COMPLEX GUIDANCE PROPERTIES OF THE SLITTED ASYMMETRIC RIDGE WAVEGUIDE

F. Frezza+, M. Guglielmi*, and P. Lampariello+

+University of Rome "La Sapienza" Rome, Italy
*New Jersey Institute of Technology, Newark, N.J., U.S.A

ABSTRACT

A new open waveguide for millimeter-wave applications, namely the slitted asymmetric ridge waveguide, is proposed and analyzed that is at the same time simple to fabricate and flexible in terms of electrical characteristics.

The analysis is based on the development of an accurate transverse equivalent network and on the derivation of a dispersion relation which gives the complex longitudinal propagation costant in terms of the structural parameters. A detailed parametric analysis is then carried out showing how the real and imaginary parts of the complex propagation constant can be controlled with a good degree of independence from each other.

1. INTRODUCTION

The expansion of modern communication systems into the millimeter-wave range has motivated in recent years the investigation of the guidance properties of a number of new open guiding structures for antenna applications that are simple to realize from a mechanical point of view. In fact, due to the reduced dimensions, structures like conventional single radiators or conventional phased arrays can become difficult to fabricate. The constraint of mechanical simplicity, however, often results in a limitation of the range of the electrical characteristics obtainable. Therefore, the main features that an ideal guiding structure should exhibit are ease of mechanical fabrication and the possibility to control independently from each other the real and imaginary parts of its longitudinal (z direction) propagation constant $k_z=\beta-j\alpha$. In an experimental investigation [1], it was recently shown that lengths of asymmetric ridge waveguide with a centered slit on the top wall could be profitably used in antenna applications. It is, in fact, well known that, due to the asymmetry, the dominant mode of the structure is leaky and that radiation from the top aperture occurs so that the longitudinal propagation constant becomes complex. The authors of [1] recognized this feature, and used resonant lengths of slitted asymmetric ridge waveguide as separate radiators for their array but did not perform a detailed theoretical analysis on which a systematic design procedure could be based.

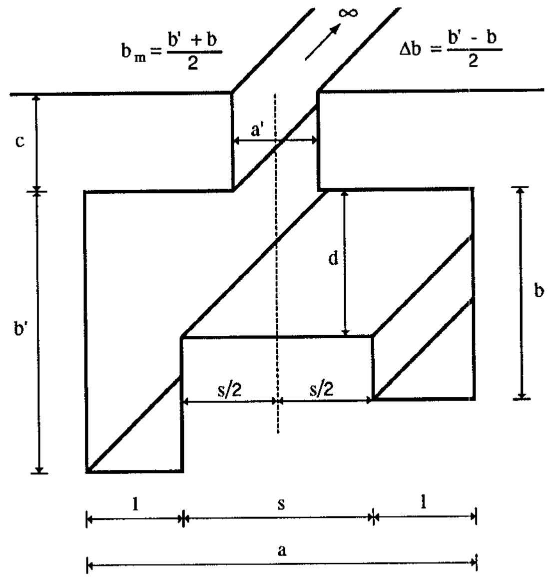

Fig. 1 The subject of this investigation: the asymmetric ridge waveguide with a slitted top wall.

In this paper we present a detailed theoretical analysis of the asymmetric ridge waveguide with a continuous slit on the top wall (Fig. 1) that shows how, in addition to being mechanically simple, this open guiding structure is also flexible from an electrical point of view. The theoretical approach that we have followed is based on an accurate transverse equivalent network and on a rigorous transverse resonance procedure. The transverse equivalent network developed takes into account the different heights of the two arms of the ridge waveguide as well as the thickness of the slitted top wall. The network has been developed by first recognizing that the cross section of the structure in Fig. 1 can be

CH2725-0/89/0000-0927$01.00 © 1989 IEEE

1989 IEEE MTT-S Digest

decomposed into a number of separate constituent parts.Each of these constituent parts can be described in terms of an equivalent network so that the complete transverse equivalent network can then be easily assembled. From this network we derived a transverse resonance equation and, through its numerical solutions, obtained the complex dispersion behavior of the structure. Next we performed a detailed parametric analysis and obtained the results presented in this paper, indicating that the slitted asymmetric ridge waveguide is indeed a very promising candidate for millimeterwave antenna applications.

2. THE TRANSVERSE EQUIVALENT NETWORK

In order to develop a transverse equivalent network for the structure in Fig. 1, we first recognize that its cross section can be decomposed into a number of constituent parts that can be independently represented in terms of equivalent networks. These costituent parts are: 1) the right and left arms of the ridge waveguide; 2) the radiating transition between the vertical parallel plate region, representing the thickness of the top wall, and the semi-infinite free space; 3) the central T-junction of the parallel plate waveguide regions. For the left and right arms of the ridge waveguide, we have used a slightly modified version of the network given in [2].

For the top radiating transition we have employed the equivalent network given in [3] (Chap. VIII, pp. 256-258), that is an improved version of the one given in the Waveguide Handbook [4] for the same transition. Finally, for the central T-junction of parallel plate waveguides we have used the novel equivalent network representation, given in [3] (Cap. V, pp. 143-159). Properly connecting to each other the separate equivalent network representations, we have finally obtained the complete transverse equivalent network for the slitted asymmetric ridge waveguide shown in Fig. 2.

3. THE TRANSVERSE RESONANCE PROCEDURE AND THE PARAMETRIC ANALYSIS

From the transverse equivalent network developed we then derived a suitable transverse resonance equation of the general form

$$f(k_t, a, a', b_m, \Delta b, c, d, s, l) = 0 \qquad (1)$$

From the solution of (1) we then computed the value of the complex propagation constant k_z as a function of all the parameters.

Figure 3 shows the behavior of the normalized phase constant β/k_o and the normalized attenuation constant α/k_o as a function of frequency for the lowest mode of the structure. The two curves show that above cutoff the behavior is as expected, with β/k_o following a standard curve shape and with α/k_o, which represents the leakage of power, decreasing monotonically with increasing frequency. Below cutoff the curve of β/k_o turns up again at very low frequencies showing a behavior not generally known, but readily understood by considering the relations between the wavenumbers. α represents primarily the reactive decay of the field, although there is still some leakage of power. Therefore, the value of α/k_o increases suddenly at cutoff.

Several other parametric studies have been performed but we report here only the ones that illustrate the most important features of the structure. In Fig. 4 we show the effect of varying $\Delta b/b_m$ from 0 to 0.5, while keeping b_m constant, at the fixed frequency of 40 GHz. As we can see, changing this parameter we strongly affect the value of α/k_o but we observe very little effect on β/k_o. This feature is of key importance in antenna applications. In fact varying $\Delta b/b_m$ we can taper the aperture distribution of the antenna in such a way to satisfy the requirements on the sidelobes, while keeping constant β/k_o along the structure in order to maintain the same angle of maximum radiation.

Next we computed the values of β/k_o and α/k_o for $\Delta b/b_m=0.4$, but changing the value of b_m from $b_m=0.4a$ to $b_m=a$, always at 40 GHz. As we can clearly see, varying this parameter we observe a significant variation of β/k_o while α/k_o remains essentially constant. Therefore, in the design procedure, we can select the desired value of β/k_o, which is related to the angle of the radiated beam.

4. CONCLUSION

In this paper we have derived an accurate transverse equivalent network for the slitted asymmetric ridge waveguide. We have obtained a dispersion relation for the structure via a rigorous transverse resonance procedure. We have presented the results of a detailed parametric analysis showing how the structure, in addition to being mechanically simple, exhibits a good degree of independence in the control of β/k_o and α/k_o, the real and imaginary parts of its normalized complex longitudinal propagation constant. All of the results obtained indicate, therefore, that the slitted asymmetric ridge waveguide is indeed a promising candidate for millimeterwave antenna applications.

REFERENCES

(1) H. Shnitkin, J. Green and P. Bertalan, "Asymmetric Ridge Waveguide Radiating Element for a Scanned Planar Array", Digest 1988/IEEE AP-S Int. Symp., Syracuse, NY, June 1988, pp.55-58.

(2) J. R. Pyle, "The Cutoff Wavelength of the TE_{10} Mode in Ridged Rectangular Waveguide of Any Aspect Ratio", IEEE Trans. Microwave Theory and Techniques, Vol. MTT-14, pp. 175-183, April 1966.

(3) A. A. Oliner, Principal Investigator, "Scannable Millimeter Wave Arrays", Final Report on RADC Contract No. F19628-84K0025, Polytechnic University, New York, September 1988.

(4) N. Marcuvitz, Waveguide Handbook, Vol. 10 MIT Radiation Laboratory Series, McGraw-Hill Book Co., New York, 1951, pp. 183-185.

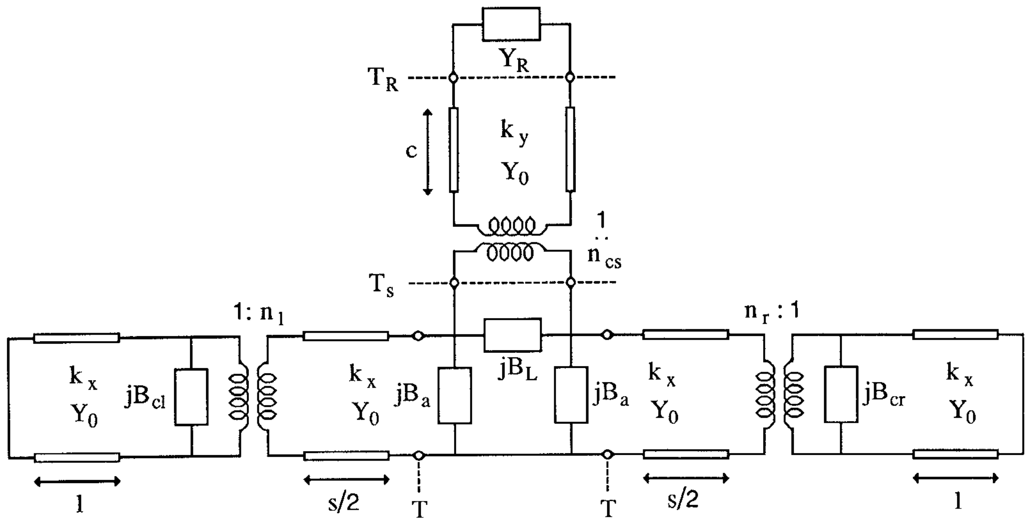

Fig. 2 The structure in Fig. 1 can be represented by the transverse equivalent network shown above.

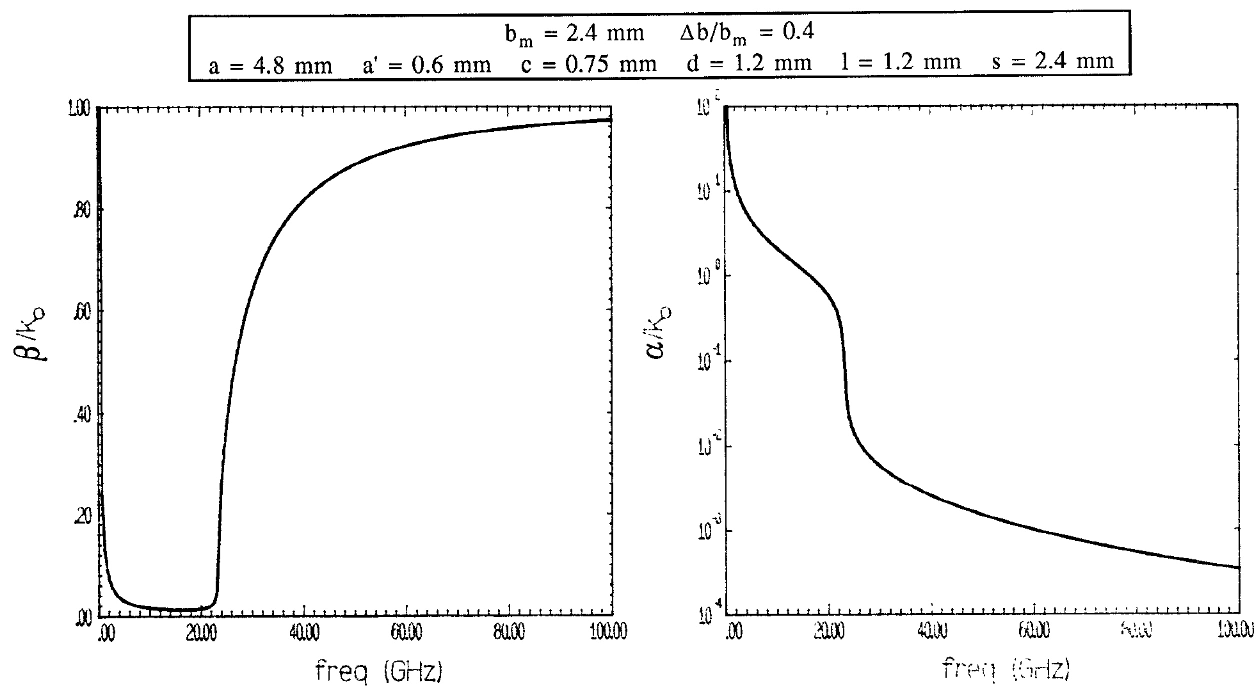

Fig. 3 Using the network in Fig. 2, and performing a rigorous transverse resonance, we can obtain the normalized complex longitudinal propagation constant $(\beta - j\alpha)/k_o$ as a function of frequency for the structure in Fig. 1.

f = 40 GHz b_m = 2.4 mm
a = 4.8 mm a' = 0.6 mm c = 0.75 mm d = 1.2 mm l = 1.2 mm s = 2.4 mm

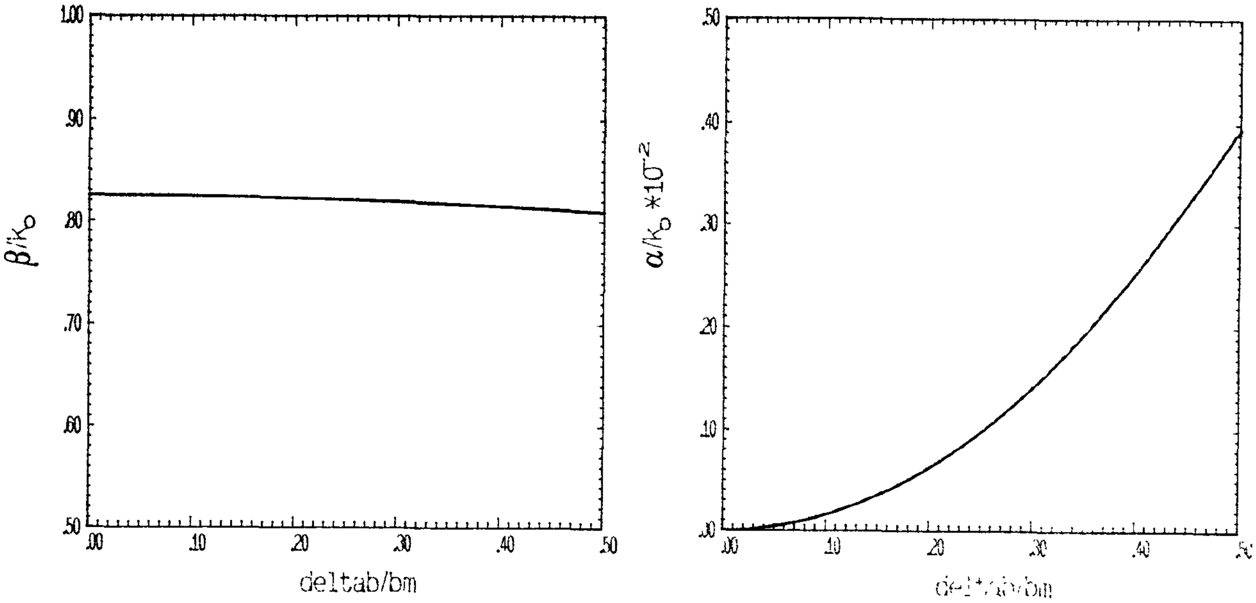

Fig. 4 In this figure we show how we can vary the normalized attenuation constant α/k_o and keep the normalized phase constant β/k_o essentially constant by varying only the parameter $\Delta b/b_m$ in Fig. 1, while keeping b_m constant.

f = 40 GHz $\Delta b/b_m$ = 0.4
a = 4.8 mm a' = 0.6 mm c = 0.75 mm d = 1.2 mm l = 1.2 mm s = 2.4 mm

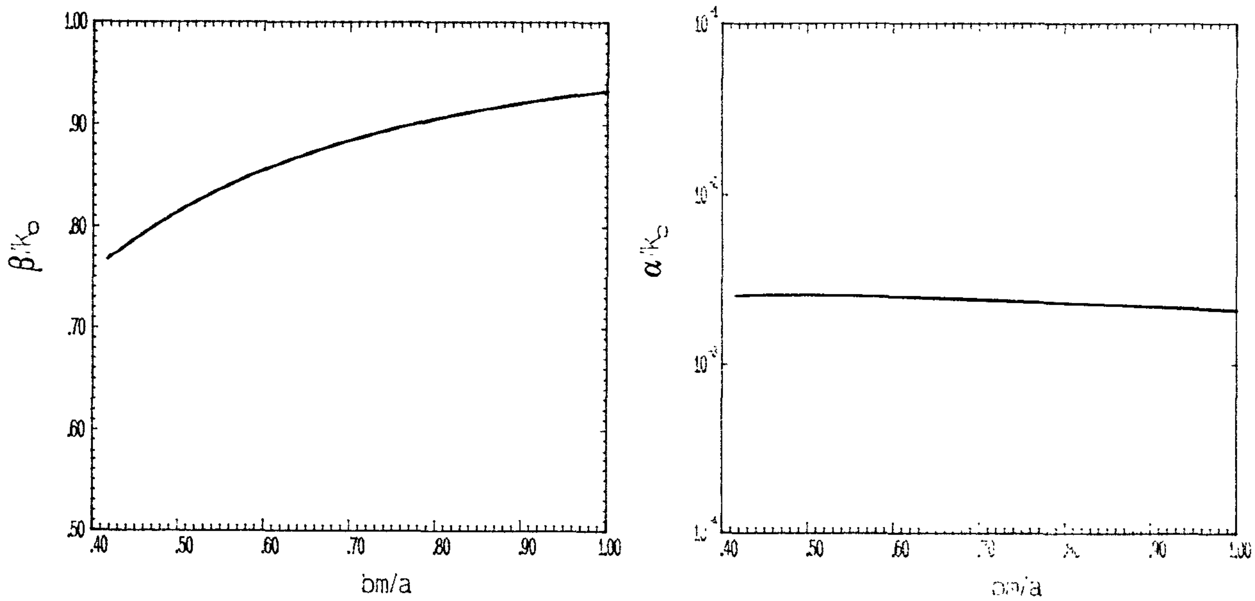

Fig. 5 The effect of varying only the parameter b_m in Fig. 1, while keeping $\Delta b/b_m$ constant, is to change considerably the value of the normalized phase constant β/k_o and to leave essentially unchanged the normalized attenuation constant α/k_o.