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Waveguide Photonic Choke Joint with Wide Out-of-band Rejection

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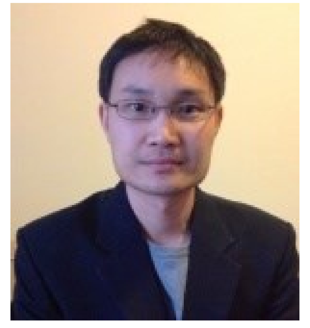

Abstract — A photonic choke joint structure with a wide- stop-band is proposed for use as a waveguide flange interface. The structure consists of arrays of square metal pillars arranged in a periodic pattern to suppress the dominant-mode wave propagation in parallel-plate waveguide over a wide frequency bandwidth. The measurement results at microwave frequencies confirm the structure can provide broadband suppression, more than 56 dB over 6.25 times its operating frequency. Applications at millimeter wavelength are discussed.

Research Motivations

- Ultra-sensitive mm-wave detectors require waveguide interfaces with thermal isolation capability.
- Waveguide flanges with thermal break capability contains dielectric gap which is susceptible to power leakages over broad frequency ranges.
- Photonic choke joint waveguide flange is less sensitive to misalignment when operated with extreme temperature than conventional waveguide flanges.
- Periodic photonic structures can be integrated into the flange to provide low in-band power leakage. However, there is spurious frequency response out-of-operating band that can interfere with external electronics (Fig. 2).

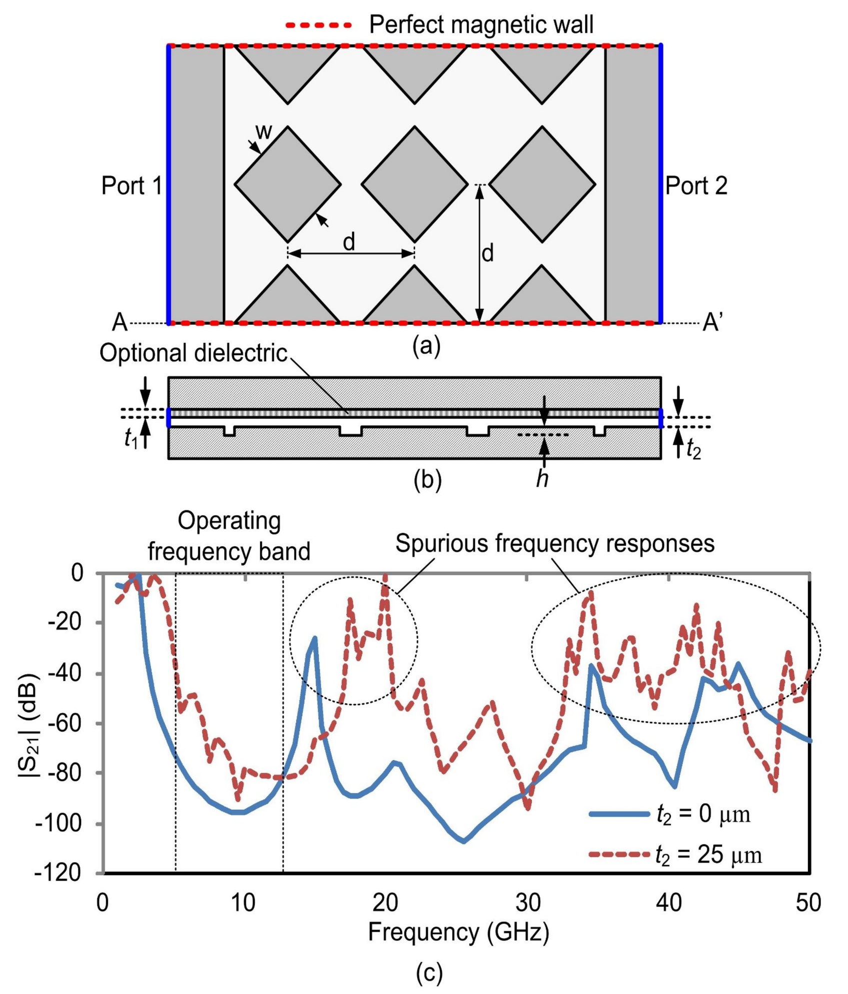

Fig. 2. A model to demonstrate spurious responses generated by a PCJ with a conventional Cartesian tiling pattern [1] when excited by plane wave (a) top view, (b) cross- sectional view A-A' and (c) simulated power transmission response (S_{21}) with optional Polyflon Cuflon (with dielectric constant of 2.05), spacer thickness t1 of 25μm between two conductors and with the pillar height h of 0.762mm.

Proposed photonic choke structure

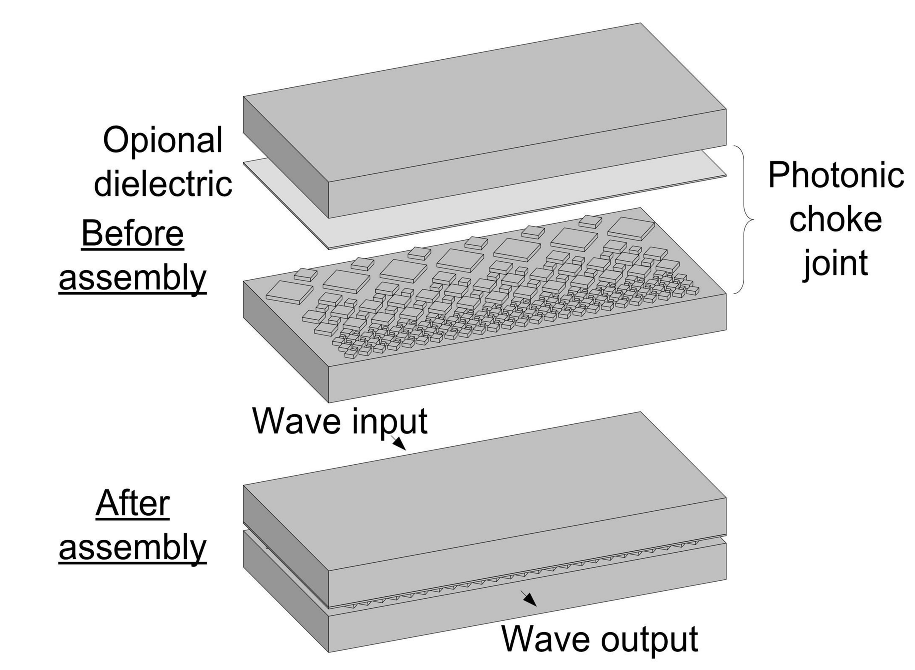

Fig. 1. The proposed photonic choke joint with wide out-of-band rejection.

- Periodic metal structures with three various sizes and spacings are placed between two metal flanges to suppress out-of-band leakage as well as to provide low-loss in-band electrical contact (see Fig. 1).
- Two metal flanges can be physically contacted or separated by a thin layer of dielectric to provide a thermal break joint.
- A prototype was constructed to verify in-band loss as well as its out-of-band power rejection capability.

Optimal photonic choke joint configurations

- Optimal unit cell pillar with spacing dimensions from [1] is used as a reference design.
- Sub-array square metal pillars are placed in series from large to small from one input to another (Fig. 3(a))
- Small square metal pillars are placed between sub-array pillar to provide addition out-of-band suppression (Fig. 3(b)).

[1] E. J. Wollack, K. U-yen and D.T. Chuss, "Photonic choke-joints for dual-polarization waveguides," 2010 IEEE MTT-S, pp. 177-180, May 2010.

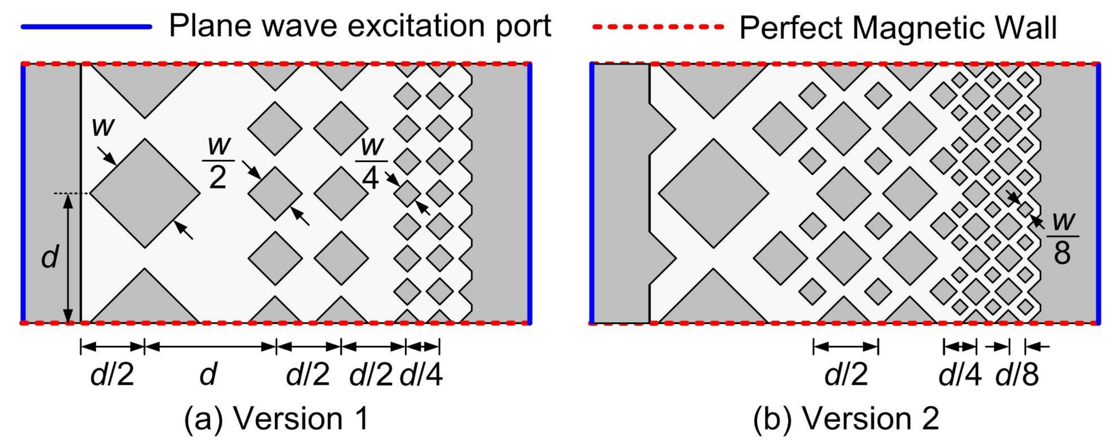

Fig. 3. The top surface of the unit cell of the proposed Cartesian tiling PCJ with w = 6.858mm and d = 12.07mm – (a) version 1 and (b) version 2.

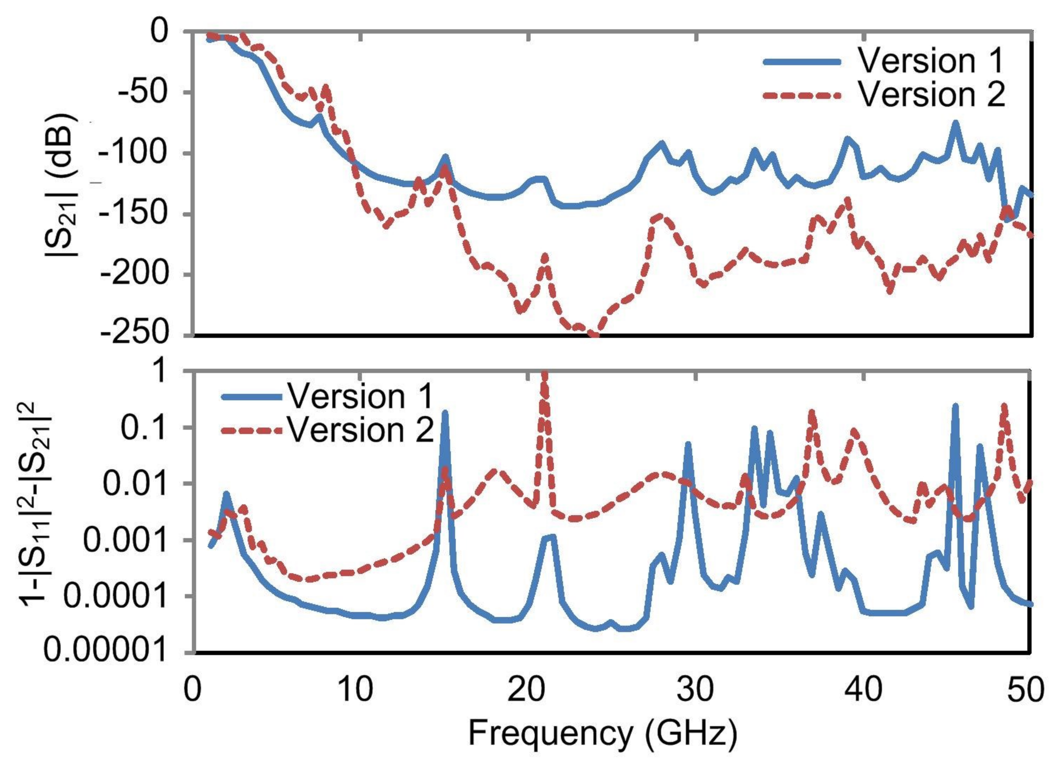

Fig. 4. The simulated power transmission (S21) and power absorption ($1-|S_{11}|^2-|S_{21}|^2$) responses of two optimal PCJs with the dielectric spacing of t_1=25μm and t_2=0μm.

Hardware Implementation and Test

- The proposed structure was fabricated to verify the structure's out-of-band rejection capability from 10 to 50 GHz. (Fig. 5(a)).
- Microstrip to pseudo-parallel plate waveguide transformers was constructed to launch and receive wave from the structure. They were also used for transmission loss calibration (Fig. 5(b-e)).
- The measurement was performed using G-S-G CPW probe and a vector network analyzer where the proposed structure was placed on top of the transformer (Fig. 5(f-g)).

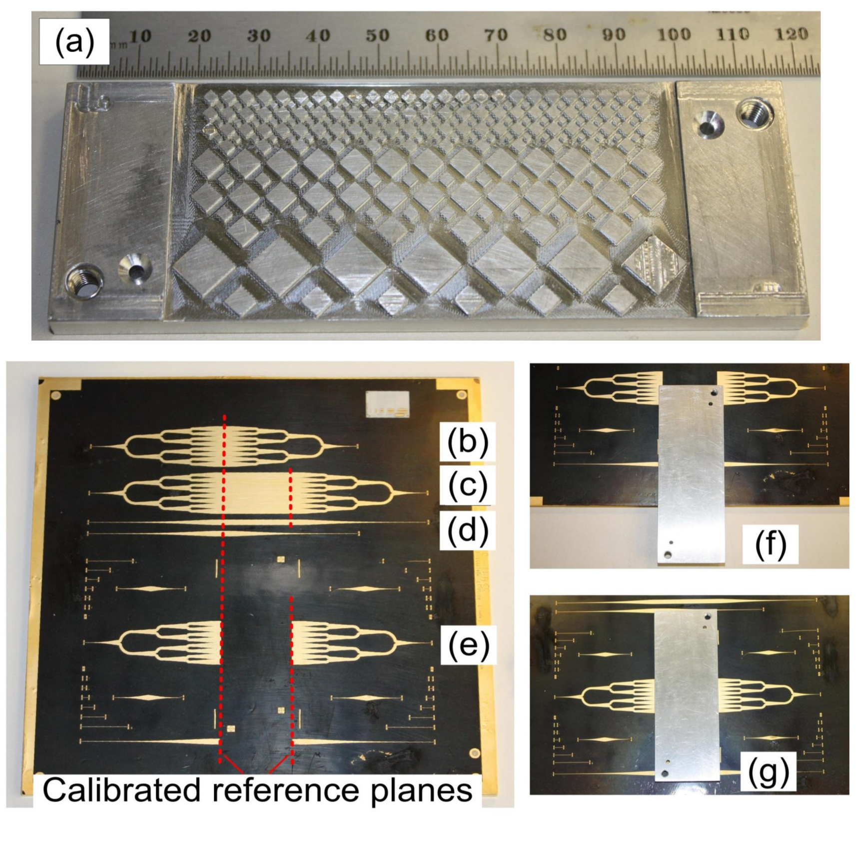

Fig. 5. Fabricated PCJ (a), impedance transformers on 25.4μm-thick Polyflon Cuflon substrate (b-e) and the PCJ placement facing of the substrate (f) and (g) for quasi-TEM and pseudo plane-wave mode measurement, respectively.

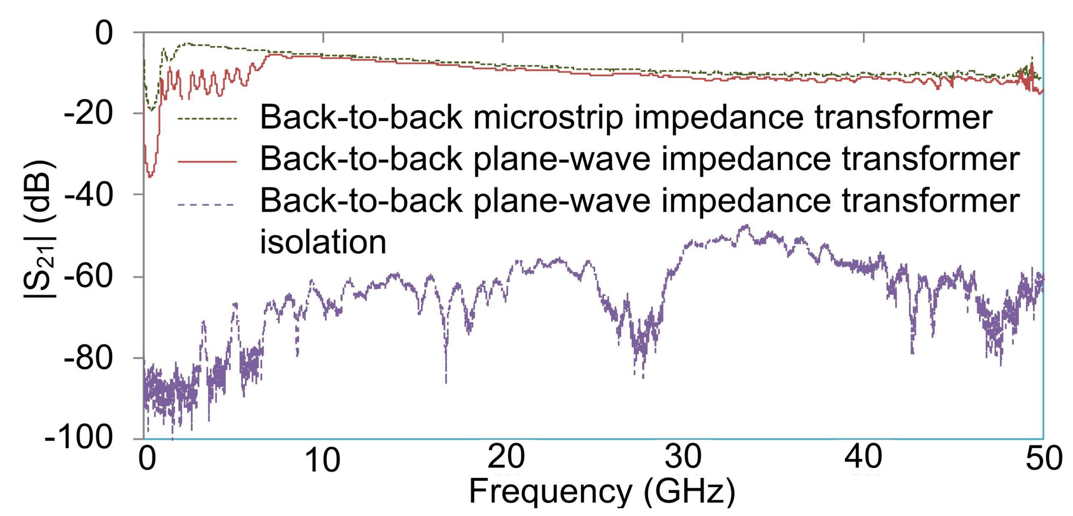

Fig. 6. The measured transmission response of the microstrip line (Fig. 5(d)) and (pseudo) plane-wave (Fig. 5(c)) impedance transformer combined back-to-back. The measured isolation between two (pseudo) plane wave ports was obtained using the planar circuit in Fig. 5(e).

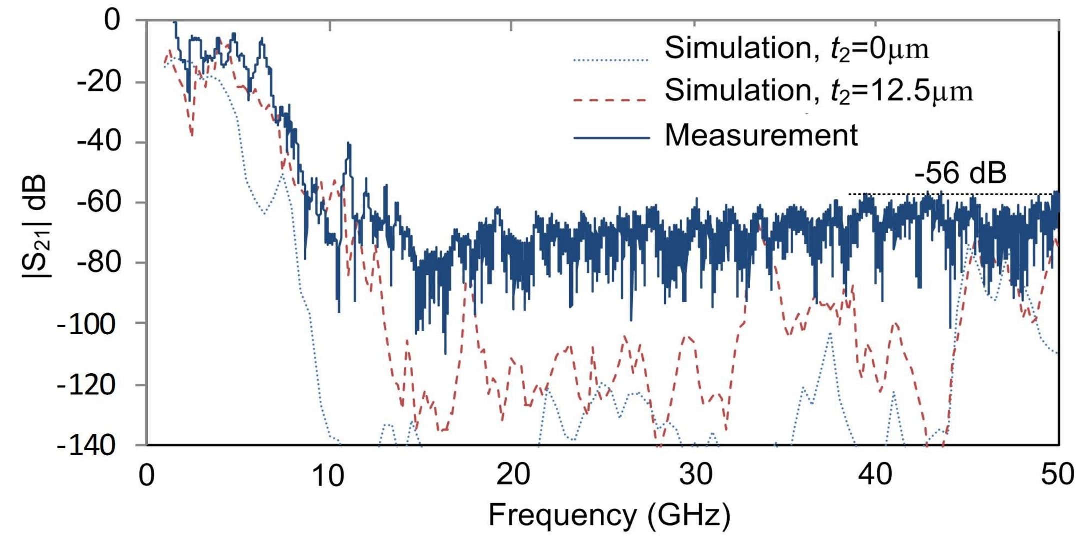

Fig. 7. The calibrated transmission measurement of pseudo plane wave propagation through the proposed PCJ.

Waveguide Flange Realization

- WR5.1 Circular waveguide flange was integrated with the proposed periodic metal structures on all sides (see Fig. 8)
- Simulated broadband frequency response shows significant improvement on out-of-band power rejection of more than 6 times its operating band (see Fig. 9)
- Low return loss was achieved in the operating band between 110 and 230 GHz.

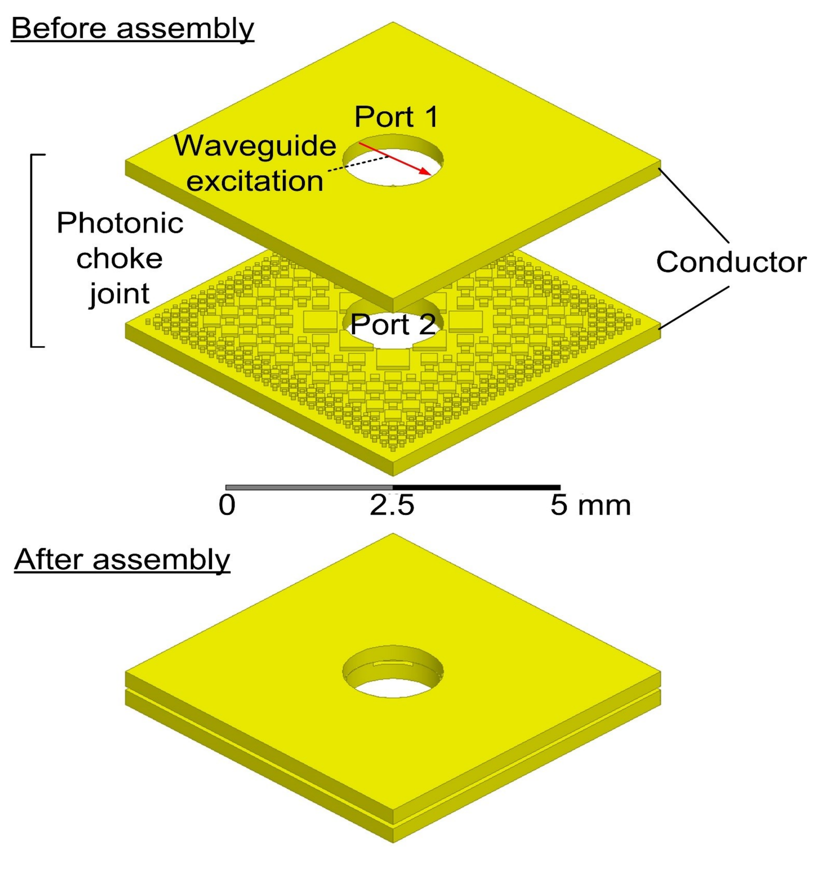

Fig. 8 The realization of the proposed PCJ pattern on as a WR5.1 circular waveguide flange.

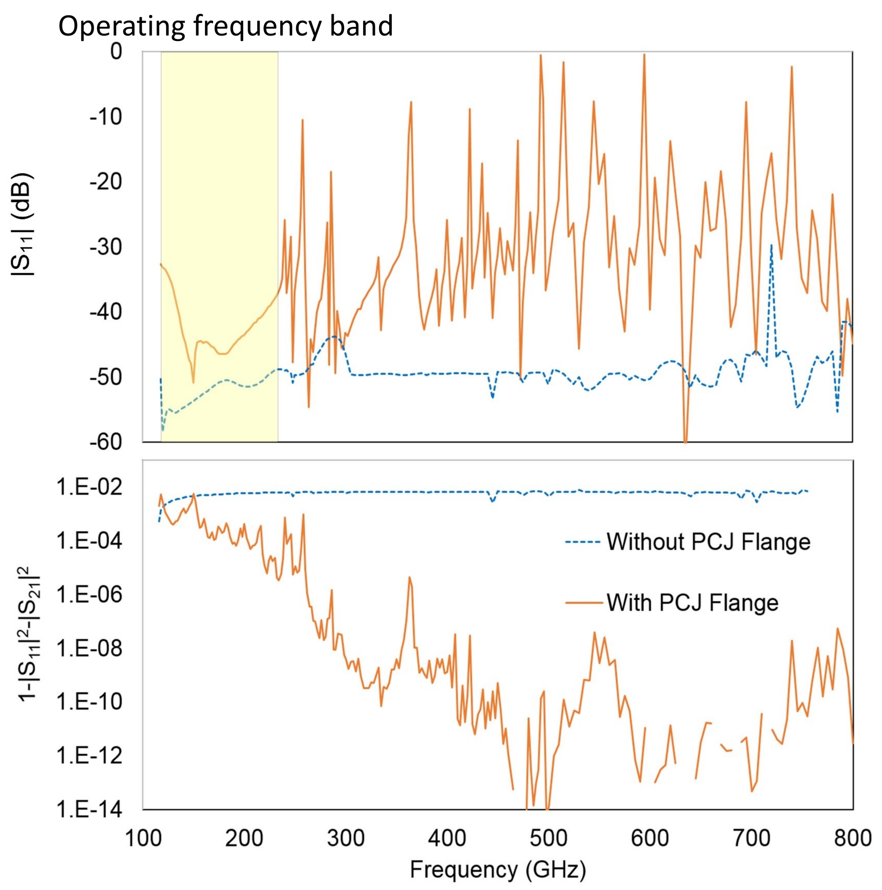

Fig. 9. The simulated circular waveguide flage input return loss (S_{11}) and power absorbsion ($1-|S_{11}|^2-|S_{21}|^2$), with and without the proposed PCJ. Both cases have a flange spacings of 6.4 μm.

Conclusion

A new photonic choke joint structure with sub-array Cartesian-tiling pillars was developed. The structure reduces the interface sensitivity and mating tolerances relative to a traditional planar interface while enabling new functionality. The PCJ design was validated with a pair of microstrip-to-pseudo-parallel-plate mode converters on a 25.4μm thick dielectric. The thin film dielectric layer was used to reduce the required spacer thickness and was observed to improve the isolation performance in the scale model. As a millimeter waveguide joint, the device provides broadband stop-band rejection and low in-band return loss.