MODELING OF THE APPARENT CHARACTERISTIC IMPEDANCE OF FINNED-WAVEGUIDE AND FINLINES

Protap PRAMANICK and Prakash BHARTIA

Department of Electrical Engineering
University of Ottawa
Ottawa, Ontario Canada

ABSTRACT

This paper models the apparent characteristic impedance of finned-waveguide and finline from the standpoint of per unit length capacitance obtained from conformal-mapping and the cutoff wavelength, without going into the controversy of definition. The model strongly supports the power/voltage definition. Closed-form synthesis equations have also been derived.

SUMMARY

The definition of characteristic impedance is unique in case of a purely TEM line. But the controversy regarding the definition of characteristic impedance arises when the transmission line supports a non TEM-mode. The problem of the apparent characteristic impedance of quasi-TEM line (like microstrip) has been solved theoretically [1] and by experimental modelling [2]. For purely non-TEM planar transmission lines like finned-wave guide and finline the definition of the apparent characteristic impedance still remains an open question. Till now there has been no adequately conclusive experimental results or theoretical arguments in favor of any of its three possible definitions, e.g. voltage/current, power/voltage and power/current. Moreover, neither the voltage nor the current can be uniquely defined in a finned waveguide or a finline. However, while the experimental findings of Meinel and Rembold [3] go towards the voltage/current definition, those of Willing and Speilman's [4] go in favor of the power/voltage definition. In the above definition voltage is defined as the line integral of the electric field over the shortest path between the fins and the current is the total longitudinal current flowing in the line. Still the experimental findings are

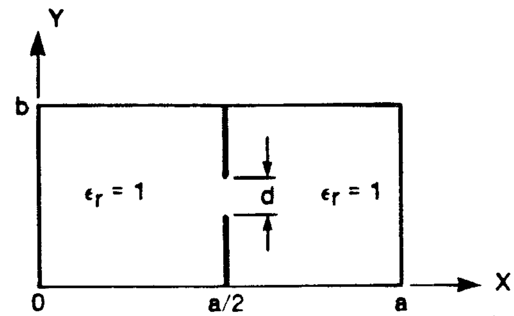

Fig. 1 Finned waveguide.

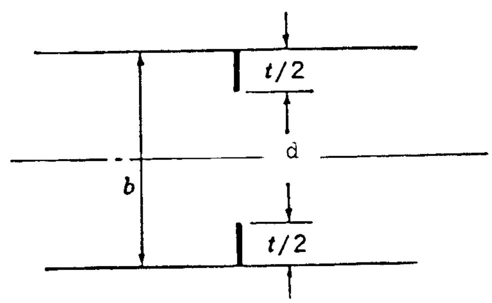

Fig. 2a Finned parallel plate.

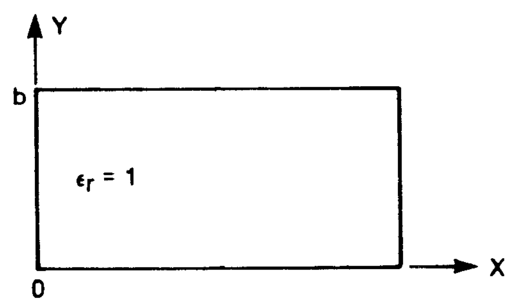

Fig. 2b Rectangular waveguide.

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widely away from the numerical computations [5,6]. Approximate ridge guide definitions of Meier [7] differ by 8 to 9% from numerically computed values [5,6]. On the other hand the slow rise in the characteristic impedance with increasing frequency at the upper edge of the useable band, as predicted by numerical computation, has not been experimentally confirmed. Keeping all these in mind the present work derives the characteristic impedance from the per unit length capacitance standpoint.

THEORY

The finned waveguide in Figure 1 can be considered to be a combination of a finned parallel plate of infinite width (Fig. 2a) and a rectangular waveguide (Fig. 2b).

The per unit length capacitance of the finned parallel plate is given by

$$C_f = \left(\frac{2}{\pi}\right)\ln[\csc(0.5\pi d/b)] \tag{1}$$

The per unit length capacitance between the broadwalls of the rectangular waveguide is given by

$$C_w = (Ka)/(2b) \tag{2}$$

where K accounts for the deviation of the field distribution from the sinusoidal in the finned waveguide cross section due to the presence of the fins. K = 1 for d/b = 1.

The cutoff wavelength of the finned waveguide is given by

$$\lambda_{ca} = 2a\sqrt{1 + \frac{\Delta C_w}{C_w}}$$
$$C_w = C_f \tag{3}$$
$$C_w = (Ka)/(2b)$$

Using the above equations K can be written as

$$K = (2b/a)[C_f/\{1 - (\lambda_{ca}/2a)^2\}] \tag{4}$$

Using the accurately computed values of λ_{ca} and (4) we obtained

$$K = 1 + 0.13\sqrt{x(b/a)}$$
$$x = \ln[\csc(0.5\pi d/b)]$$

Therefore, the characteristic impedance at infinite frequency $Z_{0\infty}$ of the finned wave guide is obtained from the cutoff condition as

$$Z_{0\infty} = 120\pi/(C_w + \Delta C_w)\text{ohm} \tag{5}$$
$$= 240\ K(b/a)/[1+(4/\pi)(b/a)Kx]$$

Using (5) the characteristic impedance at infinite frequency of the finned waveguide is computed and compared with those obtained from the Hopfer's ridged waveguide model [8] (Power - voltage (PV) and Voltage - current (VI) definitions) and the spectral domain method [5] (power - voltage definition) (Fig. 3). The agreement is found to be very close with power - voltage definition.

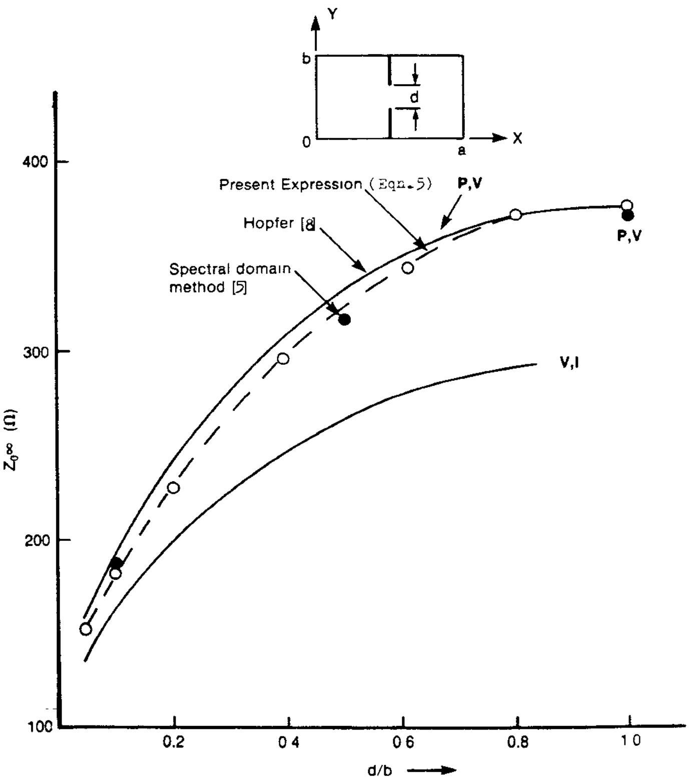

Fig. 3 Comparison of the present model with the ridge guide definition and the results from the spectral domain method.

Therefore using (5) the characteristic impedance of finline is given by

$$Z_0 = Z_{0\infty}/[k_e - (\lambda/\lambda_{ca})^2] \tag{7}$$

The equivalent dielectric constant K_e is obtained from references [9,10] in closed-form. Equation (7), however, does not necessarily fully agree with the numerically computed Z_0 based on power-voltage definition as shown in Figs. 4 and 5. It can be modified to agree with power-voltage definition as

$$(Z_0)_{pv} = Z_0\{(1-1/k_e)/(1-1/k_c)\}^{\frac{1}{2}}(k_e/k_c) \tag{8}$$

where k_c is the value of k_e at the cutoff of the finline. Equation (8) agrees very closely with numerical results (figs. 4 and 5).

Similar models have been obtained for bilateral finlines, and synthesis equations have been derived from (7) and (8). However, the results are not presented here due to lack of space.

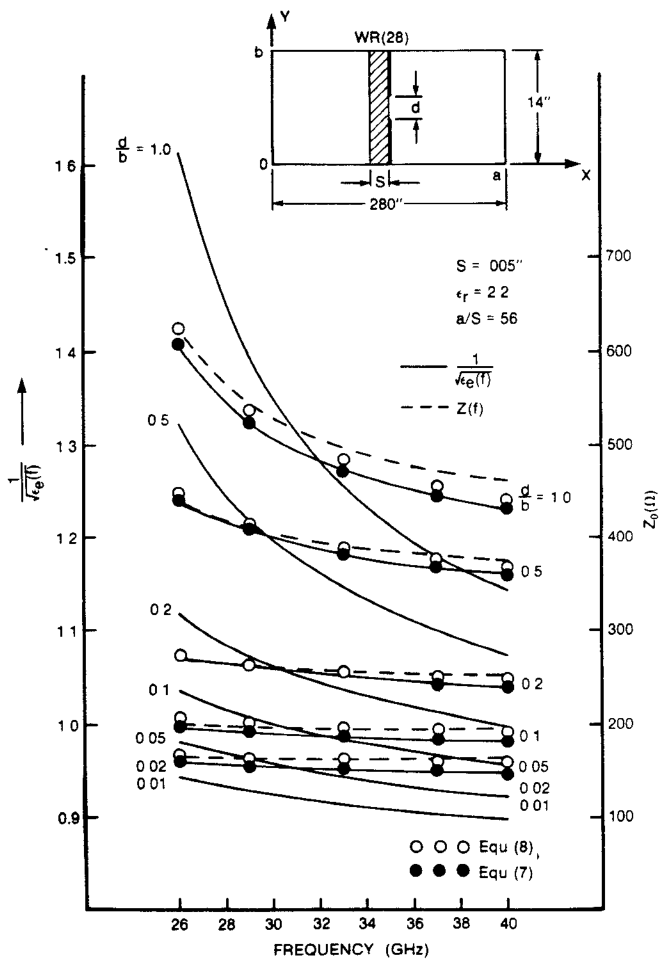

Fig. 4 Comparison with the spectral domain method.

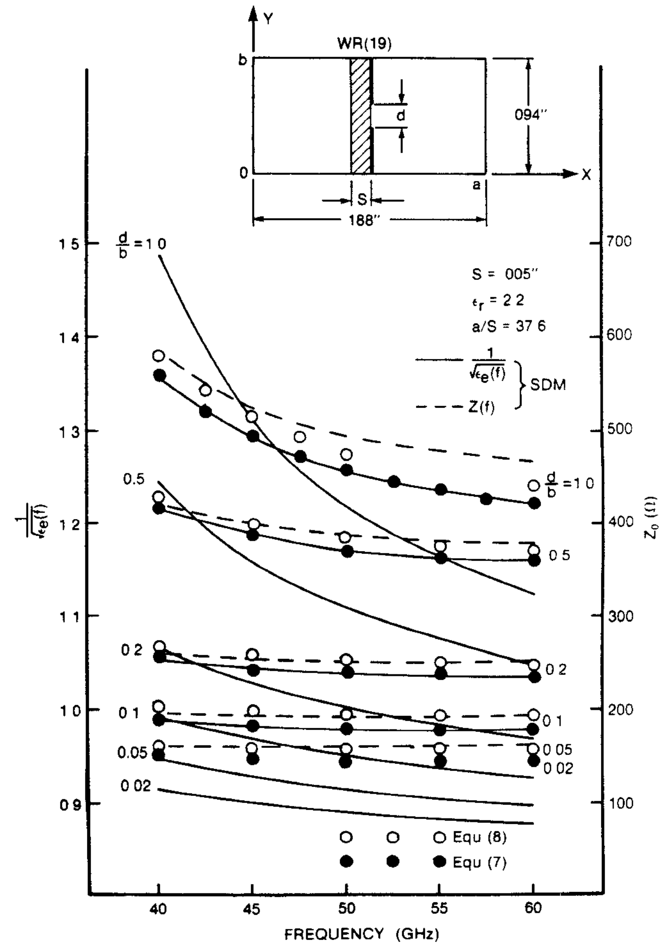

Fig. 5 Comparison with the spectral domain method.

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