Waveguide Structures with Improved Cut-off Frequency and Bandwidth

Ramakrushna Panigrahi, Siba Prasad Mishra, P.V.Y.Jayasree

***Abstract*—The wave transmission characteristics of rectangular, double-ridge, trapezoidal-ridge and anti-trapezoidal ridge waveguides are analyzed using the finite-element method. The cut-off wavelength and attenuation of these waveguides are calculated. The result shows that anti-trapezoidal ridge waveguides perform better than rectangular, double-ridge and trapezoidal-ridge waveguides. The variation of bandwidth and attenuation with respect to change in the angle of physical ridge structures has been studied while migrating from rectangular to anti-trapezoidal ridge structures.**

***Keywords*— waveguides; cut-off frequency; attenuation; rectangular, double-ridged; trapezoidal; anti-trapezoidal.**

I. INTRODUCTION

Ridge waveguides are used for a long time due to its low cut-off frequency and better bandwidth characterizes at dominant mode [1]. Ridge rectangular waveguides are also used as low impedance broadband structures. Due to wide frequency bandwidth, low dominant mode cutoff frequency and the characteristic impedance is smaller than rectangular waveguide structures ridge waveguides are used in many applications like phase shifters, duplexers, ridge waveguide transmitters and ridge bandwidth filters [1-3]. For many years various methods have been proposed for the analysis of rectangular, ridge waveguides. In recent studies various method been proposed for the study of trapezoidal waveguides. The study and analysis of trapezoidal waveguides show that in many way trapezoidal waveguides performs better than rectangular and ridge waveguides [5-7]. In ridge and trapezoidal waveguide design, the position and dimension of ridges play a major role in its performance and signal transmission in an optimized way [4]. The dimensions of ridges are optimized to minimize dominant mode cut-off frequency while the increase of the dominant mode bandwidth [1-2]. A popular method for determining the cut-off frequency, attenuation and bandwidth is Finite Element Method which is been used for a long time and it provides the accurate result.

Aim of this analysis is to develop a waveguide which will have better performance than existing all waveguide structures in WR90 waveguide category. By varying the angle of ridge starting from an existing popular plane rectangular WR90 waveguide to double ridge waveguide structure which is migrating through the number of trapezoidal structures and then through series of anti-trapezoidal structures, the dominant mode cut-off frequencies and attenuation characteristics are analyzed in detail in this paper. All these simulations are done using HFSS.

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II. DESCRIPTION OF RECTANGULAR, DOUBLE RIDGE AND TRAPEZOIDAL WAVEGUIDES

Consider a rectangular waveguide structure WR90 of length L with dimension a x b x L as shown in fig.1, where the cavity is filled with air and the wall of the waveguide are composed of perfect conducting material.

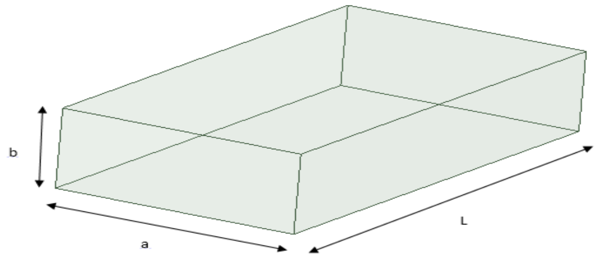

Fig. 1. A typical cross section of rectangular waveguide

The corresponding ridge waveguide structure WR90 of same length L with outer dimension a x b x L and having ridge dimension c x d is as shown in fig. 2.

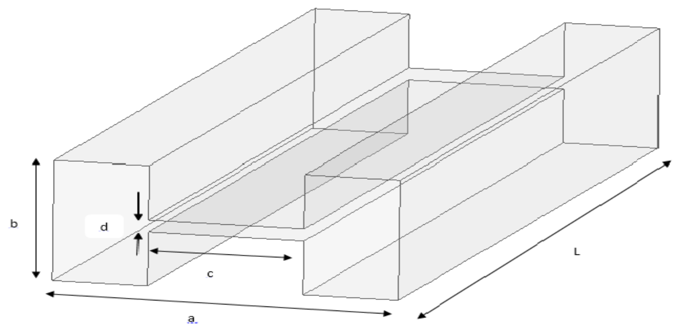

Fig. 2. A typical cross section of double ridge waveguide

For the same outer dimension, a x b x L of WR90 waveguide by keeping ridge gap ‘d’ constant and making arm ‘c’ variable as shown in fig. 3 we will obtain a series of trapezoidal and anti-trapezoidal waveguides where the angle of ridges are only variable between two extremes.

The angle variation will result in a number of trapezoidal waveguides as shown in fig. 4

from which only standard angles considered here for calculation and observation purpose. All these waveguides are prepared with the same material, and under the same constraint, same boundary conditions and same excitations. The series of waveguides which results because of angle variations are considered for analysis purpose.

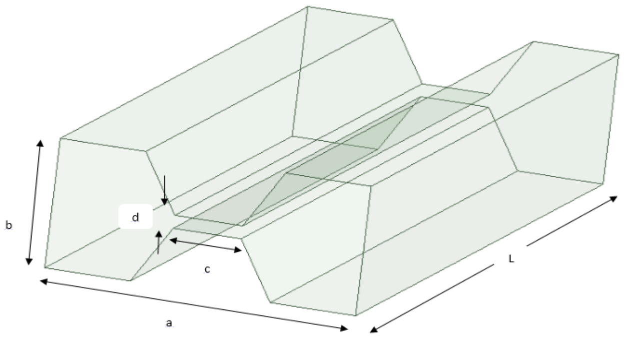

Fig. 3. Cross section of trapezoid double ridge waveguide

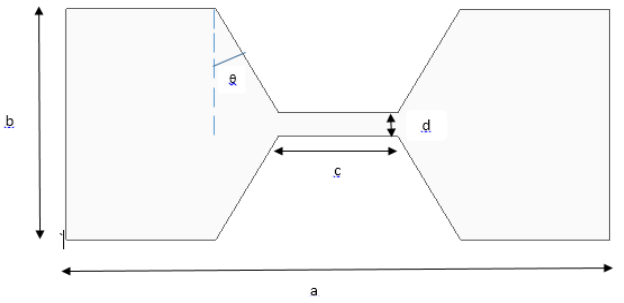

Fig. 4. Front View of trapezoid double ridge waveguide

III. RESULT ANALYSIS

The analysis of these waveguides is being done for S, C, X, Ku, K and Ka-band (2GHz – 30GHz). Waveguide dimensions are a/b = 2.25, b/d = 10, c and theta are variables.

The waveguide modal analysis is done for the first five modes. The double ridge trapezoidal waveguides results obtained by this method are compared with that of rectangular and double ridge waveguides. The rectangular and double ridge waveguides structures are being simulated and analyzed by many so far. In this paper, the modal analysis of trapezoidal and anti-trapezoidal structures are discussed.

On the basis of some standard structures, we studied the cut-off frequency of waveguide structures and the results showing their cut-off frequencies for the first five modes are as shown in Fig. 5 – 10.

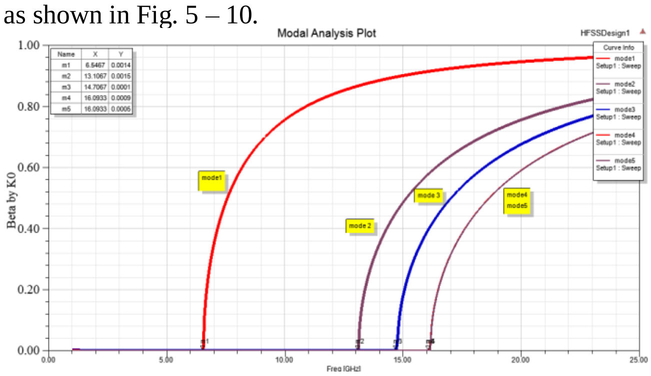

Fig. 5. First Five Modes of Rectangular Waveguide (θ = 900)

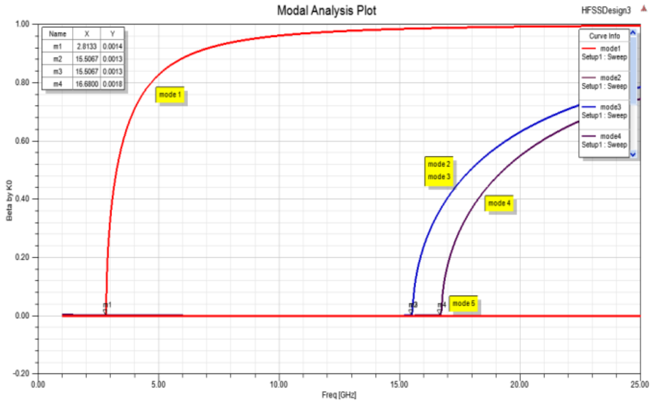

Fig. 6. First Five Modes of Trapezoidal Waveguide (θ = 300)

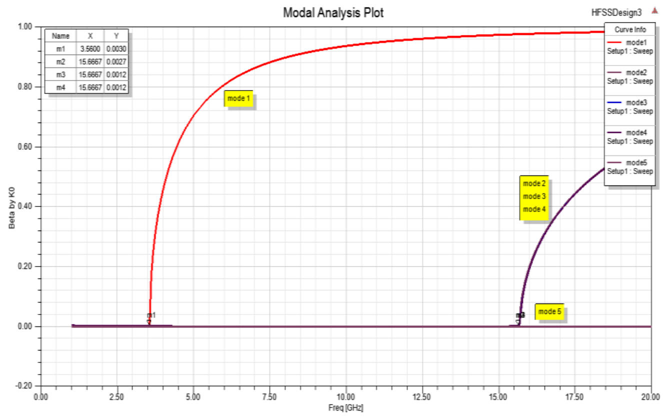

Fig. 7. First Five Modes of Trapezoidal Waveguide (θ = 450)

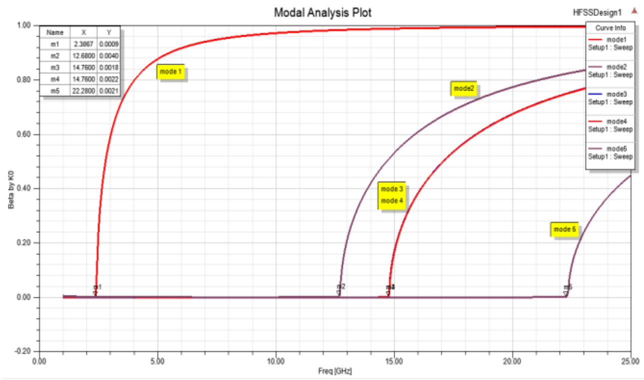

Fig. 8.First Five Modes of Double Ridge Waveguide (θ= 00)

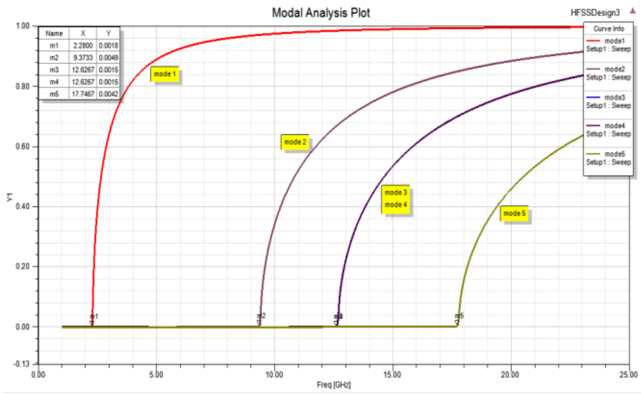

Fig. 9.First Five Modes of Anti-Trapezoidal Waveguide (θ = - 300)

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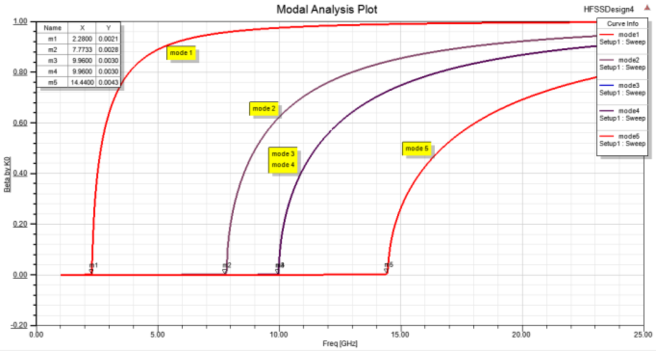

Fig. 10.First Five Modes of Anti-Trapezoidal Waveguide (θ = - 450)

With reference to the above simulation analysis, the cut-off frequencies of the first four modes of Rectangular, Trapezoidal, Double Ridge and Anti-Trapezoidal waveguides are analyzed and the results are summarized as shown in Table 1.

Table 1. Cut-off frequencies of Rectangular, Trapezoidal, Double Ridge and Anti-trapezoidal waveguides

Type	Cut - off Frequencies (GHz)			
(θ)	mode1	mode2	mode3	mode4
90^0	6.5467	13.1067	14.7067	16.0933
30^0	2.8133	15.5067	15.5067	16.6800
45^0	3.5600	15.6667	15.6667	15.6667
0^0	2.3867	12.6800	14.7600	14.7600
-30^0	2.2800	9.3733	12.6267	12.6267
-45^0	2.2800	7.7733	9.9600	9.9600

The attenuation of these waveguides are also studied and simulated in HFSS and these results also indicate that the specific anti-trapezoidal waveguide provides less attenuation as that of the rectangular, double ridge and trapezoidal waveguide structures. The simulated results are shown below from fig.11-16.

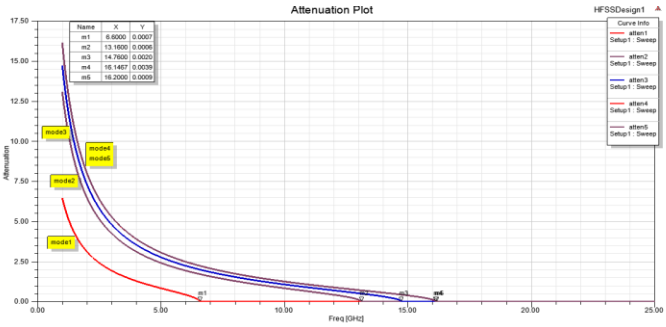

Fig.11. Attenuation Plot of Rectangular Waveguide (θ = 900)

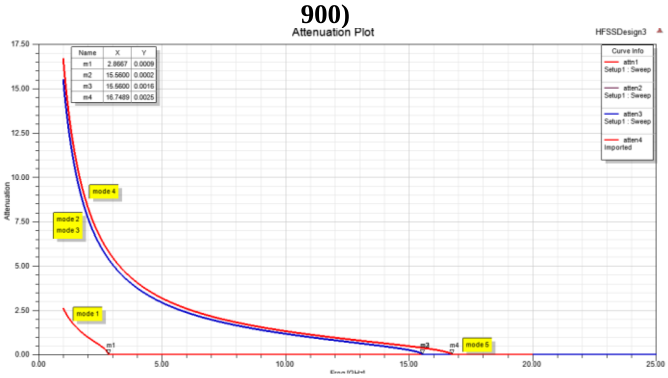

Fig.12. Attenuation Plot of Trapezoidal Waveguide (θ=300)

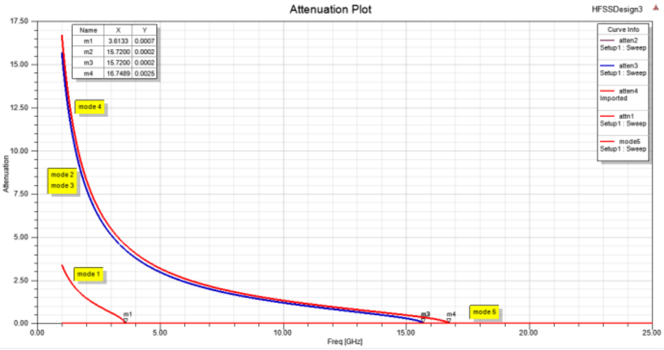

Fig.13. Attenuation Plot of Trapezoidal Waveguide (θ = 450)

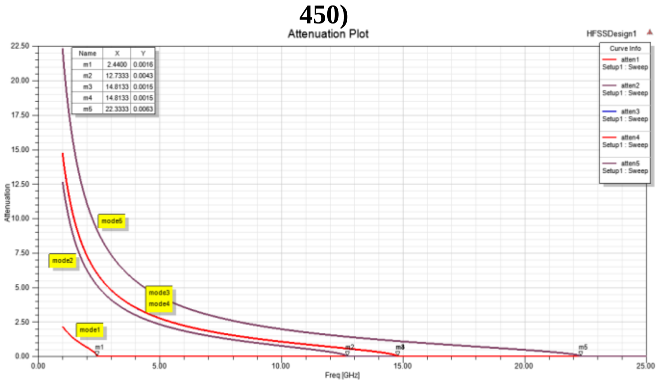

Fig.14. Attenuation Plot of Double Ridge Waveguide (θ= 00)

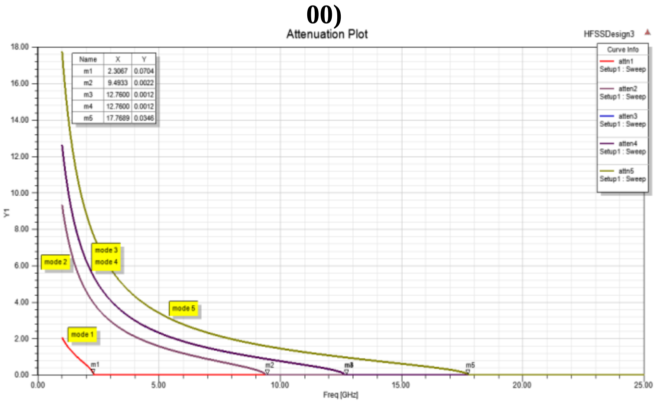

Fig.15. Attenuation Plot of Anti-Trapezoidal Waveguide (θ = - 300)

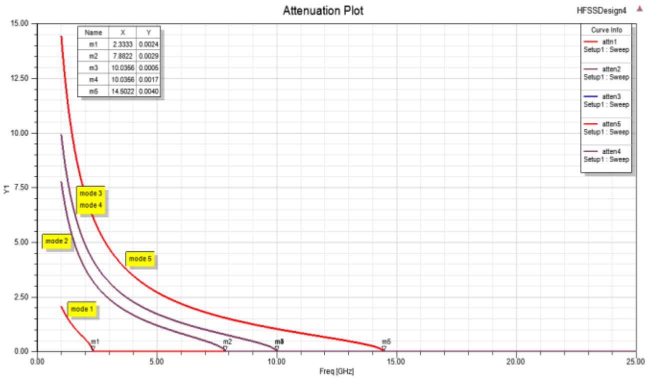

Fig. 16. Attenuation Plot of Anti-Trapezoidal Waveguide (θ = - 450)

All these above results are obtained by maintaining a/b = 2.25, b/d = 10 as per industrial standard of WR90 double ridge waveguides except the case of the rectangular waveguide where a x b is same as that of all other waveguides.

IV. CONCLUSION

In this paper, we have proposed the anti-trapezoidal waveguides having better performance than that of regular most common rectangular and ridge waveguides. As a primary matter of investigation in our study only cut-off frequencies, bandwidths and attenuations are considered. Further investigation has to be done thoroughly considering other parameters too. For the construction of these waveguides, copper is used as construction material here. Other materials need to be tested in the coming investigation process to reduce the cost and improve the efficiency of these waveguides for mass production as per industry standards. Considering the same dimension for all above waveguides for a particular value of theta will show the lowest cut-off frequency and improved bandwidth. Specific Anti-trapezoidal waveguides, provides better results than the rectangular, double ridge and trapezoidal waveguides.

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