J.N. Smith, Graduate Student Member IEEE, T. Stander, Senior Member IEEE
University of Pretoria, Pretoria, South Africa
e-mail: jamessmith@ieee.org; tinus.stander@ieee.org

AN L-BAND TAPERED-RIDGE SIW-TO-CPW TRANSITION

Abstract — A tapered ridge transition between coplanar waveguide and substrate-integrated waveguide is presented. The taper is implemented through staircase metallization across 10 layers of conventional RF substrate with sidewall expansion and upper cut-out using Vivaldi-type exponential tapers. Fractional bandwidth of 36% is achieved in the L-band, with insertion loss of 0.5 dB and return loss of 15 dB.

Introduction

Substrate Integrate Waveguide (SIW) is used extensively in the design of planar filters, power dividers and other passive RF and microwave circuit components. It is made by using two layers of metallisation as top and bottom walls of the waveguide, and rows of closely spaced vias as the side walls of the waveguide [1]. SIW can therefore be implemented in any planar process where through-hole vias are available. SIW allows components and systems with performance comparable to rectangular waveguides to be manufactured in conventional RF soft substrates, where previously the performance of these devices were limited by the loss of microstrip or coplanar waveguide (CPW) transmission lines.

Another advantage of using SIW over conventional microstrip-based planar systems is that crosstalk is effectively eliminated. This is of particular importance in applications where signal integrity is important, as is the case for the phased-array feeds of the Australian Square Kilometre Array Pathfinder (ASKAP) radio telescope [2]. At present, however, no SIW system has been shown in the frequency range of the ASKAP telescope, which ranges from 0.7 GHz to 1.8 GHz (approximately L-band).

A challenge which SIW shares with rectangular waveguide is the incorporation of surface-mount components (including many active devices) into the system. This requires an effective, low-loss transition from SIW to other planar media such as CPW.

The current state-of-the-art in low-frequency CPW to SIW transitions makes use of a combination of quarter-wavelength transformers and resonant slots [3]. The transition achieves 36% fractional bandwidth at S-band frequencies. To the author’s knowledge, no SIW-based projects have been shown operating at frequencies lower than the S-band.

This paper proposes, for the first time, the use of a tapered ridge transition [4] from SIW to CPW, and the first published design for an L-band SIW to CPW transition.

Proposed geometry

A top view of the proposed structure is shown in Fig. 1, while a sectioned side-view is shown in Fig. 2. The structure has a solid lower ground plane. Dimensions for the structure are given in Table 1.

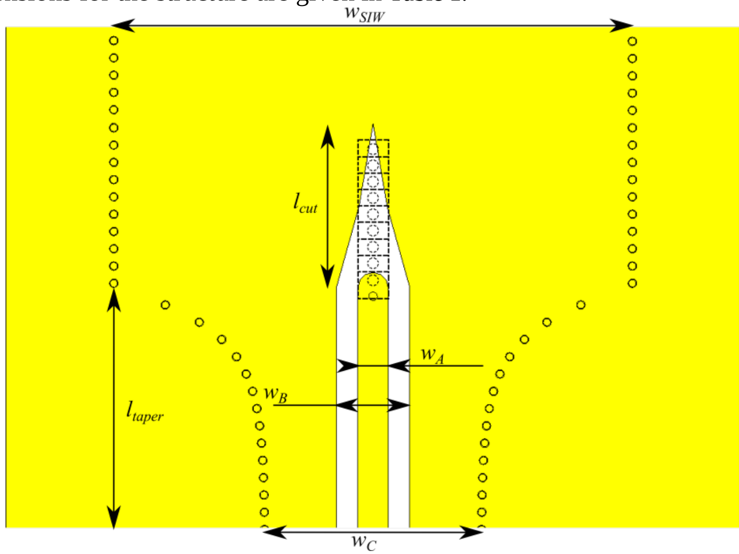

Fig. 1. Top view of the proposed CPW-to-SIW structure. Buried metal strips, and vias are indicated as hidden detail.

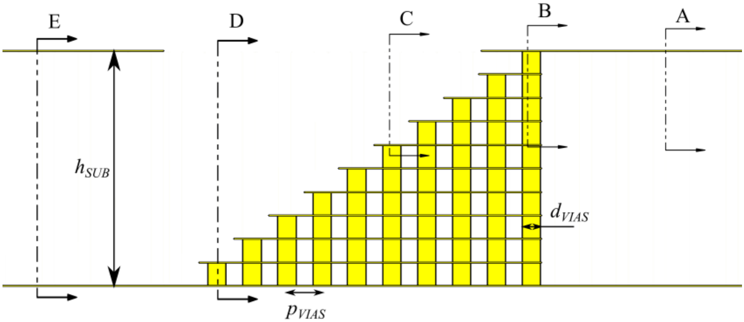

Fig. 2. Sectioned side view of the proposed structure.

Table 1. Physical dimensions of tapered ridge structure

Parameter	Description	Value (mm)
w_{SIW}	Width of the SIW measured between the centres of the two rows of sidewall vias	60
l_{CUT}	Length of the exponentially tapered cutaway in the top metallization	19
l_{TAPER}	Length of the exponential taper of the placement of via sidewalls of the SIW to the grounding vias of the CPW	25
w_A	Width of the CPW middle conductor	3.5
w_B	Separation between ground metal of the CPW, eventually becoming largest width of exponential taper.	8.5
w_C	Separation between the grounding vias of the CPW	25
h_{SUB}	Height of the substrate (thickness of individual layer multiplied by number of layers)	12.8 (1.28*10)
d_{VIAS}	Diameter of drilled and metallised via holes	1
p_{VIAS}	Pitch from centre to centre of vias in the tapered ridge	1.9

The ridged waveguide is formed in the transition from CPW to SIW by using a row of vias similar to those in the SIW sidewalls, but with each succeeding via along the length of the guide penetrating one layer fewer than the previous one, forming an effectively solid metallization staircase up to the centre conductor of the CPW line. The vias are then connected with strips of metallization at each available metal layer in the multi-layer stackup. On the top metal layer, the centre conductor of the CPW is rounded to avoid the localized E-field concentration caused by sharp edges, and a section of the top metallisation of the SIW is removed in a Vivaldi-style exponential taper [5]. The vias connecting the conductor backing of the CPW are also tapered outwards towards the width of the SIW also using a Vivaldi-style exponential taper.

Simulation results

The structure was simulated using the Time Domain solver in CST Microwave Studio, as implemented on a 10-layer board of Rogers RO 3010 dielectric of thickness 1.28 mm. Due to the comparatively low frequency, a material with a high dielectric constant is required to reduce the dimensions. The solid taper of a conventional tapered ridge CPW to rectangular waveguide transition [cite] is better approximated by staircase metallization with more layers, necessitating 10 laminated substrate layers. Thick dielectric layers were futher used to increase the height of the SIW and thereby minimise copper losses [1].

2D plots of the E-field at successive cross-sections along the length of the transition are shown in Fig. 3 to Fig. 7. Fig. 3 indicates the conventional E-field of a CPW transmission line. At the start of the taper (Cutplane B, Fig. 4) a quasi-TEM propagating mode is still exhibited, but with the lower E-field now terminating normally on the ridge (the ground potential of the 2-terminal structure) and not on the lower ground plane as previously. Further along the taper (Cutplane C, Fig. 5) the E-field terminates on the ridge both from the top and the sides, where the y-directed E-field above the ridge start to take the form of a conventional TE_{10} mode. As the taper height lowers further (Cutplane D, Fig. 6) the open slot in the upper copper plane becomes negligible and the propagating mode takes a form almost indistinguishable from the eventual TE_{10} propagating mode (Cutplane E, Fig. 7) in the SIW.

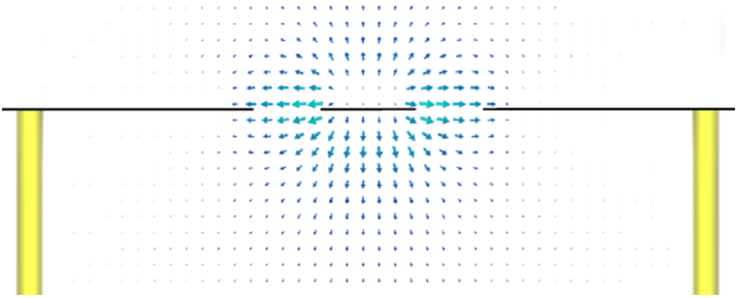

Fig. 3. 2D E-field at cutplane A.

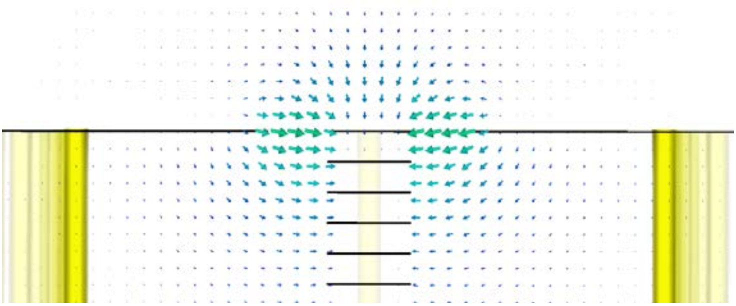

Fig. 4. 2D E-field at cutplane B.

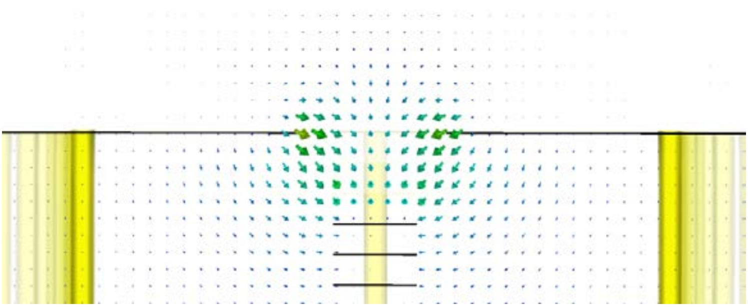

Fig. 5. 2D E-field at cutplane C

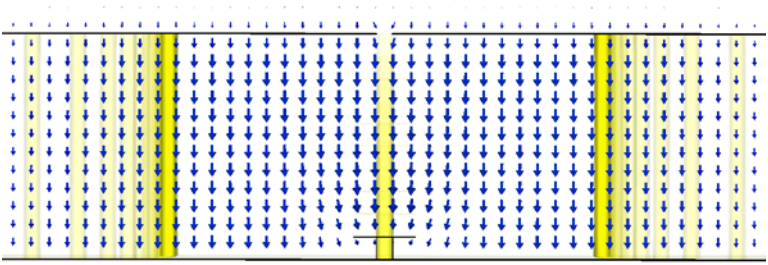

Fig. 6. 2D E-field at cutplane D.

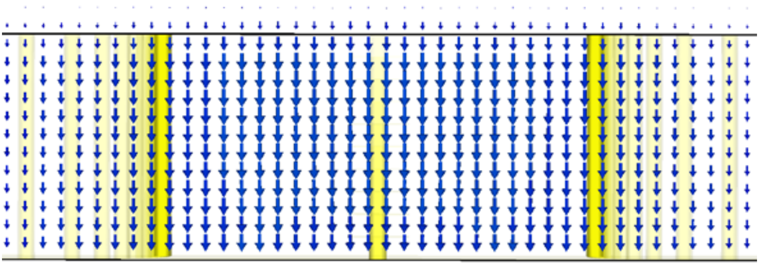

Fig. 7. 2D E-field at cutplane E.

The S-parameter results of the simulation are shown in Fig. 8.

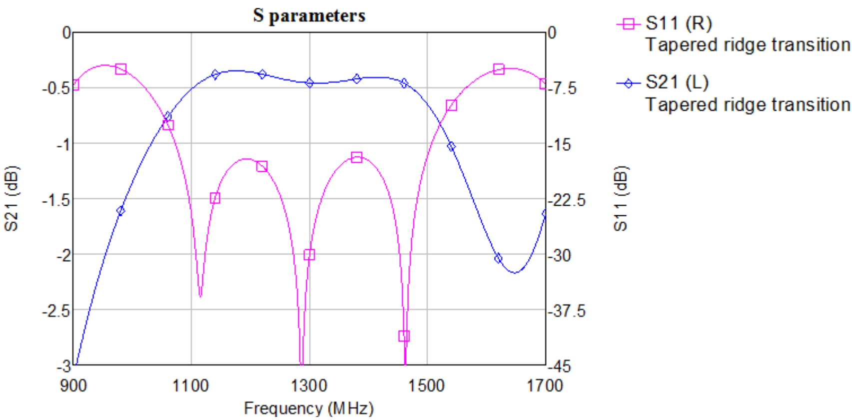

Fig. 8. S-parameters

A clear passband can be seen from 1.1 to 1.5 GHz, giving 400 MHz bandwidth or 36% fractional bandwidth. Insertion loss of less than 0.5 dB is observed, while return loss exceeds 15 dB. This is comparable to the work presented in [3], with a return loss improved by approximately 3-5 dB across the passband. This work, however, covers a frequency range centered at 1.4 GHz in comparison to 3.2 GHz, making it the first L-band transition into SIW presented in literature.

Conclusion

A novel tapered-ridge-type CPW-to-SIW structure has been presented, which shows a fractional bandwidth within the L-band of 36%, and a minimum of 15 dB return loss. This work demonstrates, for the first time, that ridge-type structures are viable in SIW. Future inquiries will investigate the use of dual-ridge type structures in SIW, potentially increasing the bandwidth of such systems further.

Acknowledgments

The authors wish to thank CST AG for use of the academic license of CST Microwave Studio. This work was supported by SKA South Africa and the Eskom Tertiary Education Support Programme (TESP) with associated Technology and Human Resources for Industry Programme (THRIP) grant № 90224.

References

1. Bozzi M. *et al.* // IET Microw Antennas Propag 2011. V. 5. N. 8. P. 909–920.
2. Hampson G. *et al* // *Proceedings of the 2012 International Conference on Electromagnetics in Advanced Applications, ICEAA'12.* 2012. P. 807–809.
3. Fang R.-Y. et al // IEEE Trans. Compon. Packag. Manufact. Tech. 2013. V. 3. N. 2. P. 247–252.
4. R. N. Simons, "Coplanar Waveguide Transmissions," // Coplanar Waveguide Circuits, Components and Systems. New York, NY: John Wiley & Sons. 1949. P. 288–345.
5. Gibson P. J. // Conf Proc Eur Microwave Conf 9^{th}. 1979. P. 101–105.