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Simulation of the TM_{01} to TE_{11} Mode Converter by using Monostair Technique

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Abstract- This paper presents the simulation of TM_{01} to TE_{11} mode conversion. A waveguide has two modes TE and TM. Here the requirement of the converter is important to measure the power in a more accurate way in a circular waveguide. In a circular waveguide, the power at the centre is maximum for TE_{11} mode and zero for the TM_{01} mode. In TM_{01} mode, power is maximum at about 0.78 of the waveguide radius which makes it bit difficult to measure the power in an accurate way. Hence the conversion is required for TM_{01} to TE_{11} mode in circular waveguide. This mode converter is useful for the low power calibration. The TM_{01} to TE_{11} mode converter is designed for the S-band application for the circular waveguide with the operating frequency of 3.0 GHz. The simulation has been carried out by using the CST microwave studio solver. Here axial feed is considered to generate TM_{01} mode of the circular waveguide. Aluminium slab is used for the partition in the circular waveguide with integrated three Teflon slabs for mode conversion. A maximum bandwidth of the 560 MHz has been achieved with the 10 dB of return loss.

Index Terms- Circular Waveguide, Mode Launcher, Mode Conversion, SYMPLE

1. INTRODUCTION

A mode converter is simply converting the mode from one mode to another mode. The modes are the variation of the E-field and H-filed with the direction of the propagation. This mode conversion depends on the application and user requirement. An advantage of the mode conversion is used for long transmission where high frequency is required for the system. The microwave radiation of TM_{01} is propagated through the horn antenna which is resulting in the minimum at centre along the axis at the far field distance. Many of the high power microwave sources like the Vircator and backward wave oscillator generate the output signal in the form of the TM_{01} mode for the circular waveguide [1]. Bandwidth is a very important factor in the mode conversion. Uncertainty variation of the frequency at the operation of the high power microwave sources [2]. A tapered metallic baffle is used for the mode conversion but no centre mode is discussed [3]. The coaxial feed is connected as centre conductor with cone, which applied to the axis of the circular waveguide for generation of the TM_{01} mode, there monocone, monocone with skirt and monocone with inverted cone are explained [4].

Proposed mode converter is designed for the S-band applications. Section 2 explains the design methodology of the mode converter. Section 3 describes the simulation and result and Section 4 finally conclude the work.

2. DESIGN METHODOLOGY

In a general situation, it is impossible to direct conversion of signal without losing information. In a circular waveguide of TM_{01} mode has a higher cut-off frequency than the TE_{11} fundamental mode. The idea for proposed mode convertor is divided into a two parts: In 1st part the generation of TM_{01} mode is done from the coaxial feed in the circular waveguide and in 2nd part the generation of TE_{11} mode is carried out from the TM_{01} mode by simply inserting the dielectric slab in the circular waveguide as shown in Fig. 1. The dielectric slab is used for the mode conversion.

Inserted dielectric slab in the whole circular waveguide can produce the phase shift but it will not give the purely TE_{11} mode. So we can't insert the slab in the whole circular waveguide without any partition. In the circular waveguide there are only two possibilities to insert slab in upper and lower section. Out of that two section we decide the lower section to insert the slab in the circular waveguide as shown in Fig. 2, which produce the phase shift for the mode conversion. In the circular waveguide an aluminium plate is used for partition of the circle. Three Teflon slabs are used with 45 degree for the mode conversion.

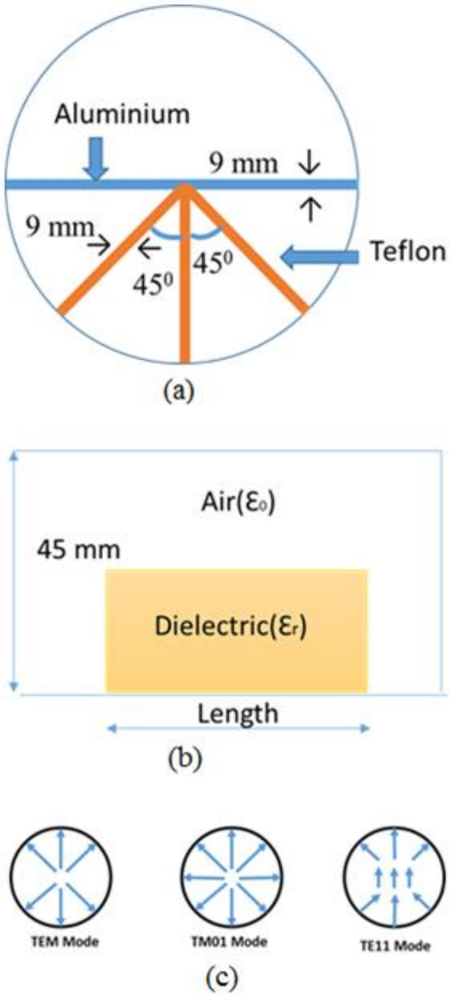

Fig. 1 Mode converter with 3 Dielectric Slab a) Front view b) Side view c) Mode converter with internal view

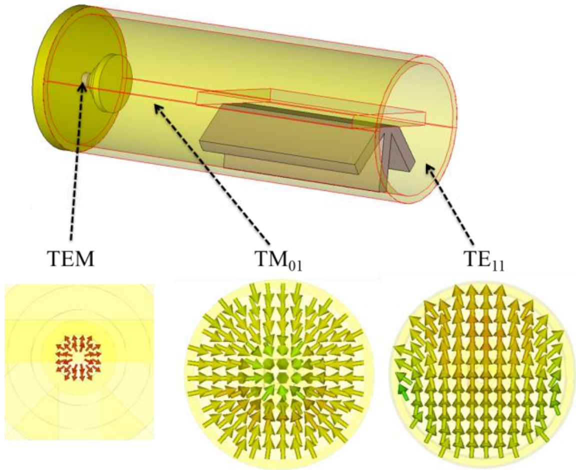

Fig. 2 Model of mode converter with E-field distributions

3. DESIGNING EQUATIONS

The length chosen in the circular waveguide for the slab is given by the formula [5].

$$\text{Length} = \frac{\pi}{\beta d - \beta o} \qquad (1)$$

where βd = Dielectric propagation constant
βo = Air propagation constant

Length of circular waveguide can be calculated by using the standard expression that is given by $\lambda = c/f$.
where λ = wavelength
c = speed of light
f = operating frequency
The calculated values of different parameters of mode convertor are shown in Table 1.

Table 1 Dimensional of circular waveguide

Parameter	**Values**
Diameter of circular waveguide	90 mm
Length of Monostair antenna	15 mm
Wave Guide Length	250 mm
Outer Diameter of Flange	100 mm

4. SIMULATION RESULT

CST (Computer simulation technology) microwave studio solver is used for the simulation. The propagation of the TE_{11} mode can be seen in the simulation with particular checking the E- field and H-field. If any mode is fully propagated it means S_{21} is at 0 dB. It shows the complete transmission from the input to the output side. Here, TE_{11} mode is propagated with the impedance bandwidth of the 560 MHz as shown in Fig. 3.

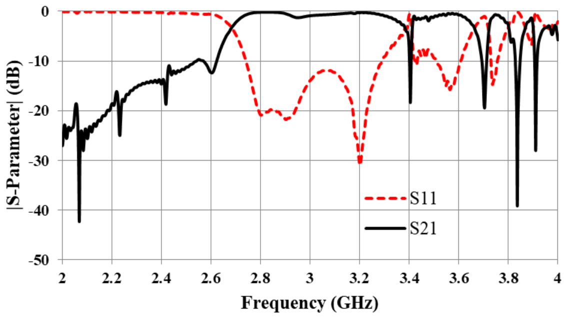

Fig. 3 S-Parameter for TM_{01} to TE_{11}

4.1 Effect of Angle of slab

Various value of angle (θ) of Teflon slabs are taken as parameter of optimization for achieving the best return loss. The optimization of slab's angle is carried out and found best value of the angle is 45° as shown in Fig. 4.

Development steps are as follows: Initially Aluminum slab with 9 mm is used for dividing the whole circle in the two parts with upper half circle and the lower half circle. With that lower circle the three Teflon slab with 9 mm are used for the mode conversion. Next, inserted the one by one slab for mode conversion with phase change and finally three Teflon slab is used for mode conversion. These slabs change the phase for the TE_{11} mode. In the waveguide the slab angle changes from the 0^0 to 90^0 with that variation the 45° angle which gives the good E-field variation same as the TE_{11} mode.

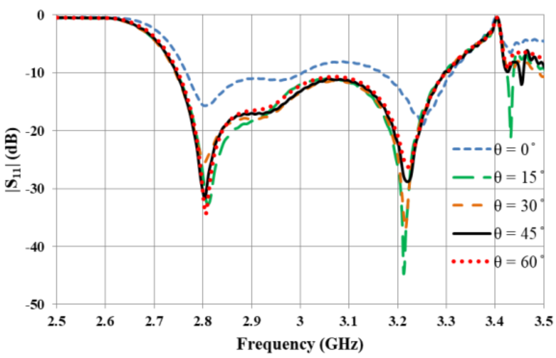

Fig. 4 Variation of Angle with slab

4.2 Effect of width of slab

Here variation of slab width (*a*) from 7 mm to 11 mm is carried out to achieve good result. The best optimized value of width is 9 mm which gives the bandwidth of 560 MHz below the 10 dB as shown in Fig. 5.

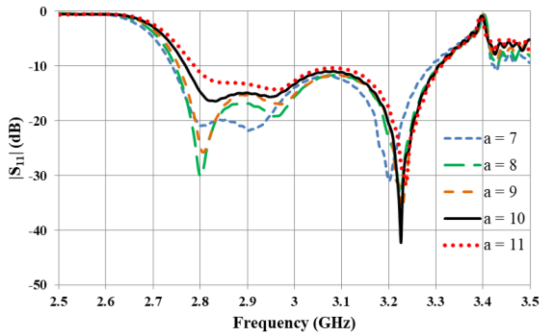

Fig. 5 Variation of width with slab

5. CONCLUSION

The simulation of the TM_{01} to TE_{11} mode conversion in the circular waveguide has done successfully by using the special Monostair shaped geometry. The design of the circular waveguide is easy with compact in size and the simulation also. In the circular waveguide the maximum return loss of 32 dB is achieved by using 45° angle of the slab and 9mm width of slab in the circular waveguide. The analyzed impedance bandwidth is 560 MHz with the 10 dB below power at the operating frequency of the 3 GHz. The simulation of the TM_{01} to TE_{11} mode conversion is used for the low power calibration and it will also be useful for the high power microwave/laser plasma system.

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