International Journal of Electronics and Communication Engineering.
ISSN 0974-2166 Volume 4, Number 1 (2011), pp.61-68

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Performance Characteristics of Transverse Wall Round End Slot Coupled Junctions

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Abstract

In this paper a computationally efficient Method of Moments (MoM) formulation for the analysis and evaluation of performance characteristics of transverse wall round end slot coupled junction between two similar and dissimilar waveguides is presented. The junction has been analyzed for the three types of slots, namely the basic rectangular slot, rectangular slot with semicircular ends (Type 1) and rectangular slot with slightly curved ends (Type 2). The computations are carried out for both types of round end slots and rectangular slots, coupling two similar WR-90 X-band rectangular waveguides. Numerical results are presented for the variations of reflection coefficient, VSWR, normalised conductance (g) and susceptance (b) with slot length and slot width for slot coupled junction between two similar waveguides. A comparison among the numerical results for round end slots of (Type 1 and Type 2), and the rectangular slots has been presented.

Keywords: MoM, round end slot, waveguide, junction.

Introduction

Waveguide fed slots are finding applications in space vehicles, supersonic aircrafts and guided missiles [1]. Waveguide fed slot radiators are used as antennas in Direct Broadcasting from Satellite (DBS). Such radiators can be configured by milling the slots either in the broad wall or in the narrow wall or in the transverse cross-section of the rectangular waveguide. Waveguide based antennas are finding potential applications in Satellite and Mobile Communication Systems [2]. Waveguide fed transverse cross-sectional wall slots are quite useful in the formation of two port junctions, which can also be configured to realize transitions or step junctions between dissimilar waveguides. Such applications can also be effectively used to study the performance characteristics of waveguide diaphragms or waveguide discontinuities.

In most of these formulations, the basic rectangular shape of the slot alone has been taken into account and the analyses are confined to the case of narrow rectangular slots only. In practice, it is difficult to have rectangular slots with perfectly rectangular ends, because of fabricational process limitations. The two ends of these rectangular slots will have slight curvatures, and the slots can therefore be termed as "round end slots". A rectangular slot with round ends, will therefore give a more meaningful description of the shape of the slot aperture, in all practical problems of interest, if the curvature effects are logically modeled and systematically taken into account.

Sangster and McCormick successfully[3] presented the mathematical formulation for the 3-sectional slot model advocating the use of three trigonometric basis functions for computational accuracies. Two different types of round end slot models have been proposed in this paper to take into account the deeply curved ends of the rectangular slots (round end slot - Type 1) and slightly curved ends of rectangular slots (round end slot - Type 2). The analysis and formulations have been carried out by considering the thick coupling slot as a short section of a rectangular waveguide designated as the stub waveguide, taking into account the effect of finite thickness of the metallic wall in which the slot is milled and the higher order mode coupling with in the slot/stub waveguide region [4]. The inner products in the MoM analysis have been evaluated using Galerkin's technique and the solution of resulting matrix equation provides the coefficients for the basis functions representing the electric field distribution in the aperture plane of the slot. The impact of slot width variation and slot length variation on input VSWR, reflection coefficient and normalized admittance have been presented for rectangular and round end slots.

MoM Analysis of Round End Slot Coupled Junction

Fig. 1 shows the geometry of a round end slot coupled junction between two similar rectangular waveguides and the co-ordinate systems used for the analysis. The round end slot is centered with respect to the cross-sections of the two collinear waveguides, whose axes coincide. The coupling aperture is in the form of a round end slot, milled in a metallic plate of thickness 't', which becomes the length of the stub waveguide, having cross-sectional dimensions 2L x 2W.

Along the length of the slot, the field distribution is

$$E_{X'}\left(X', Y'\right) = \sum_{q=1}^{N} E_q \; e_q\left(Y'\right) \quad \text{for} \quad \begin{Bmatrix} -L \le Y' \le L \\ -W \le X' \le W \end{Bmatrix} \tag{1}$$

Considering the excitation from guide 1, for the set of boundary conditions given in [5], the amplitude coefficients for the total tangential electric fields at the two interfaces of the stub waveguide, were given by

$$[E^{d,1}] = \{[U]+[B][R^{cw}][B]\}\ [R^{rw}][B][R^{cw}][B]-[U]\}^{-1}.\ [Y^{rw}]^{-1}\ 2.[h^{inc}] \tag{2}$$

$$[E^{c,1}] = \{[B]+[R^{cw}][B]\}\ [R^{rw}][B][R^{cw}][B]-[U]\}^{-1}.\ [Y^{rw}]^{-1}\ 2.[h^{inc}] \quad (3)$$

The expressions for Y^{r}_{qs}, h^{inc} and Y^{c}_{qs} are evaluated for round end slots [6].

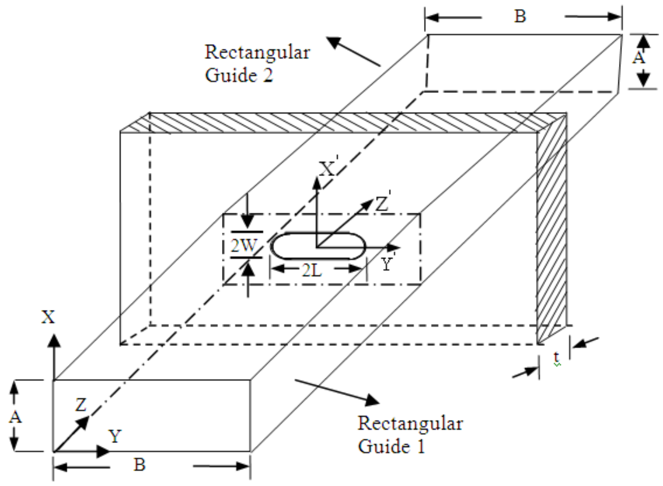


Figure 1: Round end slot coupled junction between two similar waveguides.

Reflection Coefficient, Shunt Admittance and VSWR

The Reflection Coefficient Γ for rectangular end slot coupled junction between two similar waveguides is expressed as

$$\Gamma = -1 + \sum_{\substack{q=1 \\ (odd)}}^{N} E_q^{d,1} \sqrt{\frac{2}{AB}}\ 2W \frac{\frac{q\pi}{L}}{\left[\frac{q\pi}{2L}\right]^2 - \left[\frac{\pi}{B}\right]^2} \cos\left(\frac{\pi L}{B}\right) \quad (4)$$

For round end slot coupled junction Γ is obtained as

$$\Gamma = -1 + \sum_{\substack{q=1 \\ (odd)}}^{N} E_q^{d,1} \sqrt{\frac{2}{AB}}\ \frac{4W}{3} \frac{1}{\left[\frac{q\pi}{2L}\right]^2 - \left[\frac{\pi}{B}\right]^2}. \quad (5)$$

$$\left[\frac{q\pi}{2L}\cos\left(\frac{\pi L}{B}\right) + 2\sin\left(\frac{q\pi}{2}\right)\left[\frac{q\pi}{4L}\left\{\sin\left(\frac{q\pi L_1}{4L}\right)\cos\left(\frac{\pi L_1}{2B}\right)\right\} - \frac{\pi}{B}\left\{\cos\left(\frac{q\pi L_1}{4L}\right)\sin\left(\frac{\pi L_1}{2B}\right)\right\}\right]\right]$$

The normalised shunt admittance seen by guide 1 is of the form

$$\frac{Y}{Y_o} = y = g + j\,b = \frac{1-\Gamma}{1+\Gamma} \quad (6)$$

Numerical Results

For the slot coupled junction shown in Fig. 1, the complex amplitude coefficients are evaluated from the three types of slots mentioned above. The computations are carried out for number of basis functions N = 5 for both Type 1 and Type 2 slots, coupling two similar WR-90 X-band rectangular waveguides. The feed waveguide and coupled waveguide are assumed to be identical; in which case, the round end slot coupled junction can also be treated as that of a resonant window or resonant diaphragm in a rectangular waveguide. Substituting the numerical values of the amplitude coefficients $E_q^{d,1}$ in (4) for rectangular end slots and in (5) for round end slots (Type 1/Type 2) and using (6) the reflection coefficient and shunt admittance seen by the feed waveguide are obtained. The performance characteristics are evaluated for different slot widths, and lengths over the X-band frequency range of interest.

The variation of magnitude of Γ, VSWR for f = 9.375 GHz, t = 0.127 cm and 2W = 0.127 cm are presented in Fig. 2 and VSWR, magnitude of Γ, g and b for 2W = 0.508 cm are shown in Figs. 3- 4. The variations of VSWR, $|\Gamma|$, g and b, for 2L = 1.6 cm, f = 9.375 GHz and t = 0.127 cm, with slot width in the range 0.0794 cm - 0.635 cm, for rectangular and round end slots are shown in Figs. 5-6 respectively.

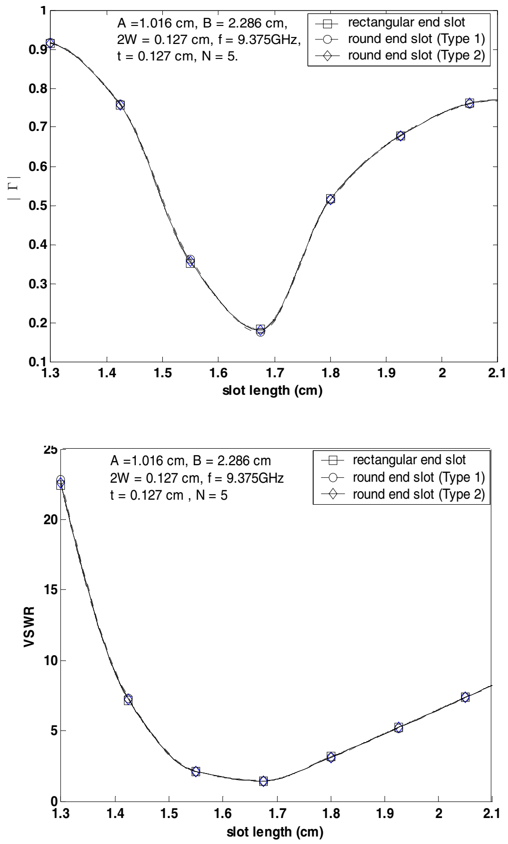


Figure 2: Variation of the magnitude reflection coefficient and VSWR with slot length.

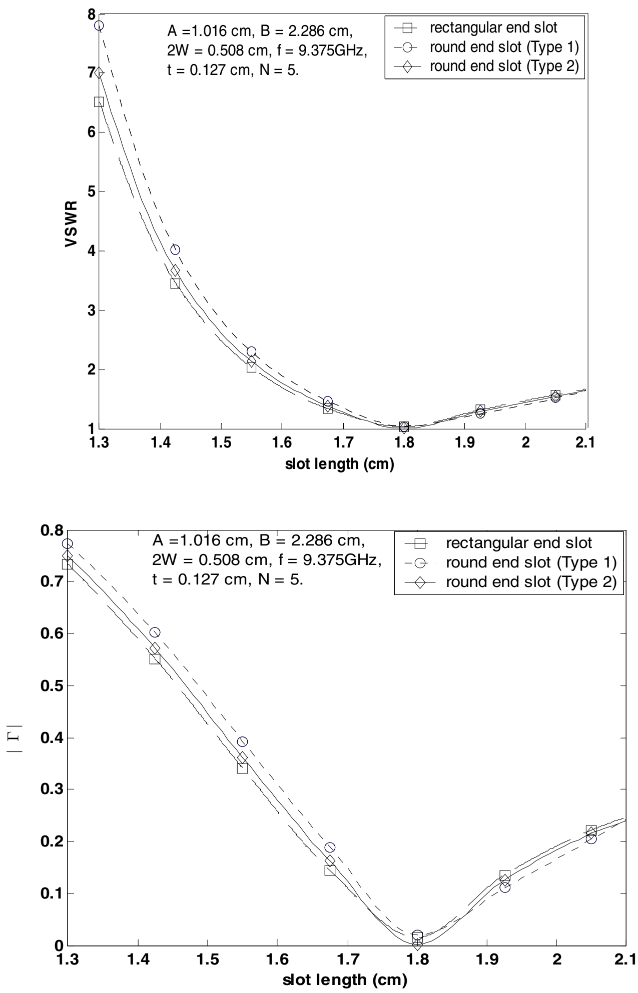
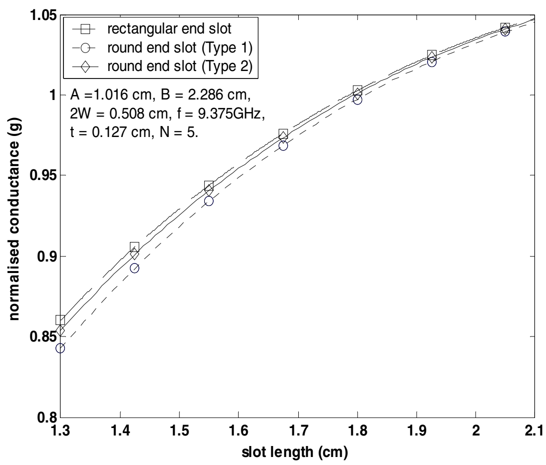


Figure 3: Variation of VSWR and the magnitude reflection coefficient with slot length.



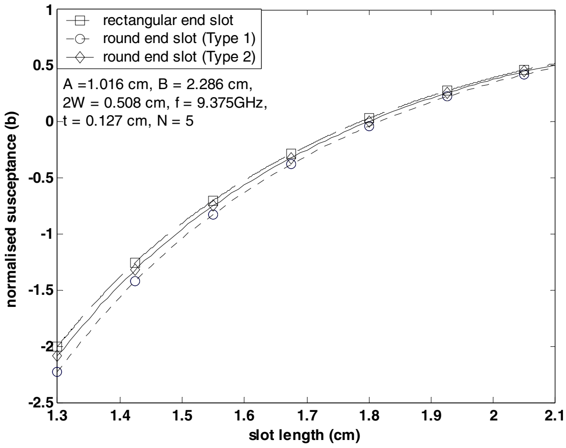
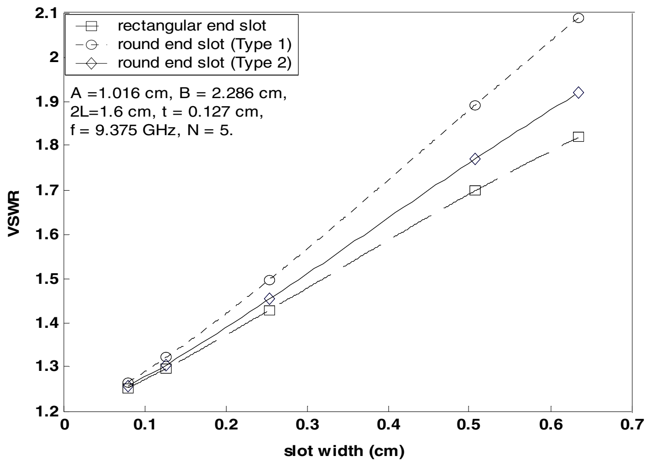


Figure 4: Variation of normalised conductance (g) and susceptance (b) with slot length.



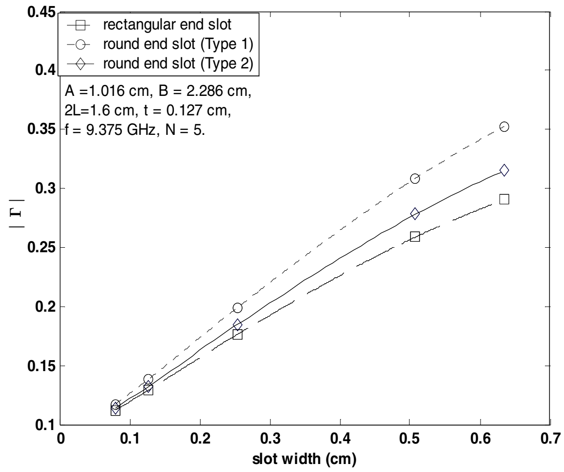


Figure 5: Variation of VSWR and magnitude of reflection coefficient with slot width.

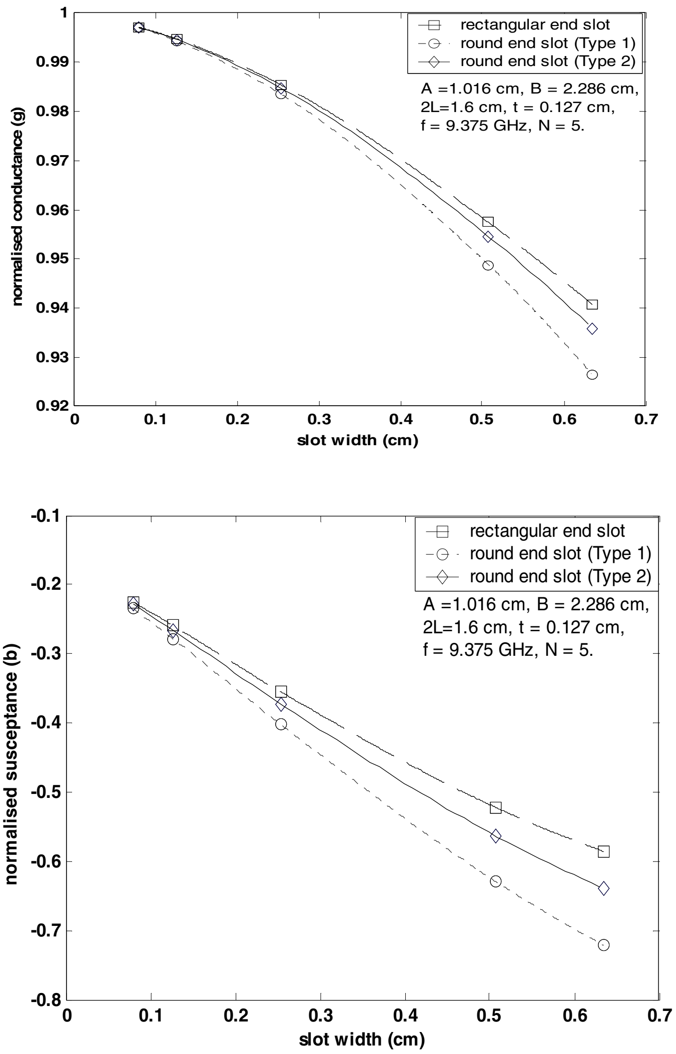


Figure 6: Variation of normalised conductance (g) and susceptance (b) with slot width.

Discussions

Analysis by moment method using entire sinusoidal basis and testing functions is found to be computationally efficient, as the numerical results for all the three types of slots converge very well for number of basis functions N = 5. It is evident from Figs.2 - 3 that the nature of variation is same for all the three slot models considered. However, for a slot width of 0.508 cm, the numerical results show considerable deviation for round end slot (Type 1). Figs. 2-3 also show almost identical variations for the electrical parameters of interest, when slot length variations are considered, for the same thickness of 0.127 cm, and slot width of 0.127 cm. As the slot width is increased to 0.508 cm, the variations in the numerical results are more pronounced, as is evident from Figs. 3-4. It is significantly observed from Figs. 3-4, that the deviations between the numerical results, even at higher slot widths are significantly reduced, when larger slot lengths are taken into consideration. A similar effect is observed from Figs. 5-6, where the deviations become significant when the slot length is reduced to 1.6 cm. For the transverse wall slot coupled junction between two rectangular waveguides, the rounding effects are less significant for smaller slot widths and longer slot lengths and Type 2 slot characteristics are closer to those of rectangular end slots.

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