Multilayer Printed Circuit Board Square Waveguide in Ka Band

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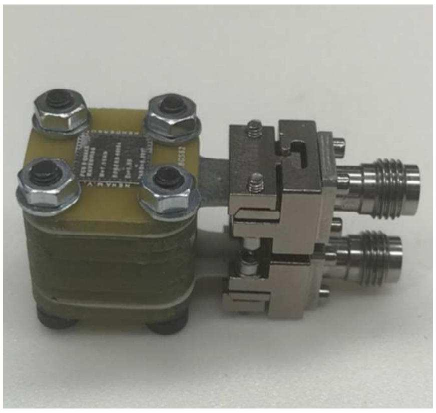
Substrate integrated waveguide (SIW) techniques have been used to develop novel circuits and systems with printed circuit board (PCB) manufacturing methods [1]. SIW designs can take advantage of the in-plane capability to realize various waveguiding structures that offer improved quality factor. In [2], PCB layers were stacked vertically to mimic a dielectric filled rectangular waveguide. Losses in the dielectric limit the performance of such a design but does show the potential to create low cost three-dimensional structures. This work presents the design, fabrication, assembly and performance of a Ka band square waveguide realized with multilayer PCBs. The waveguide metallic walls are manufactured using plated through hole via fences based on SIW dimension guidelines. Two-port measured results agree with finite element method simulations and show the dominant mode cutoff of 21.1 GHz. The operating bandwidth is limited by the probe feed and mismatch due to the coaxial connector pin dimensions. This square guide can support TE_{10} and TE_{01} modes and shows 20 dB isolation when the microstrip feed is rotated 90 degrees.

The design is based on WR28 waveguide dimensions of 7.11 mm x 7.11 mm. To improve performance, the FR4 dielectric (h = 1.6 mm, $\varepsilon_r = 4.5$, tan $\delta = 0.018$) material that fills the waveguide is completely removed resulting in ($\varepsilon_r = 1$, tan $\delta = 0$). By removing the substrate material in the center, the substrate loss in the waveguide region is eliminated and higher performance can be achieved. A microstrip feed line is designed on Rogers RO4003C (h = 0.6 mm, $\varepsilon_r = 3.55$, tan $\delta = 0.0027$). The probe feed is inserted 1.57 mm inside the waveguide to excite the dominant mode. The current probe design limits the maximum waveguide operating frequency to 27 GHz. Multiple pieces of 1.6 mm thick four-layer FR4 boards, with two inner metals and two outer metals, are manufactured to form the outer housing and back-short. Plated through holes in each layer form the via fence for the air filled waveguide. 67 GHz Southwest Microwave connectors are used to assist in transitioning the RF signal in measurement. Figure 1 (left) shows the assembled waveguide and the measured versus simulated S-parameters.



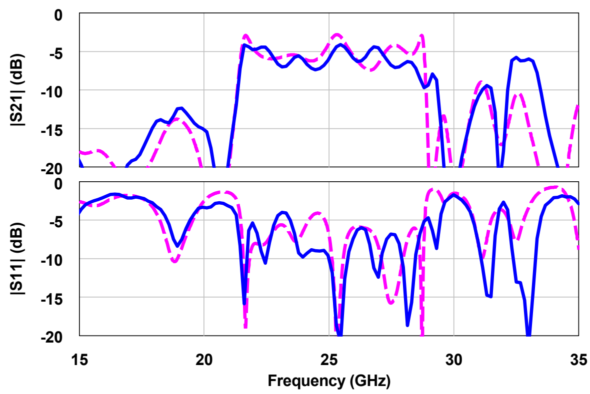


Figure 1. Left: photograph of the two port SIW PCB air-filled square waveguide. Right: measured (solid) and simulated (dashed) $|S_{21}|$ and $|S_{11}|$ of the air filled waveguide with solid.

References

[1] M. Bozzi, A. Georgiadis, K. Wu, "Review of substrate integrated waveguide (SIW) circuits and antennas," *IET Microwaves Antennas and Propagation*, vol. 5, no. 8, pp. 909-920, June 2011.

[2] M. Gomez and R. Henderson, "Printed circuit board rectangular waveguide with full band microstrip to waveguide transition," *2016 Texas Symposium on Wireless and Microwave Circuits and Systems (WMCS*), Waco, TX, 2016, pp. 1-4. doi: 10.1109/WMCaS.2016.7577490.