In circularly polarized antenna feed systems, polarizers are used to convert linearly polarized signals into circularly polarized signals [1,2]. We had previously presented a novel type of polarizer that is composed of several grooved circular waveguides [3]. The grooved circular waveguide polarizer is suitable for realizing high performance and low fabrication cost in the Ka-band and above. The design method of the polarizer applies in the well-known design method of the branch waveguide coupler [4], and the design is performed by the full-wave analysis of circular-to-rectangular waveguide T-junction or cross-junction using mode-matching techniques. In practice, Ka-band grooved circular waveguide polarizers fabricated with the aid of the analysis and design techniques had realized excellent performance without tuning elements [3]. According to the above design method, it is considered that a broadband polarizer can be designed by applying many grooves. On one hand, it is evident that a compact-size polarizer can be realized by reducing the number of grooves. However, the supremely compact grooved circular waveguide polarizer, that is, the polarizer with an only groove cannot be designed by the above design method.

In this paper, we present a compact-size polarizer that is composed of a circular common waveguide with an only groove. The polarizer can be designed as the length is less than two third of the circular waveguide wavelength. And the presented polarizer is suitable for realizing high performance and low fabrication cost in the W-band and above because of extremely simple structure. And further, accurate analysis and design of the presented polarizer can be performed using full-wave mode-matching techniques for circular-to-rectangular waveguide T-junctions [3,5-8]. An X-band polarizer fabricated with the aid of the analysis and design techniques has realized excellent performances. And further, a W-band polarizer has been designed and the error analysis with the manufacturing accuracy has been performed.

CONFIGRATION

Fig.1 shows a structure of the proposed mono-grooved circular waveguide polarizer. The polarizer is composed of a circular common waveguide and a coupling groove situated partially at sidewall of the circular waveguide. As shown in Fig.1, incident linearly polarized TE_{11} modes that exhibit +/-45degree offset with respect to

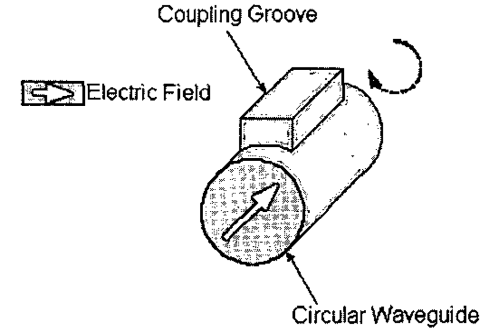

Figure 1: Mono-Grooved Circular Waveguide Polarizer

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the diagonal alignment of the groove can be converted into right/left-hand circularly polarized output waves. The mono-grooved circular waveguide polarizer has the advantage of reducing the degradation in antenna feed performance due to manufacturing inaccuracy, because the polarizer has the coupling grooves in the sparse electromagnetic field (i.e., in the wall of the circular waveguide) [3,5]. In addition, the presented polarizer can be designed as the width and depth of the groove are larger than them of any other polarizer which has several grooves, so it is assumed that the proposed polarizer can reduce influence of manufacturing inaccuracy in the W-band and above. And further, an accurate design of the polarizer can be performed by fast full-wave analysis on account of the simple structure.

ANALYSIS

Fig.2 illustrates the concept for full-wave analysis of a mono-grooved circular waveguide polarizer. As shown in Fig.2, the grooved circular waveguide is composed of two key-building block elements, that is, a circular-to-rectangular waveguide T-junction and a short-circuited rectangular waveguide. Therefore, analysis of the presented polarizer is performed using mode-matching techniques for circular-to-rectangular waveguide H-plane and E-plane T-junctions associated with the generalized S-matrix techniques [3,5-8]. The full-wave analysis techniques have the capability of including high-order mode influences and the advantage of shortening the computing time as compared with other numerical techniques. Finally, an accurate design of the mono-grooved circular waveguide polarizer can be realized by deciding the size of the groove according to the fast full-wave analysis discussed below.

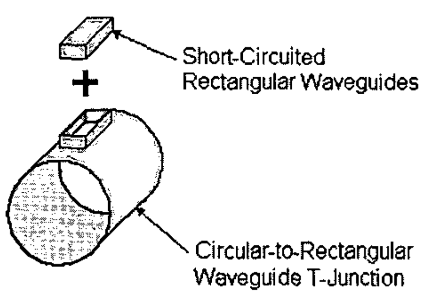


Figure 2: Analysis Concept of Mono-Grooved Circular Waveguide Polarizer

Fig.3 shows calculated reflection characteristics of a circular waveguide polarizer with a groove designed in the W-band. In the simulation model, the diameter of the circular waveguide is 2.2mm, the width and depth of the groove are 0.8mm and 0.7mm respectively, and the length of the groove is varied from 2.5mm to 4.5mm. The incident linearly polarized TE_{11} modes exhibit 45degree offset with respect to the diagonal alignment of the groove. As shown in Fig.3, calculated characteristics vary gradually with the length of the groove, and a good match, that is, the VSWR less than 1.1 over the frequency range between 86.5GHz and 102.5GHz is obtained when the length is 3.5mm. Incidentally, similar results are obtained in other simulation model with a different length of groove. These results indicate that the length of the groove is a efficient parameter for matching and the proposed polarizer can be used for various applications require a good match in bandwidth of less than 17%. Moreover, it is estimated that the compact-size polarizer can be designed as the length is less than two third of the common circular waveguide wavelength of the fundamental mode at the center frequency.

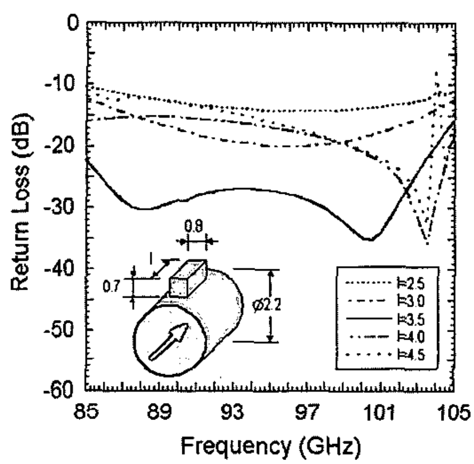


Figure 3: Calculated Return Loss in the W-Band Mono-Grooved Circular Waveguide Polarizer

Fig.4 show calculated axial ratio characteristics of a circular waveguide polarizer with a groove designed in the W-band. In the simulation model, the diameter of the circular waveguide is 2.2mm, the length and depth of the groove are 3.5mm and 0.7mm respectively, and the width of the groove is varied from 0.6mm to 1.0mm. As shown in Fig.4, calculated characteristics vary systematically with the width of the groove, and a pure circular polarization, that is, the axial ratio less than 1.0dB over the frequency range between 86.5GHz and 102.5GHz is obtained when the width is 0.7mm. Similar calculated results are obtained in a simulation model for various depths of a groove. The above results indicate that the width and depth of the groove are convenient parameter to adjust axial ratio and the proposed polarizer can obtain high performances in bandwidth of less than 17%.

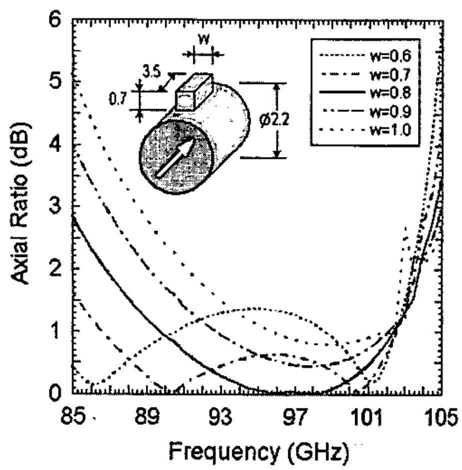
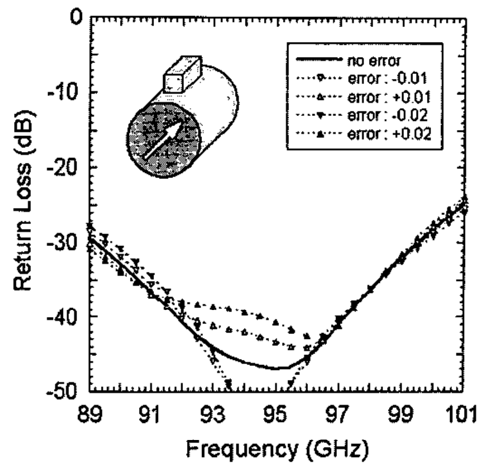


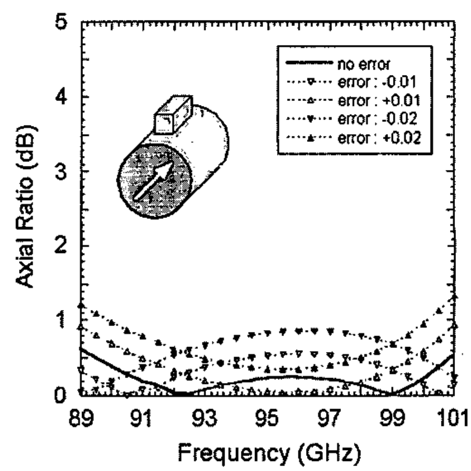
Figure 4: Calculated Axial Ratio in W-band Mono-Grooved Circular Waveguide Polarizer

DESIGN

Fig.5 shows the computed reflection and the axial ratio characteristics of a W-band mono-grooved circular waveguide polarizer designed with the aid of the above-mentioned analysis techniques. This polarizer is designed to provide a good match (VSWR < 1.08) and a pure circular polarization (axial ratio < 0.5dB) over frequency range between 90GHz and 100GHz by computer optimization. The length of the designed polarizer is 3.3mm, the diameter of the circular common waveguide is 2.2mm, and the width and depth of the groove are 0.8mm and 0.7mm respectively. Moreover, Fig.5 shows the degradation in the frequency responses due to manufacturing inaccuracy, that is to say, giving errors (+/-0.01mm or +/-0.02mm) to all dimensions of the designed groove. The results of the error analysis indicate that the high performance (i.e. the VSWRs less than 1.1 and the axial ratio less than 1.0dB over frequency range between 90GHz and 100GHz) can be obtained in the error less than 0.02mm. The error 0.01mm and 0.02mm are practical manufacturing tolerance. The above results verified the high efficiency of the presented mono-grooved circular waveguide polarizer.



(a) Return Loss



(b) Axial Ratio

Figure 5: Computed Frequency Response of the W-band Mono-Grooved Circular Waveguide Polarizer: The Degradation in Performance due to Giving Errors to All Dimensions of the Designed Groove

EXPERIMENTAL RESULTS

Fig.6 shows the reflection and the axial ratio characteristics of a mono-grooved circular waveguide polarizer fabricated in the X-band. This X-band polarizer is designed with the aid of the above-mentioned analysis techniques. The length of the polarizer is about three fifth of the circular common waveguide wavelength. In the processing of the fabrication, an allowable error with the manufacturing accuracy is 0.01mm. The fabricated X-band polarizer has realized excellent performance without tuning element, that is, the VSWR less than 1.08 and the axial ratio less than 0.5dB over 10% bandwidth. And further, a good agreement is obtained between the experimental and the calculated data. These results verified the high accuracy and high efficiency of the above analysis and design techniques.

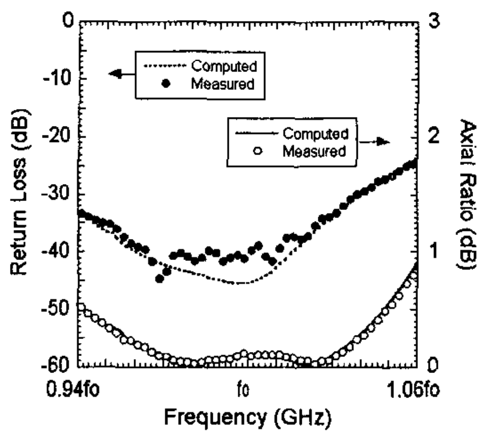


Figure 6: Computed and Measured Frequency Responses of the X-band Mono-Grooved Circular Waveguide Polarizer

CONCLUSIONS

A configuration, analysis and design of a mono-grooved circular waveguide polarizer have been introduced. This presented polarizer is very small because it is composed of an only grooved circular waveguide. In addition, the polarizer is suitable for realizing high performance and low fabrication cost in the W-band and above because of the simple structure. The accurate design of the polarizer has been performed by the full-wave analysis of circular-to-rectangular waveguide T-junctions using mode-matching techniques. A W-band mono-grooved circular waveguide polarizer has designed with the aid of the above-mentioned analysis techniques, and excellent reflection and axial ratio characteristics have been calculated by full-wave analysis. Moreover, the results of error analysis have verified the high efficiency of the presented polarizer. And further, a mono-grooved circular waveguide polarizer fabricated in the X-band has realized excellent performance without tuning element. The theory has been verified by a good agreement with measurements.

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