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Compact millimeter-wave air-filled substrate-integrated waveguide crossover employing homogeneous cylindrical lens

Key words: Crossover; Homogeneous cylindrical lens (HCL); Millimeter-wave; Substrate-integrated waveguide (SIW)

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Motivation

1. With the development of microwave and millimeter-wave radio frequency circuits and integrated circuits towards greater compactness and versatility, crossovers inevitably play an increasingly important role as they can effectively address multiple intersection issues.

2. As the circuit complexity increases, intersections among more than two channels appear and they should be taken into account in circuit designs. The design of crossovers dealing with more than two channels simultaneously has become a significant and challenging research topic.

3. Crossovers in the microstrip technology are not suitable for millimeter-wave or above millimeter-wave applications. Some crossovers have been proposed that use close or quasi-close transmission lines, which generally suffer from a relatively large footprint.

Method

An extra homogeneous cylindrical lens (HCL) is inserted at the intersection. This two-channel topology can be extended to three- and four-channel cases by adjusting the diameters of the crossover cavity and the inserted HCL.

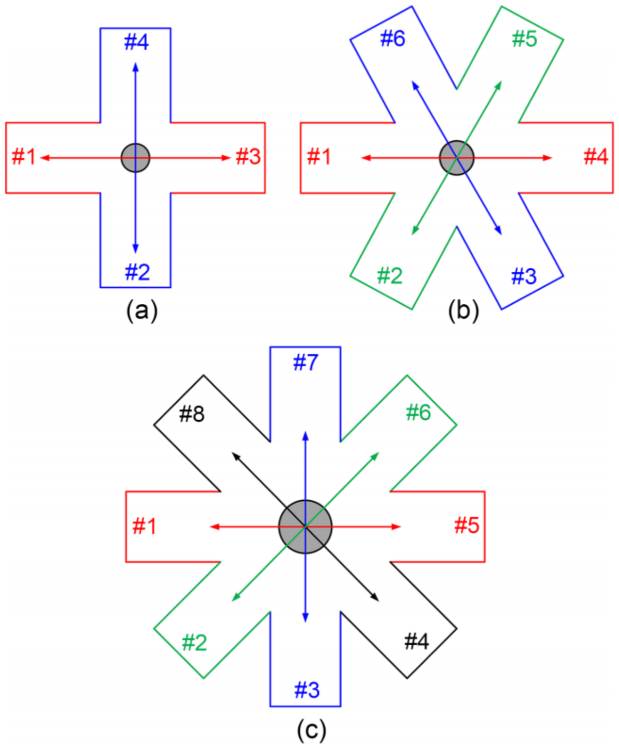


Fig. 1 Topologies of two-channel (a), three-channel (b), and four-channel (c) crossovers

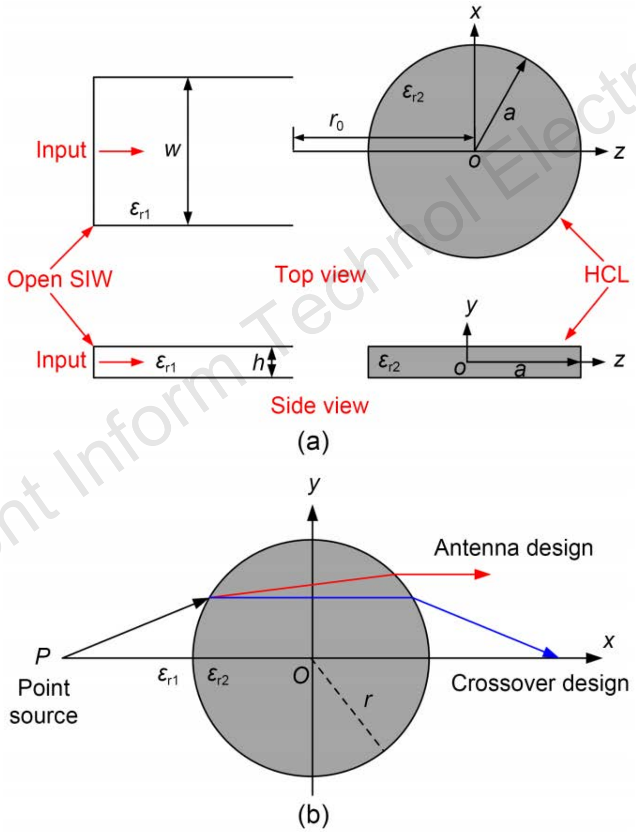


Fig. 2 Design parameters of the HCL (a) and ray-tracing analysis of the crossover with HCL (b)

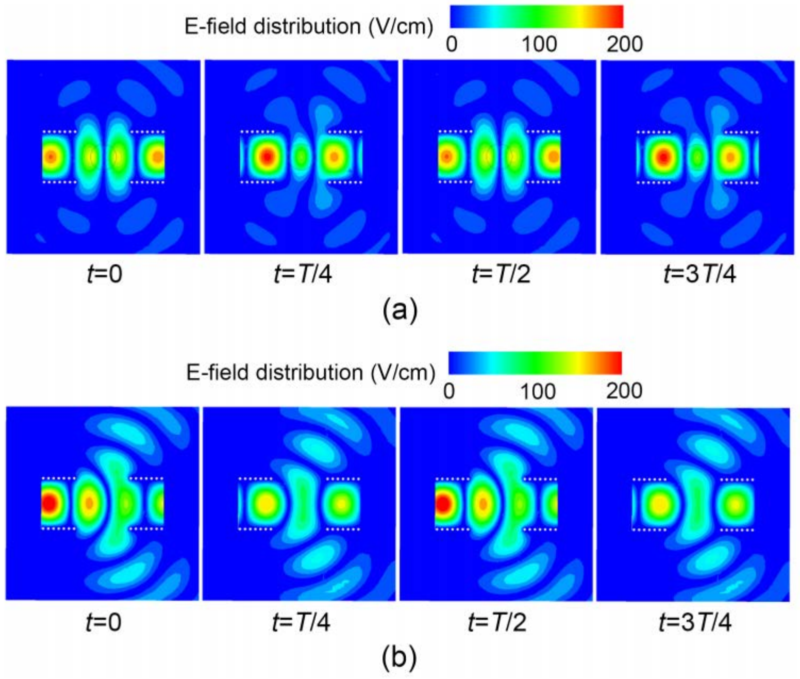


Fig. 3 E-field distribution with (a) and without (b) HCL at 30 GHz (T is the period of the electromagnetic field)

Method

Parametric study is carried out to furtherly determine the parameter design values.

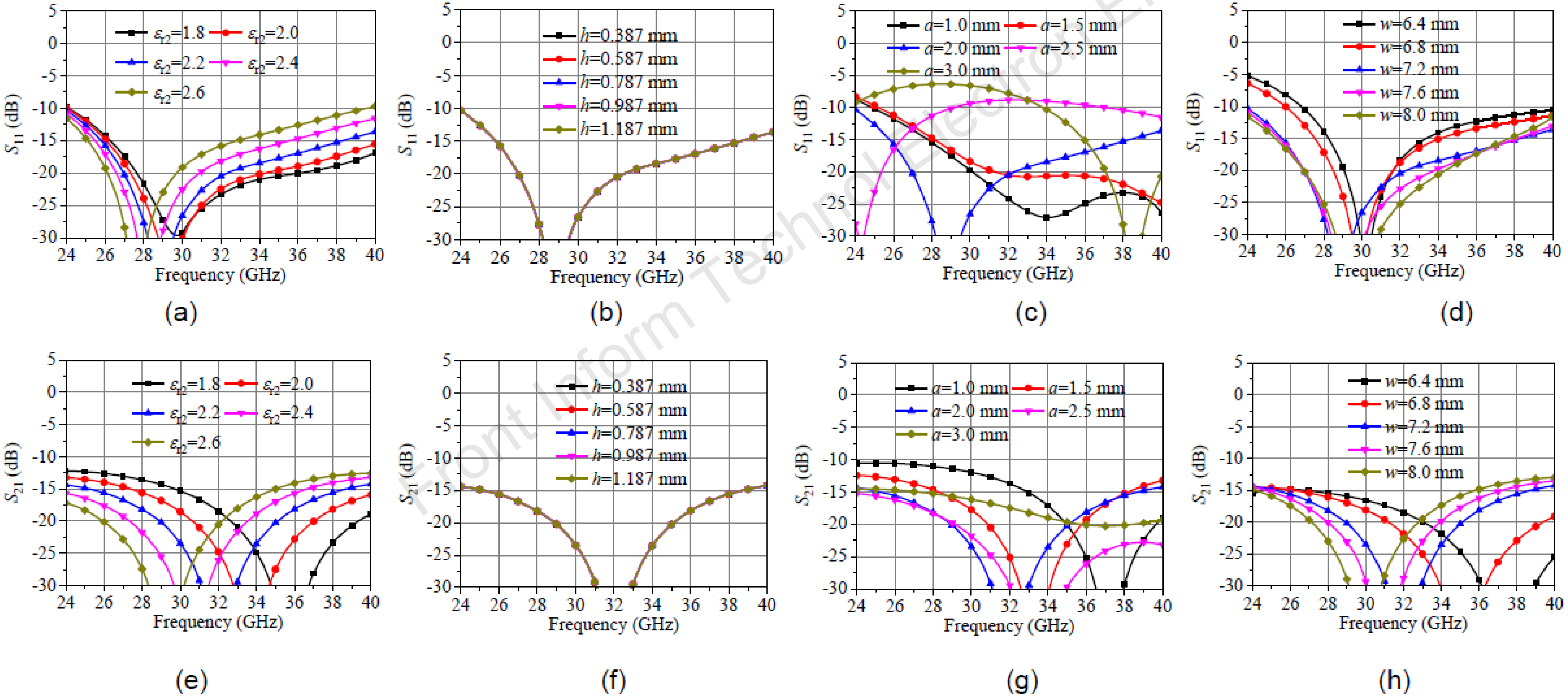


Fig. S1 S_{11} **with different** ε_{r2} **(a),** h **(b),** a **(c), and** w **(d) and** S_{21} **with different** ε_{r2} **(e),** h **(f),** a **(g), and** w **(h)**

Method

Derived from the abovementioned topology, two-, three-, and four-channel air-filled SIW crossovers are designed and analyzed.

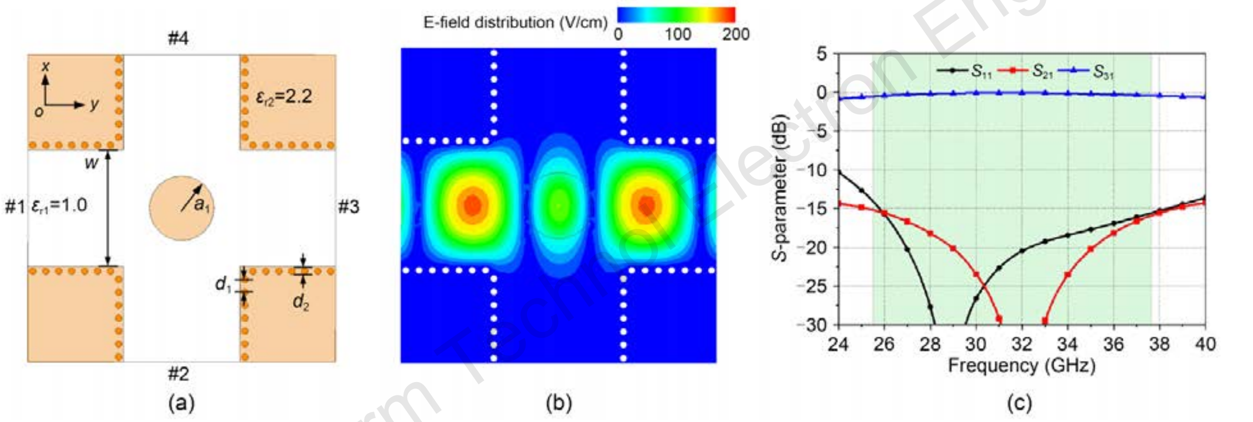


Fig. 4 Simulated HFSS model (a), E-field distribution (b), and *S*-parameters (c) of the two-channel SIW crossover (d_1= 0.80 mm, d_2=0.40 mm, a_1=2.00 mm, and w=7.20 mm)

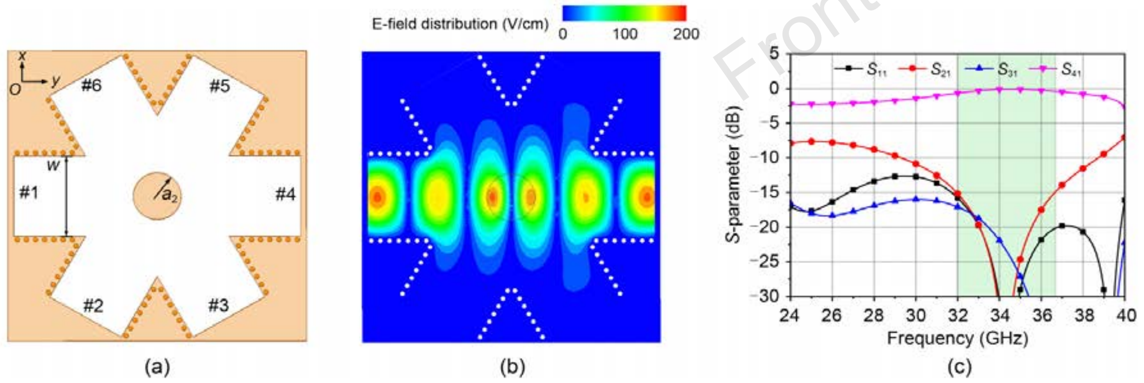


Fig. 5 Simulated HFSS model (a), E-field distribution (b), and *S*-parameters (c) of the three-channel SIW crossover (a_2= 2.10 mm, w=7.20 mm)

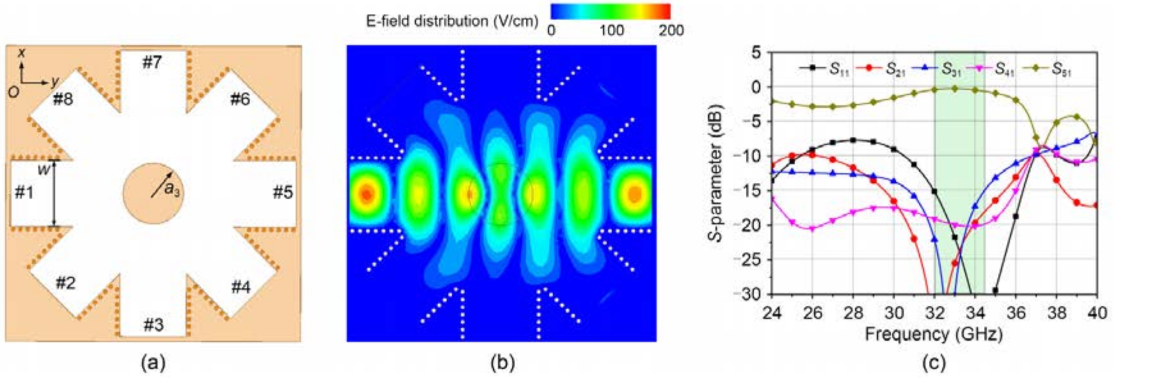


Fig. 6 Simulated HFSS model (a), E-field distribution (b), and *S*-parameters (c) of the four-channel SIW crossover (a_3= 4.00 mm, w=7.20 mm)

Method

For the experiments, transitions from substrate-integrated waveguide (SIW) to air-filled SIW and coplanar waveguide to SIW are designed; two-, three-, and four-channel air-filled SIW crossovers are fabricated successively to demonstrate the feasibility of the proposed method.

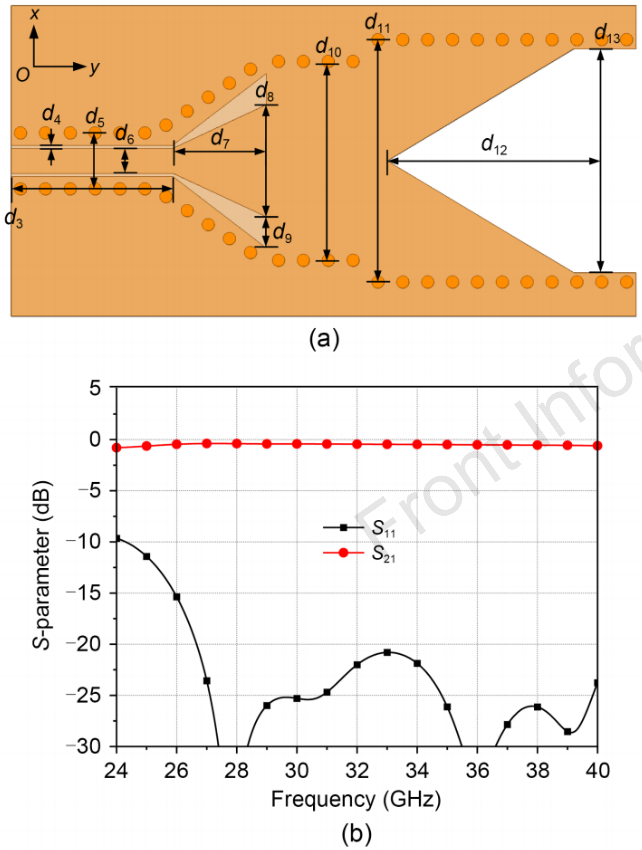


Fig. 7 Simulated HFSS model (a) and *S*-parameters (b) of the transition

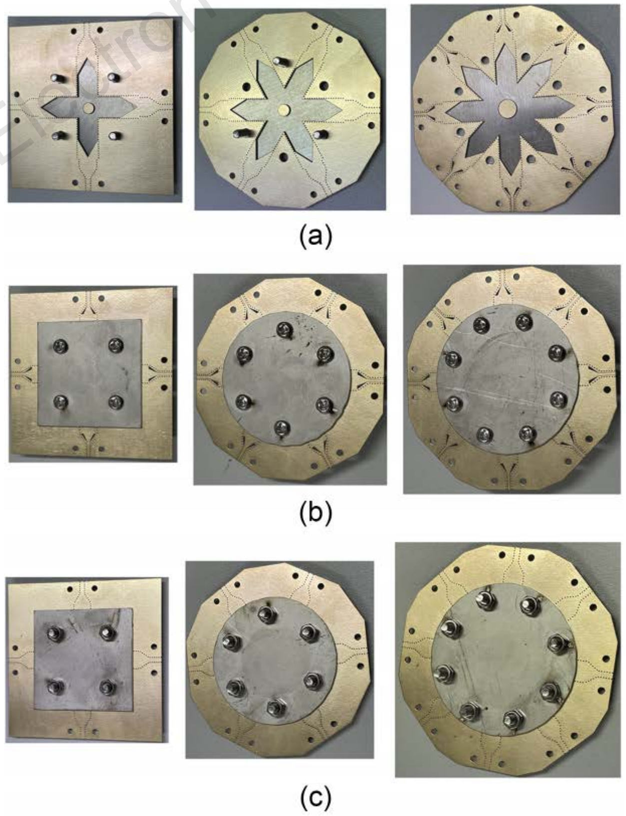
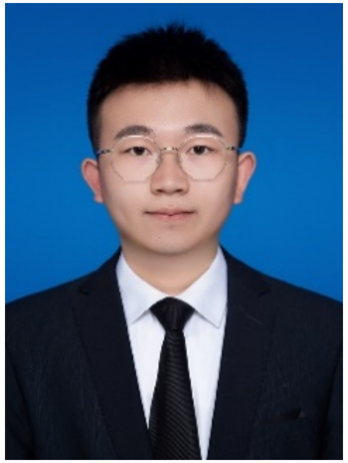


Fig. 8 Interior (a), top (b), and bottom (c) views of the fabricated prototypes (two-channel, three-channel, and four-channel crossovers from left to right)

Conclusions

1. We proposed a new method of crossover designs by introducing an HCL in the middle of the air-filled SIW crossover cavity.
2. Two-, three-, and four-channel air-filled SIW crossovers are designed and fabricated successively to demonstrate the feasibility of the proposed method.
3. Compared with similar approaches, the designed crossovers show the merits of simple structure, compactness, and wide fractional bandwidths.



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Mr. Geng was the recipient of First Place Award for the IEEE MTT-S Multilingual Graduate Video Competition at the IEEE International Wireless Symposium in 2023, the Scholarship of Technical Institute of Physics and Chemistry, and the Chinese Academy of Sciences in 2023.

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