ATTENUATION AND POWER-HANDLING CAPABILITIES OF GENERALIZED RIDGE WAVEGUIDES

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ABSTRACT

The generalized ridge waveguides are analyzed using mode matching method. The attenuation, cutoff frequencies, and power-handling capability characteristics in antipodal ridge waveguides, ridge-trough waveguides and cross finger double ridge waveguides are presented. Numerical results are obtained which are useful in design of microwave components and subsystems.

I. INTRODUCTION

Ridged waveguides have found many applications in microwave and millimeter wave devices. The advantages of this type of waveguides include large single mode broadband operation, large dominant cutoff wavelength and low impedance characteristics. Early investigations were focused on properties of single and double ridge waveguides [1,2]. Later other structures were reported to be superior alternatives to the conventional single and double ridged waveguide. These structures include rectangular waveguides with one or two T-shaped septa [3,4,5], two double ridge waveguides [6], antipodal ridge waveguides [7] and double antipodal ridge waveguides[8]. Among these structures, the double antipodal ridge waveguide is of particular interest, because of its larger dominant mode cutoff wavelength, its use will result in miniature compact components.

The properties of waveguides of this kind such as attenuation and power handling capabilities can not be found in the literature. A general mode matching approach is proposed and applied to the analysis of the generalized ridge waveguides.

II. ANALYSIS METHOD

The general ridged waveguide configuration to be investigated is shown in Figure 1. For a symmetrical waveguide, only half the structure is shown. Even modes and odd modes exist in the waveguide when

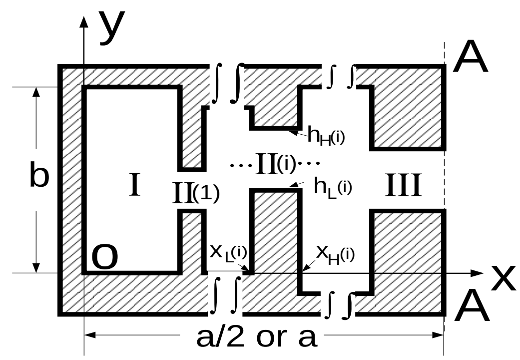

Fig.1 The Cross Section of A General Ridged Waveguide

PMC (perfect magnetic conductor) and PEC (perfect electrical conductor) are placed on the plane A-A, respectively. For an asymmetric waveguide, a PEW is placed on the plane A-A. The structure can be divided into three regions: Region I ($0 \le x \le X_L(1); 0 \le y \le b$), Region II ($\bigcup_{i=1}^{M}$ II(i), where II(i)= $(X_L(i) \le x \le X_H(i), h_L(i) \le y \le h_H(i)), M = N-1$ and N is the number of subregions in Fig.1 except Region I) and region III ($X_L(N) \le x \le X_H(N), h_L(N) \le y \le h_H(N)$). The electromagnetic fields for TE or TM modes in each region can be written as the superposition of those of the eigen modes. The tangential fields on the boundaries between each of the subregions are matched successively in the following way. First, fields on the boundary between regions I and II(1) are matched. This yields coefficients in region I in terms of those in region II(1). Then the fields on the boundary between regions II(1) and II(2) are matched and coefficients in region II(1) can be obtained in terms of the coefficients in region II(2). This procedure is repeated until all the fields on the boundaries are matched. Finally, an equation involving only the coefficients in region III are obtained. Setting the determinant of coefficient matrix of this equation to zero leads to an algebraic equation. Solving this algebraic equation, the cut off frequencies of TE and TM modes can then be obtained. Substituting the cutoff frequencies back into the above algebraic equation, all the coefficients in re-

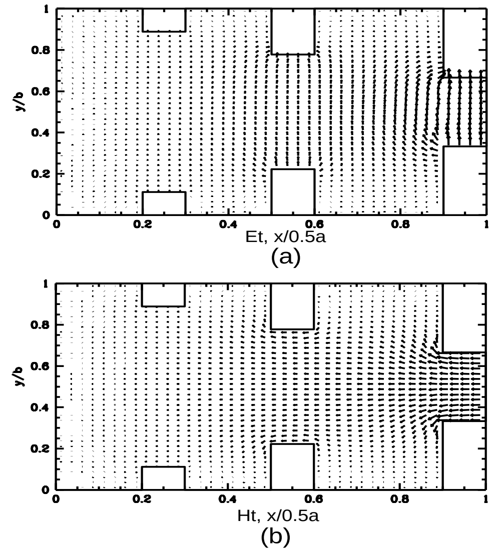

Fig.2 (a) The Electrical Fields in the Waveguide (b) The Magnetic Fields in the Waveguide

gions I, II, and III can be obtained. Thus, all the fields in each region can be readily calculated. The power loss per unit length, the power transmitted and the attenuation in the waveguide can be found. Maximum electrical field in the waveguide is obtained, and hence its maximum power handing capability.

III. NUMERICAL RESULTS AND DISCUSSIONS

The normalized attenuation α_n is defined as the ratio of the ridged waveguide attenuation to the rectangular waveguide attenuation of identical aspect ratio and identical cutoff frequency, evaluated at the frequency $f = \sqrt{3} f_c$. The power handling is indicated by the ratio of P_m to λ_c^2, where P_m represents the power carried by the waveguide at infinite frequency with the maximum electrical intensity E_0 in the waveguide being equal to the breakdown field in air ($30KV$ per centimeter). λ_c is the cutoff wavelength of the waveguide. The maximum normalized propagating power at any frequency is then obtained by multiplying P_m/λ_c^2 by $[1-(f_c/f)^2]^{0.5}$. To compare the properties of different waveguides, relative bandwidth is also used. This relative bandwidth is equal to $\lambda_{c1}/\lambda_{c2}$, where λ_{c1} corresponds to the cutoff wavelength of the dominant mode and λ_{c2} corresponds to the cutoff wavelength of the first higher order mode.

To validate the formulation and verify the accuracy of this approach, several checks of the numerical results are made. First, the vector fields in the waveguide are calculated and plotted as shown in Fig.2. It is clear that all the boundary conditions are satisfied. Second,

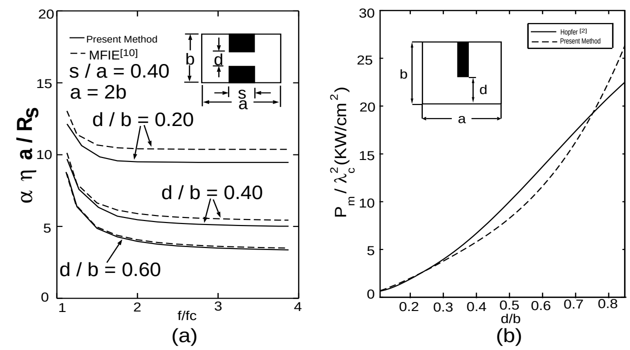

Fig.3 (a) The Attenuation Comparison (b) Power Handling(without corner breakdown) Comparison

the numerical results are compared with the analytical results when all the ridges are reduced to zeros. The normalized attenuation α_n becomes 1 and power handling is in agreement with that in [9]. Third, we compare the numerical results with those published in the literature as shown in Fig.3. Good agreement is obtained and therefore accuracy of the approach is established.

The attenuation and power-handling capability in several ridged waveguides are investigated. These structures are all special cases of Fig.1. For reference, Fig.4 shows the attenuation, power handling, dominant mode cutoff wavelength, and relative bandwidth in the single ridge and double ridge waveguide.

A) Antipodal Ridge Waveguides

The attenuation and power handling capabilitis in the antipodal ridge waveguides and double antipodal ridge waveguides are shown in Fig.5 and Fig.6. From these figures, it can be concluded that antipodal ridge waveguides and double antipodal ridge waveguides have almost the same characteristics. Compared to single ridge waveguides, although the bandwidth is narrower, the attenuations and power handlings in both of these structures are improved. The dominant mode cutoff wavelengthes are much longer than those in single ridge waveguides. With more antipodal ridges in the waveguides as shown in Fig.7, the dominant mode wavelengths increase and power handling capabilities improve. However, bandwidth becomes narrower. From Fig.7, it is also seen that the longer the lengths of the fourth and fifth ridges, the longer the dominant mode cutoff wavelengths.

B) Ridge-Trough Waveguides

Fig.8 shows the cross rectangular waveguide characteristics. This waveguide has lower attenuation than the rectangular waveguide with the same cutoff frequency. Fig.9 shows the attenuation and power handling capa-

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bilities in ridge-trough waveguides, which are used in design of microwave wafer probe [11]. The bandwidth of the ridge-trough waveguide is narrower than the single ridge waveguide of the same cutoff frequency. However, the ridge-trough waveguide has better attenuation and power-handling characteristics.

C) Cross Finger Double Ridged Waveguides

As can be seen from Fig.4, single ridge waveguides have lower attenuation than double ridge waveguides. However, the bandwidth and power-handling are both poorer for the single ridge waveguide than those in the double ridge waveguides. In order to make full use of this property and the characteristics of the above discussed antipodal ridge waveguides, two new configurations of ridged waveguides are proposed whose characteristic are shown in Fig.10. The new configuration have characteristics between those of antipodal ridge waveguides and those of double ridge waveguides. The bandwidth is improved. The attenuation, dominant mode cutoff wavelength and power-handling capability could be all better than those in single ridge waveguides. These two new configurations of ridged waveguides can be used in applications, where their superior characteristics justify their somewhat complex mechanical configurations.

IV. CONCLUSION

The attenuation and power handling capacities in antipodal ridged waveguides, ridge-trough waveguides and cross finger double ridged waveguides are investigated. Numerical results for the characteristics of these waveguides are presented. Attenuation and power handling characteristics are compared to the single ridge waveguide.

Numerical results show that loss and power-handling in the antipodal ridge waveguides and the ridge-trough waveguides can be improved and dominant mode cutoff wavelengths can be increased with slight decrease of the bandwidth. In order to make full use of the properties of antipodal ridge waveguides, cross finger ridge waveguides have been proposed and their characteristics have been presented. Cross finger ridge waveguides could have better attenuation, power handling and longer dominant mode wavelength than single ridge waveguides but still have good bandwidth.

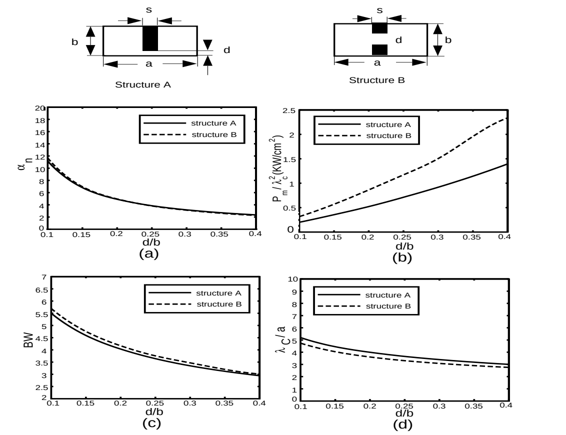

Figure 4 (a) Attenuation, (b) Power-Handling, (c) Bandwidth, and (d) Dominant Mode Cutoff λ_C vs d/b ($b/a = 0.45, s/a = 0.2$)

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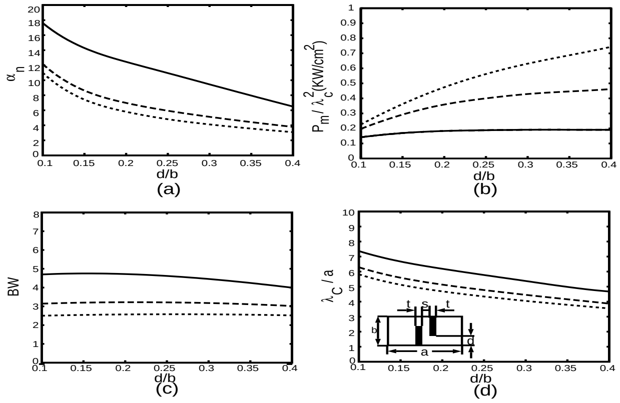

Figure 5 (a) Attenuation, (b) Power-Handling, (c) Bandwidth, and (d) Dominant Mode Cutoff λ_C vs d/b ($b/a = 0.45, t/a = 0.1$, solid line: $s/a = 0.05$, dashed line: $s/a = 0.10$, dotted line: $s/a = 0.15$)

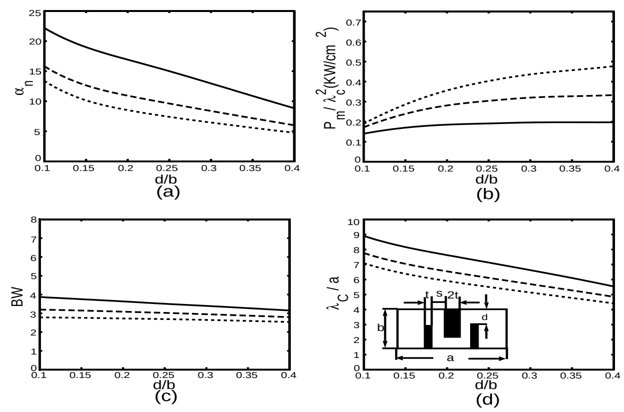

Figure 6 (a) Attenuation, (b) Power-Handling, (c) Bandwidth, and (d) Dominant Mode Cutoff λ_C vs d/b ($b/a = 0.45, t/a = 0.1$, solid line: $s/a = 0.05$, dashed line: $s/a = 0.075$, dotted line: $s/a = 0.10$)

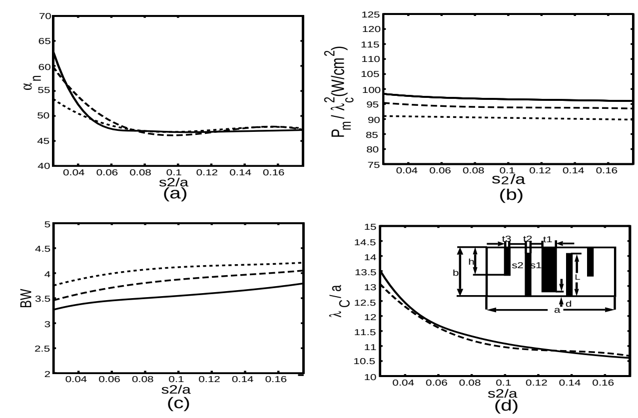

Figure 7 (a) Attenuation, (b) Power-Handling, (c) Bandwidth, and (d) Dominant Mode Cutoff λ_C vs $s2/a$ ($b/a = 0.45, t1/a = 0.2, t2/a = 0.05, t3/a = 0.05, s1/a = 0.025, d/b = 0.1, L/b = 0.9$, solid line: $h/b = 0.9$, dashed line: $h/b = 0.75$, dotted line: $h/b = 0.5$)

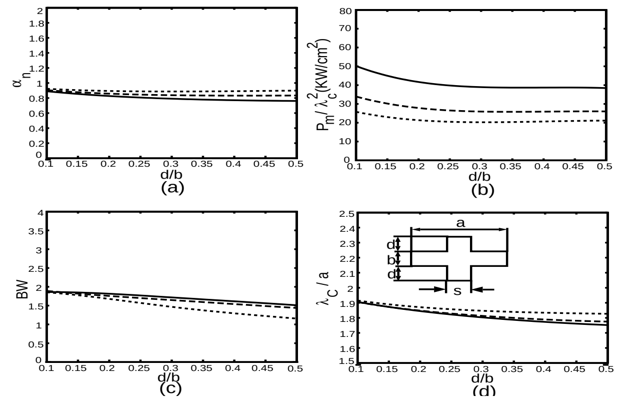

Figure 8 (a) Attenuation, (b) Power-Handling, (c) Bandwidth, and (d) Dominant Mode Cutoff λ_C vs d/b ($b/a = 0.45$, solid line: $s/a = 0.6$, dashed line: $s/a = 0.5$, dotted line: $s/a = 0.4$)

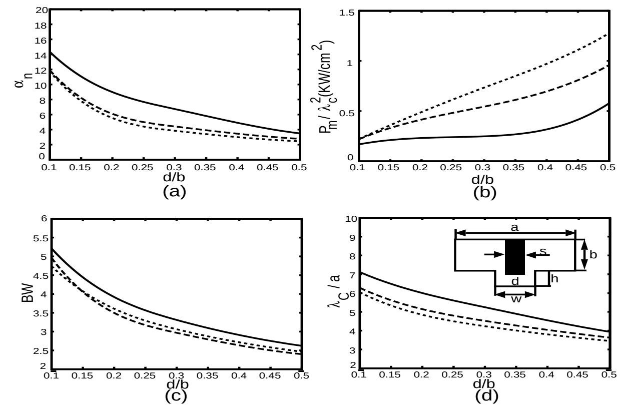

Figure 9 (a) Attenuation, (b) Power-Handling, (c) Bandwidth, and (d) Dominant Mode Cutoff λ_C vs d/b ($b/a = 0.45, h/b = 0.4, s/a = 0.2$, solid line: $w/a = 0.3$, dashed line: $w/a = 0.4$, dotted line: $s/a = 0.5$)

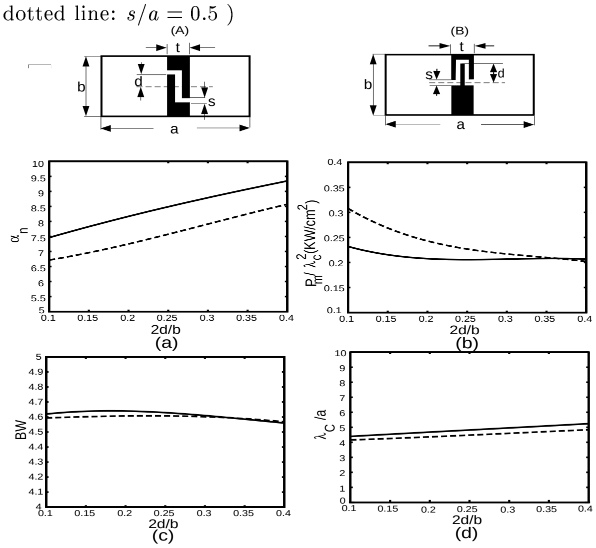

Figure 10 (a) Attenuation, (b) Power-Handling, (c) Bandwidth, and (d) Dominant Mode Cutoff λ_C vs d/b ($b/a = 0.45, s/b = 0.15, t/a = 0.2$, solid line: structure A, dashed line: structure B)