Design analysis of a Tunable Tapered Metallic Baffle TM_{01} to TE_{11} HPM Mode Converter

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Abstract: Tapered metallic baffle mode converter for TM_{01} to TE_{11} mode has been presented. Using a triangular axially movable baffle, frequency tuning has been acheived. Conversion efficiency more than 98% at 2 GHz whereas more than 93% at 2.32 GHz, has been achieved and this enables to choose the mode converter frequency of operation accordingly. Mode converter RF beam stability has also been improved by adding a coaxial section at its output end. The proposed mode converter is an all metal structure, light in weight, higher in return loss, stable output beam and with frequency tunability feature; suitable for HPM system application.

Keywords*:* Mode converter; HPM; High power microwave; Tapered Baffle

Introduction

High power microwave (HPM) mode converter is an important component of the HPM systems. HPM sources generate GW range of power and provide output in azimuthally symmetrical *TEM* and TM_{01} modes. The azimuthally symmetrical modes have null at the center and when radiated their pattern are like doughnut shape. So, HPM system requires a suitable mode converter which direct RF beam towards a point [1-4]. TE_{11} mode is the dominant mode of cylindrical waveguide and having directivity at the axis of propagation and best suited in directing RF beam at a point. Hence, TM_{01} to TE_{11} mode converter posses importance in HPM systems.

Conventional mode converter contains a serpentine structure or bends [5]. Sectoral waveguide (SWG) mode converter provide good efficiency but heavy in design [1-4]. Reconfigurable SWG mode converter has also exhibited good conversion efficiency over a frequency band, but the designed structure is still heavy in weight. As low-weight mode converter, circular sectoral waveguide mode converter is an option however, its conversion efficiency is poor [6].

Elsherbeni *et al.* have discussed metal plate field arrangement in the cylindrical waveguide [7]. Chittora *et al.* used this single metal plate arrangement as a tapered metallic baffle mode converter [8]. This mode converter is low weight and also provide mode conversion of TM_{01} to TE_{11} over a wider bandwidth, but having moderate conversion efficiency, ~ 90% to 95% over the frequency band. Moreover, such mode converter produces an unstable beam output. The reason for low conversion efficiency for TM_{01} to TE_{11} mode because of outer cylinder radius decreases the cutoff frequency and supports higher-order modes generation [~~8~~ 9].

The proposed mode converter consists of a sliding tapered metallic baffle inside the cylindrical waveguide, as shown in Figure 1. Any difference between developed and designed converter conversion efficiency can be easily fine-tunned with baffle at the desired frequency of operation. The design proposed is light weight, high conversion efficiency and tunable to adjust the desired frequency to achieve high conversion efficiency. Also, beam stability is achieved with using design modification, i.e., by additing a coaxial section at the output end.

Simulation and Results

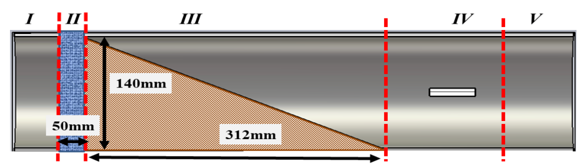

Figure 1. Schematic of the proposed tunable tapered metallic baffle TM_{01} to TE_{11} HPM mode converter.

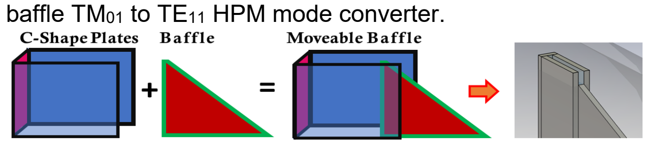

Figure 2. C-shape plate and baffle: 3D view sliding tapered metallic baffle.

The proposed design is based on a tapered movable metallic baffle inside the cylindrical waveguide (Figure 1); can be divided in five regions, cylindrical waveguide input TM_{01} mode as Region *I*, and output Region *V* is also cylindrical waveguide TE_{11} mode. Here, mode conversion is accomplished by the right angle traingular mettalic baffle placed in Region *III*. Detail of Regions *II* and *III* are shown in Figure 2, where Region *II* is a C-shape metal plate. Region *IV* is a coaxal waveguide section provided for beam stability. The triangular metal baffle is tuned inside the gap of C-Shape metal plate. By tuning the axial position of the triangular baffle, frequency tuning is achieved and results in improved conversion efficiency.

Region *I* shows the RF electric field at the input port of TM_{01} mode, Region *II* shows the separation of TM_{01} mode in TE_{11} mode of a sectoral waveguide having sectoral angle π rad. Region *III* introduce tunable tapered metallic baffle in the axial position. In this region electric fields bends towards the top edges of tapered baffle, whereas tapered edge approximate length is near to $2\lambda_g$ (two times of guided wavelength) of TE_{11} mode. The complete mode conversion of primary design (without inner conductor) is shown in Figure 3. Here Region

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IV is avoided and is added later on to visualize the beam stability, shown in Figure 4. Placing a solid inner metallic conductor having radius 5 mm and length 48 mm (~ $\lambda_g/2$ for TE_{11} mode), at the axis of propagation after baffle, results in achieving the RF beam stability. This modification in design enables mode converter to keep directivity stable while radiating the RF beam [4].

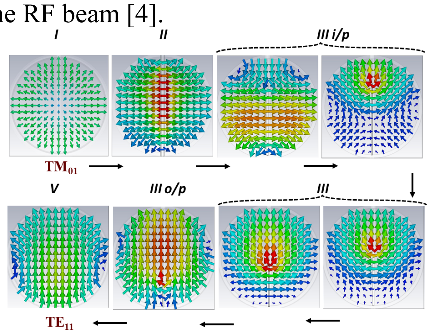

Figure 3. Mode conversion progression of the proposed mode converter through E-field distribution at the different regions cross-sections along z-plane.

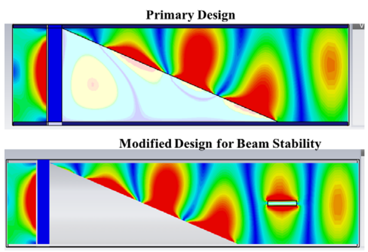

Figure 4. Mode conversion progression of the proposed mode converter through E-field distribution at different cross-sections along z-plane.

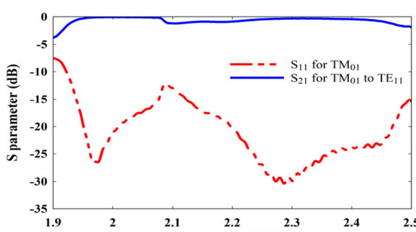

Figure 5. Transmission and reflection parameter having input mode TM_{01} and output mode TE_{11}.

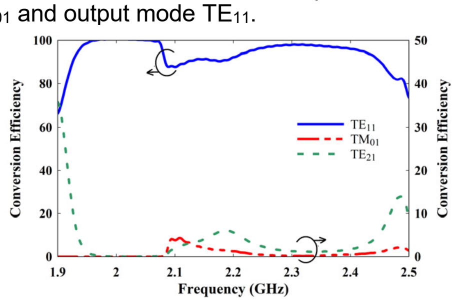

Figure 6. Convergence efficiency (in %) for different modes for the input TM_{01} mode.

The design reported earlier has result very similar to the s-parameter results from 2.1 GHz to 2.5 GHz of Figure 5. But the transmission parameter for converted mode is achieved maximum around the frequency 2 GHz. That is because the cutoff frequency of TE_{21} mode is 2.08 GHz and is higher than operating frequency 2 GHz.

Figure 6 shows the Conversion efficiency 98.36% at 2 GHz whereas 93.30% at 2.32 GHz. Also, Conversion efficiency more than 80% for 2.13-2.45 GHz and for this frequency range reflection parameter is less than -15 dB. So, it is as per the requirement of conversion efficiency to choose pure TE_{11} mode with smaller mode conversion bandwidth or mix mode output with lower participation of TE_{11} mode over the large frequency range. Also, during HPM analysis power handling capability is obtained by simulating the mode converter model with the 1.5 GW level signal at the input port of the mode converter. At 1-atm air pressure is used as a medium, the maximum electric field inside the mode converter is 82.13 kV/mm. The field values are within the breakdown limit of 100 kV/mm [3, 4, 6]. Therefore, the proposed all-metal light-weight mode converter has the ability to be used for the HPM systems of the Giga-watt power levels.

Conclusion

This paper presents design of an improved TM_{01} to TE_{11} mode converter using a tapered movable metallic baffle. The converter can be easily tuned at the desired frequency with the help of movable triangular metallic baffle and conversion efficiency more than 98% is acheived. The converter RF beam stability is also shown to be improved by additing a coaxial section at the output end. The proposed mode converter is an all metal structure, light in weight, higher in return loss, stable output beam and with frequency tunability feature. In future, mode converter design can be studied to achieve reconfigurable property.

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