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# A design of Rectangular Waveguide $TM_{11}$ to $TE_{10}$ Mode Converter for S-band Applications

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**Abstract**

A design of a compact, easy to fabricate and applicable structure rectangular waveguide $TM_{11}$ to $TE_{10}$ mode converter is presented in this paper. The design procedure of the proposed structure can be divided into two parts in sequence. The beginning one is dedicated to the transformation from $TM_{11}$ to TEM mode using a central conductor, while the second part is the transformation from TEM to $TE_{10}$ mode using a dielectric loaded waveguide carrying out 180° phase shift. The proposed structure has the advantage of high efficiency of above 90 %, which are demonstrated in simulation results.

**Keywords:** Mode converter; S-band applications; $TM_{11}$ to $TE_{10}$ mode conveter;high power microwave (HPM) applications

## 1. Introduction

High power microwave (HPM) systems have been much improved, recently, due to their trait of high power transmission. Mode converting should be considered in overmoded waveguides to achieve the desired mode. Rectangular waveguide has lower loss than circular waveguide and usually is the preferred structure in many applications. Therefore, efforts are made to achieve the dominant mode in rectangular waveguide, $TE_{10}$. A $TM_{01}$ to $TE_{11}$ mode converter in circular waveguide has been presented in [1] using a tapered conductor and a Teflon dielectric. A $TM_{01}$ to $TE_{11}$ mode conversion procedure has been presented in [2] utilizing an octagonal shaped structure which could not simply be fabricated. Another $TM_{01}$ to $TE_{11}$ mode converter has been proposed in [3] using an indirect $TM_{01}$-TEM-$TE_{11}$ method. The expressed method is expensive, not easy to fabricate, and narrow band. In [4-6], some serpentine shaped mode converter structures have been presented which are commodious, not compact, and not easy to fabricate.

In this paper, we tried to design an applicable and easy to fabricate S-band $TM_{11}$ to $TE_{10}$ mode conversion procedure considering high conversion efficiency in rectangular waveguides. The desired simulations for aforesaid mode converter are performed in *CST Microwave Studio* computer program. The simulation results show that the proposed structure takes the advantage of high conversion efficiency, above 90%, and provides an appropriate mode conversion bandwidth. The paper is organized as follows. In Section II, the intended structure is defined, while the respective simulation results are presented in section III. The dielectric loss is presented in Section IV, and finally, the paper is concluded in Section V.

## 2. Main structure

The design procedure of the expressed mode converter can be divided into two parts. First, it is tried to convert $TM_{11}$ to TEM mode, as an intermediate mode, in rectangular waveguide structure. Therefore, the second part is the conversion of TEM to $TE_{10}$ mode. To achieve the first demand, we have utilized a tapered conductor. To achieve the $TE_{10}$ mode as the expected output mode, a proper $180^o$ phase shift is needed, which is obtained using Teflon®/PTFE (Polytetrafluoroethylene). Figure 1 shows an overview of the main structure with all dimensions. It should be mentioned that section 2 in Fig. 1 has been considered to prevent abrupt changes in electric field pattern. The length of loaded dielectric can be achieved using [1]:

$$\beta_d L_d - \beta_0 L_0 = \pi. \tag{1}$$

If $L_d = L_0 = L$ , we have:

$$L = \frac{\pi}{(\beta_d - \beta_0)}. \tag{2}$$

We can rewrite the above equation as

$$L = \frac{\lambda_0}{2\left(\sqrt{\varepsilon_r} - 1\right)}. \tag{3}$$

Cross-sectional views of the simulated electric field patterns in proposed structure are presented in Fig. 2 at operation frequency. Simulations are performed with a $10 \times 5$ rectangular waveguide. It is necessary to say that all units are in centimeters. Obviously, cutoff frequencies of $TE_{10}$ and $TM_{11}$ modes can be calculated analytically using:

$$f_{c_{mn}} = \frac{1}{2\sqrt{\mu\varepsilon}}\left(\sqrt{\left(\frac{m}{a}\right)^2 + \left(\frac{n}{b}\right)^2}\right). \tag{4}$$

Therefore, cutoff frequencies $fc_{TE_{10}}$ and $fc_{TM_{11}}$ are 1.5 and 3.35 GHz, respectively.

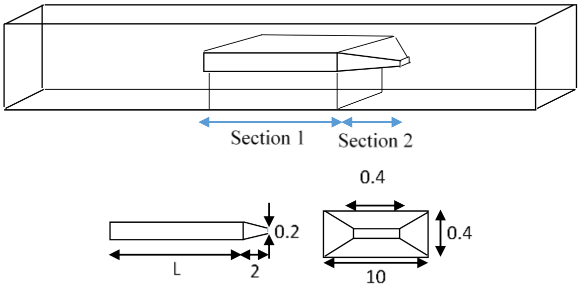

**Fig. 1: An overview of the main structure**

## 3. Simulation results

Figure 2 shows cross-sectional views of simulated electric field patterns at operating frequency, *i.e.* 3.6 GHz. It is clear that the incoming $TM_{11}$ mode can be transformed into TEM using the centered conductor and then, the $180^o$ phase shift is obtained using PTFE dielectric loaded. The choice of PTFE for dielectric part is based on its high efficiency according to the simulated results in Fig. 3. In this figure, the comparison between different materials is presented. Table 1 shows a detailed comparison of different materials. In the case where the compactness is intended, Mica could be considered; otherwise Teflon/PTFE is preferred. A proper coaxial cable is utilized as the feeder for the waveguide in order to excite $TM_{11}$ mode. It should be mentioned the coaxial cable is located at the center of X-Y plate which is shown in Fig. 4.

## 4. Dielectric loss

As we mentioned previously, a loaded dielectric structure is needed to obtain $180^o$ phase shift in the TEM to $TE_{10}$ mode conversion procedure. According to the choice of lossy PTFE dielectric, a dielectric loss is encountered depending on the operation frequency, loss tangent of the dielectric, and the specifications of materials (e.g. dielectric constant, dielectric types) [1]. Figure 5 indicates the loss tangent for PTFE.

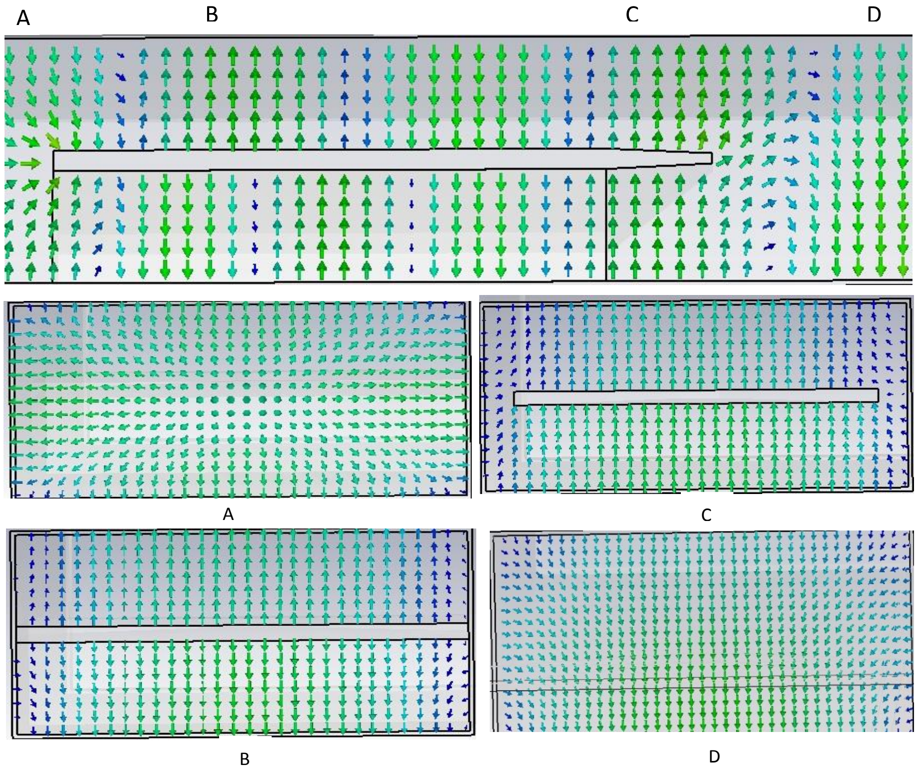

**Fig. 2: Cross-sectional views of electric wave patterns**

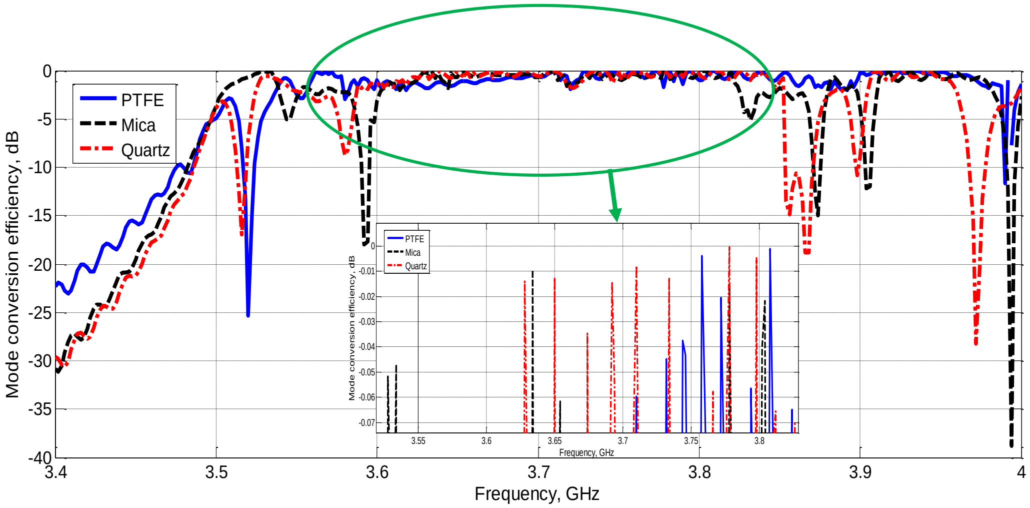

**Fig. 3: Mode conversion efficiency comparison between different materials**

| Material | Band wide(MHz) | efficiency | Length(cm) |
|---|---|---|---|
| **PTFE** | 450 | 95.5% | 10.4 |
| **Mica** | 280 | 91% | 3.2 |
| **Quartz** | 270 | 93% | 5 |

**Table 1: Comparison of different materials**

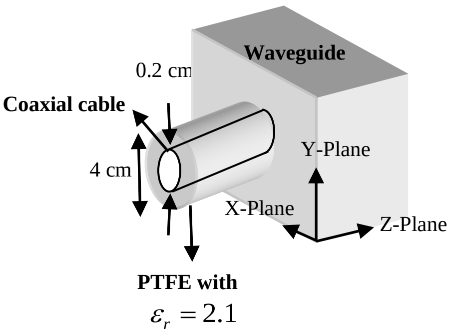

**Fig. 4: A coaxial cable feed for $TM_{11}$ mode excitation.**

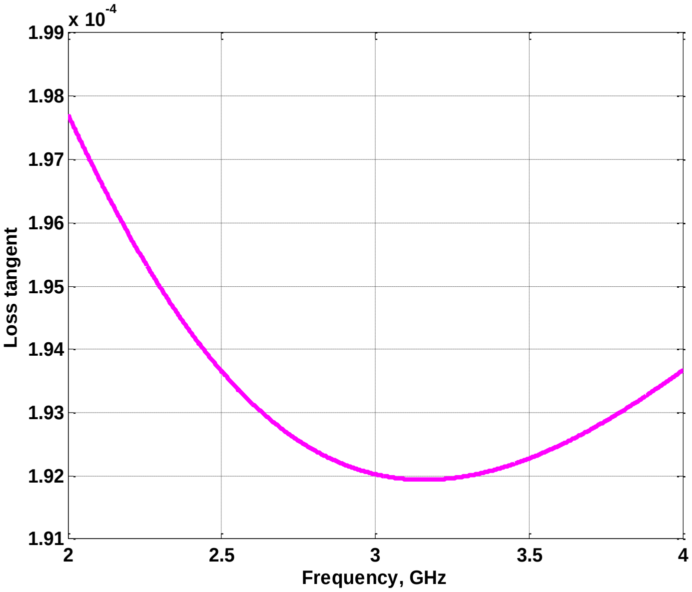

**Figure 5. Loss tangent for PTFE**

## 5. Conclusion

In this paper, a novel structure is presented which is able to convert $TM_{11}$ mode to $TE_{10}$ dominant mode in the rectangular waveguide. The proposed structure can be simply fabricated and provides sufficient bandwidth. Simulation results show that the presented structure has the advantage of more than 90% conversion efficiency.

## References

[1] A. Chittora, J. Mukherjee, S. Singh and A,Sharma, “Dielectric Loaded $TM_{01}$ to $TE_{11}$ Mode Converter for S-band Applications,” IEEE Trans. Dielectrics and Electrical insulation, vol. 22, pp. 2057-2063, August 2015.

[2] A. Tribak, J. Zbitou, A. Mediavilla, A,Sharma and NA. Touhami, “Ultra-broadband High Efficiency Mode Converter ,” Progress in Electromagnetics Research, vol. 36, pp. 145-158, January 2013.

[3] R. L. Eisenhart , “A Novel Wideband TM01-to-TE11 Mode Converter,” Microwave Symposiun Digest, vol. 1, 1998, pp. 249–252.

[4] K.S.S. Prasad, S.A. Singh, S.S. Shanmukha, R. Seshdri and M.V. Kartikeyan “Design of a TM01-TE11 Circular Bend Mode Converter Operating at 3GHz,” IEEE International Vacuum Electronics Conf., pp. 177-178, February 2011.

[5] S.H. Lee, B.M. Lee, J.Ahn, Y.J. Yoon and J.H. So “The Design of X-band Non-constant Serpentine TM01-TE11 Mode Converter with Short Length,” Asia-Pasific Microwave Conf., Vol. 1, pp. 4, 2005.

[6] B.M. Lee, W.S. Lee, Y.J. Yoon, J.H. So, “X-band $TM_{01}$-$TE_{11}$ Mode Converter with Short Length for High Power,” Electronics Letts, vol. 40, No. 18, pp. 1126-1127, 2004.