SURVEY OF DESIGN METHODS FOR CIRCULAR WAVEGUIDE TAPER

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***Abstract*— It always a need of tapered waveguide section for connection between two components that has different shape or dimensions. It plays an increasingly important role in microwave technology such as in long distance waveguide transmission systems. Tapers have wide area of research. Many analysis on mode conversion, designing methods, mode matching techniques for tapers were done in past. Main concern of a waveguide taper is maximum power transmission and reduces mode conversion loss. To choose appropriate shape profile for taper according to our application in millimetre wave frequencies, we have presented survey of various types of circular waveguide tapers in this paper.**

Keywords— circular waveguide taper; mode conversion; transmission response; shape profile and spurious mode

I. INTRODUCTION

Circular waveguide tapers connect two different waveguide sections having different apertures. Such tapers are available in various shapes (e.g. exponential, parabola, linear, raised cosine). One can design either straight tapers with constant taper angle and abrupt discontinuities at each end or variable taper with taper angle varied continuously along the length of the taper. Major problem with tapers is mode conversion loss. Power may be converted into spurious modes. Spurious modes are unwanted modes in which power is converted. Detailed work was done on mode propagation in circular waveguide tapers for various applications and waveguide discontinuities for analysis of complex waveguides & the propagating modes. Mode matching theories are developed for taper design. These complex calculations are also implemented in various computer codes which are described in this paper. Some computer codes and software are also developed for taper analyses that reduce time to calculate complex parameters. This paper described review on tapers designed on different principles. One can choose proper method of designing taper according to application.

II. REVIEW AND ANALYSES OF DESIGN METHODS OF TAPER

H. G. Unger [1] suggested raised cosine profile taper which had very low mode conversion. In this design, mode conversion is given by Tschbycheff polynomial and geometry is designed using Fourier transform of this polynomial. He has proved that power conversion from TE01 to higher modes occurring in conical transitions can be reduced by changing the cone angle gradually. Solymer [9] had suggested linear shaped taper with gradual change in radius with length. If we increase radius of taper gradually over length than impedance mismatching can be reduced. The normalized amplitude coupling coefficient between TE01 and TE02 modes at the output junction is given by,

$$C = 0.142\frac{D_2(D_2 - D_1)}{\lambda L} \quad \ldots\ldots\ (1)$$

Where, D1 and D2 are input and output diameter respectively. L is length of taper and λ is corresponding to frequency at which taper is to be designed. Paul-Henri Tichit [2], Shah Nawaz Burokur and et' applied spatial transformation to design a taper between two waveguides with different cross sections. Three transformation formulations have been tested: a linear, a parabolic and an exponential one. Each formulation is used to generate material parameters and it has been observed that the parameters profile depend on the formulation considered. They have measured performance of their design in finite element based software Comsol Multiphysics.

TomiyasuKlyo developed a waveguide taper of minimum length at General Electric Company [6]. Rudolf P Hecken has demonstrated that optimum taper has maximum bandwidth for a given length or minimum length for a given bandwidth [7]. Heckenhas introduced some modification in taper design equation for the condition when ratio of end diameter becomes so large as reconversion from the spurious mode to incident mode is neglected. [8]

To overcome complexity in calculations & save time, H Flugel and E Kuhn developed the rigorous analysis of circular waveguide tapers using the high speed digital computer. Jeff M. Neilson (1989) has worked on development of cascaded scattering matrix code for analysis of tapers with complicated electromagnetic equations. This code solves equations of coupling coefficients for tapers. W. Lawson [3] has designed non-linear taper by solving the generalized telegraphist's equations numerically and is compared with the results of a cascaded scattering matrix code. FEM and FDTD based various software like HFSS, COMSOL Multiphysics and CST Microwave studio are used for validation and analysis.

D.S Nagarkoti and Rajiv Sharma [5] presented modal matching field analytical techniques for the analysis of arbitrarily shaped nonlinear waveguide tapers. Linear, parabolic, exponential and raised cosine shaper profile have been taken and it have been found that the raised cosine shape profile nonlinear taper has been found most suitable since it has minimal shaper variation at both end thereby ensuring minimal reflections. Transmission response from this analysis at 50GHz is as shown in table-1. Shape profile of taper must be smooth enough to provide good transmission. Nagarkoti has described some basic shape profiles can be obtained using equation shown in table-1. [4]

Suppose, we want to model a taper for input dimension a1= 3mm and output dimension a2= 12mm and l=400mm length. We have obtained results for four basic shapes of taper in MATLAB using above equations. One can simulate it in finite element method based software and compare the transmission response. Exact taper shape can be obtained by swiping these geometries around the central axis.

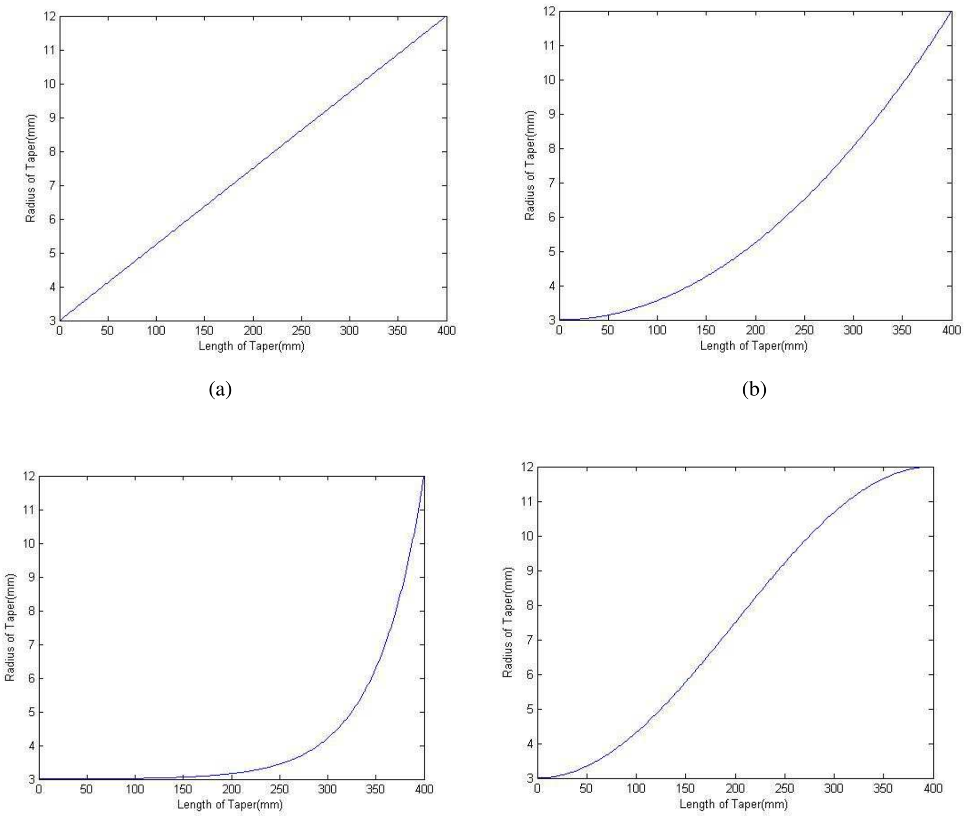
Table 1 TRANSMISSION PARAMETERS OF BASIC TAPER SHAPE PROFILES

Profile	**Transmission**
Linear	89.9%
Parabolic	71.5%
Exponential	32.5%
Raised Cosine	93.9%

Table 2 EQUATIONS FOR TAPER PROFILES

Profile	**Equation**
Linear	$a(z) = a_1 - (a_2 - a_1)(z/L)$
Exponential	$a(z) = a_1 - (a_2 - a_1)e^{8(z-L)/L}$
Parabolic	$a(z) = a_1 - (a_2 - a_1)(\frac{z}{L})^2$

Raised Cosine	$a(z) = 0.5(a_2 - a_1) + 0.5(a_2 - a_1)\cos\left[\left(\frac{z}{L} - 1\right)\pi\right]$



(a) (b) (c) (d)

Fig.1 Shape profile of circular waveguide tapers
(a) Linear, (b) Parabola, (c) Exponential, (d) Raised cosine

III. Conclusion

Various methods of taper design to reduce spurious mode conversion is discussed in this paper. From above analysis, we can conclude that raised cosine and linear tapers are best in term of transmission. However, sometime it is very difficult to fabricate raised cosine taper for very small dimensions. So, linear taper is more suitable at that time. One can design such taper for low mode conversion loss.

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