Analysis and design of broad-band Square-to-Circular Waveguide Transitions

Vivek Yadav, Udaybir Singh and AK Sinha

Gyrotron laboratory, MWT Area, Central Electronics Engineering Research Institute, Pilani-333 031, INDIA

Council of Scientific and Industrial Research (CSIR)
Email: vivek.ceeri@gmail.com, Ph.+91-1596-252229

Abstract:- **This paper presents the design of square-to circular waveguide transitions. The design is based on the asymmetric rectangular-to-circular and circular-to-circular waveguide junction) associated with the generalized S-matrix technique for the composite structure. The performances of initial and optimized transitions are presented. A transition from square to circular waveguide provides 30dB return loss between 10GHz and 12GHz, which shows that more sections are required for broad-band transitions. Design and analysis procedure is performed through the commercially available field solver HFSS and CST, which is in good agreement with experimental results.**

Keywords:- **square waveguide, circular waveguide, transformer.**

I. INTRODUCTION

Transitions from square to circular waveguides are required in measurement of ceramic used in gyrotron beam tunnel and RF window. The design of rectangular-to-rectangular or circular-to-circular impedance matching transformers is well documented. The shortest design consists of a direct connection between the square and circular guides using an iris in the plane of transition. Transitions from square to circular require special consideration caused by different field configurations in the two guides as in rectangular to circular waveguides [1].
A design procedure for rectangular-to-circular transitions is presented in [7]. Therefore, this paper presents initial design procedure for square-to-circular waveguide transitions and demonstrates optimization results for broad-band applications as shown in fig.1. The estimation of the initial dimensions is carried out by a minor modification of a rectangular to rectangular step impedance transformation procedure. It provides small transformer which immediately lead to return-loss values between 30 and 40 dB. The performance provides enough bandwidth for practical applications. Therefore, this paper establishes a new and compact square to circular waveguide trans-former concept which is based on small and rapidly stepped rectangular and circular waveguide sections.

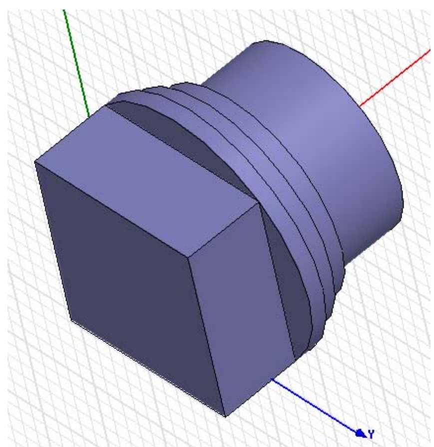

Fig.1. 22.86X22.86 square to 13.5 mm diameter circular transition with 7.2 mm transformer length (HFSS model)

II. INITIAL DESIGN

The optimization procedure will drastically vary the widths/heights of square and the diameters and length of circular waveguides. The different discontinuities between square and circular waveguides must be considered [1]-[3]. The basic transformer in Fig. 2 contains an on-axis connection of one square and one circular waveguide section. The other circular section is introduced for further return-loss improvement. Although the relationships of the fundamental mode cut-off frequencies in square and circular waveguides generally vary for different designs, the following initial dimensions have been broadly tested and will commonly yield a return loss of better than 20 dB. In the design procedure of square-to-circular transitions, we first assume that all transformer sections be circular as shown in the Fig. 1. The diameters of the circular sections can now be related to a. where a is the dimension of square waveguide. The diameters can equal the width/height of the square design, i.e., d =*a*. combination of *a(i)* and *b(i)* can be used to determine the diameters. In order to limit the influence of the rather large *b* dimensions, we choose the diameter of circular waveguide equal to the diagonal of the square waveguide.

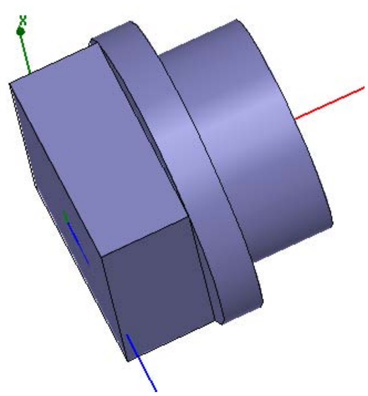

Fig.2. 22.86X22.86 square to 13.5 mm diameter circular transition with 4.4 mm transformer length.

It should be pointed out, however, that the direct connection between the square (22.86mm x 22.86mm) and the circular (32.32mm diameter) waveguide results in a broadband performance, which will satisfy specifications for many applications. For the initial design the transformer length is 7.2mm shown in Fig. 3.

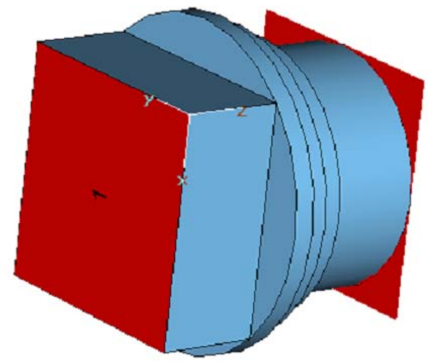

Fig.3. 22.86X22.86 square to 13.5 mm diameter circular transition with 7.2 mm transformer length (CST model).

III. OPTIMISATION

The fine optimization is carried out using the Mode-Matching Technique (MMT) [5], the diameters and lengths of the circular sections between the square input and the circular output guide are optimized using a Mini-Max based algorithm [6]. The function to be minimized is given by

$$F = \sum_i [R_n / R(f_i)]^2$$

where R_n and $R(f_i)$ are the desired and actual return loss, respectively, at frequency f_i.

IV. RESULTS

A square to circular waveguide transformer as fig was designed for 22.86X22.86 square to 32.32 mm diameter circular. Fig shows the performance designed by commercial software HFSS and validate by CST microwave studio. The 30 dB return loss is achieved and transformer length is 4.4 mm. to increase the return loss and frequency band of this design a circular section is added. The transformer length is now 7.2 mm and the bandwidth increase 25 percent. The performance of the final design was computed by commercial software HFSS and CST. The results from both softwares and practically achieved results have a good agreement.

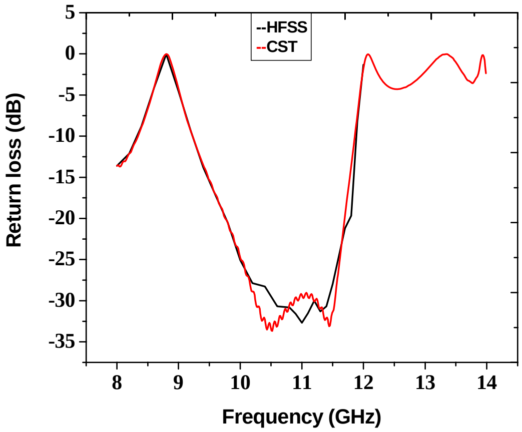

Fig.4. Performance of square to circular waveguide transformation according to fig.2.

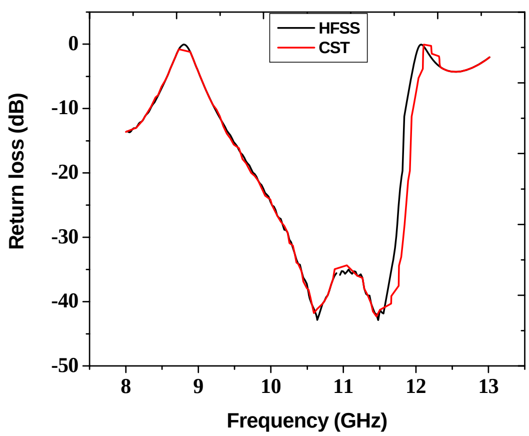

Fig.5. Performance of square to circular waveguide transformation with two additional circular waveguide sections according to fig. 3.

At 10 GHz comparison between computed results and measurement results is shown in fig. The structure has been realized from one piece with CNC milling techniques by machining from the waveguide faces at both sides [5]. Computed and measured results overlap perfectly up to 35 dB return loss, representing a 19 percent bandwidth with more than 30 dB.

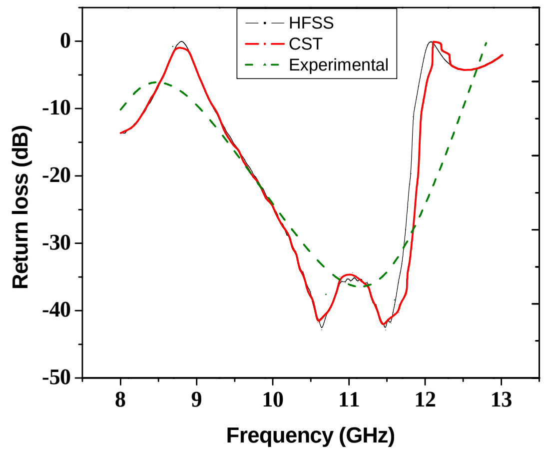

Fig.6. Comparison between computations and experimental for a square to circular waveguide transition (22.86X22.86 to 23.5 mm diameter).

V. CONCLUSION

A new and small square to circular waveguide transformer design has been presented and this paper offered high performance broad-band square to circular waveguide transition. The design procedure has been verified by comparison with experimental results and simulated results, which obtained from commercial available field solver HFSS and CST.

ACKNOWLADGEMENT

Authors are grateful to the Director, CEERI, Pilani, for permission to publish this paper. Thanks are due to Dr SN Joshi, Dr. V Srivastava and Team Members for their continuous support and authers are also thankful to Dr, LM Joshi and Mr. Devashish Pal, klystron group, CEERI for providing the PNA facility.

REFRENCES

[1] M. Mongiardo and C. Tomassoni, “Modal analysis of discontinuities between elliptical waveguides”, *IEEE Trans. Microwave Theory Tech.*, vol. 48, pp. 597-605, Apr. 2000.

[2] H.D. Knetsch, “Contribution to the theory of abrupt cross-sectional changes in waveguides” (in German), *Int. J. Electron. Commun. (AEÜ)*, vol. 22, pp. 591-600, Dec. 1968.

[3] H.D. Knetsch, “Mode converters and filters with rectangular and circular waveguide elements” (in German), *NTZ*, pp. 57-62, Feb. 1970.

[4] R.H. MacPhie and K.-L. Wu, “Scattering at the junction of a rectangular waveguide and a larger circular waveguide”, *IEEE Trans. Microwave Theory Tech.*, vol. 43, pp. 2041-2045, Sep. 1995.

[5] U. Rosenberg and M. Schneider, "High performance transitions for overmoded operation of elliptical waveguides", *IEEE Trans. Microwave Theory Tech.*, Vol. 48, pp. 1749-1755, Oct. 2000.

[6] K. Madsen, H. Schaer-Jacobsen and J. Voldby, “Automated minimax design of networks,” *IEEE Trans. Circuits Systems*, Vol. CAS-22, pp. 791-796, Oct. 1975.