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Planar dual-polarized millimeter-wave shared-aperture array antenna with high band isolation

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Key words: Shared-aperture; Planar antenna; Millimeter-wave antenna; High isolation; Substrate integrated waveguide (SIW)

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Motivation

- Modern wireless system usually adopts multiple antennas for the application of multiple polarization and multiple operating frequency bandwidth. These antennas usually occupied large space in the system.
- Miniaturized system requires the antenna have a very compact size and high integration performance.
- Millimeter-wave (mm-wave) wireless systems have become popular due to the wide available frequency bandwidth. When multiple mm-wave antennas integrated tightly together, it is hard to realize a high isolation in a wide frequency bandwidth for each antenna.
- Planar shared-aperture antennas have merits of very compact size and multiple-functions such as different polarizations and operating bandwidths. However, it is a challenge to design both the element and array in the mm-wave band, and only rare few works have been reported with good performance in recent years.

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Shared-aperture element antenna

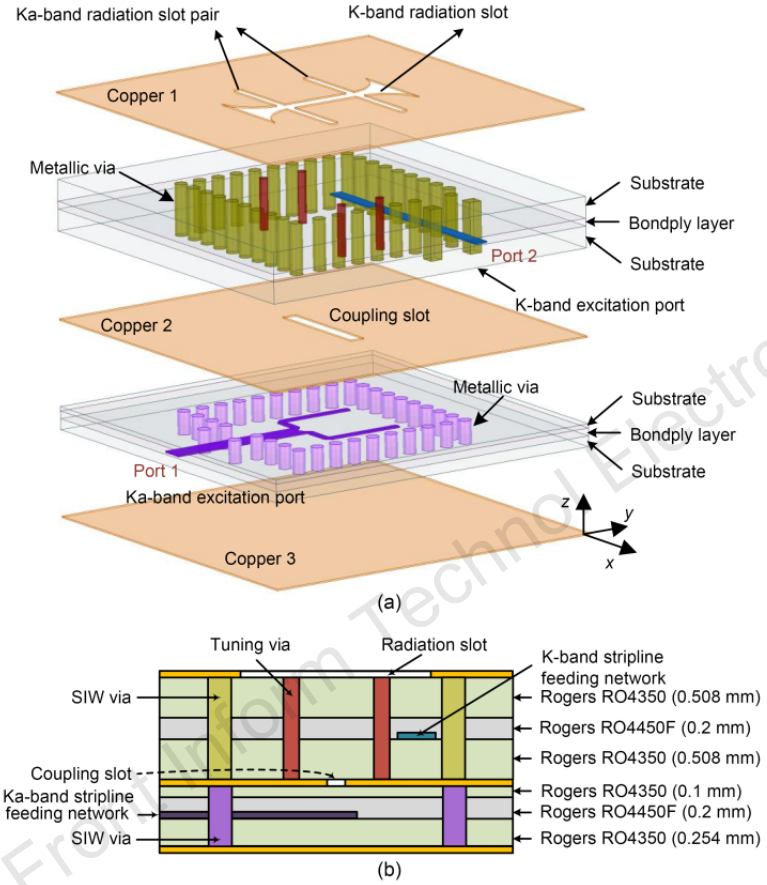

Fig. 1 Configuration of the proposed K-/Ka-band shared-aperture antenna element: (a) three-dimensional view; (b) cross-sectional view

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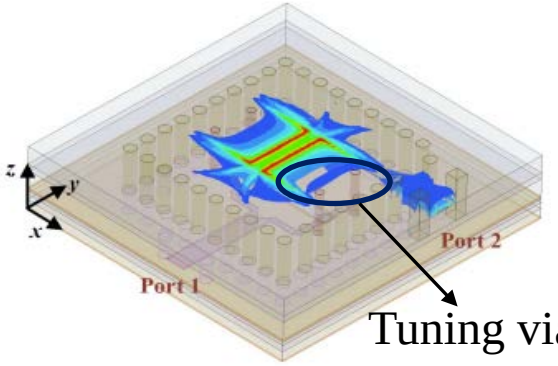
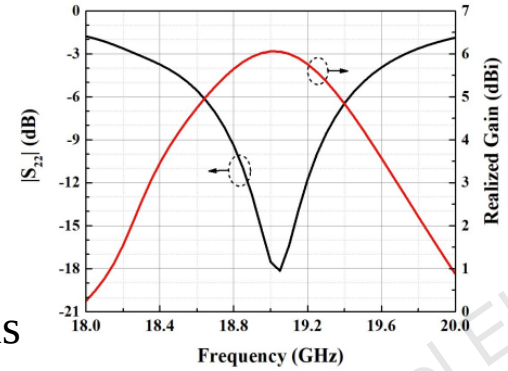
- the K- and Ka-band antennas are integrated and share the same radiation aperture on the top surface of the substrate integrated waveguide (SIW) cavity.
- **Ka-band antenna**: two rectangular slots, excited by the SIW cavity from port 1
- **K-band antenna**: a butterfly-shaped slot, excited by a stripline from port 2

Shared-aperture element antenna

- K-band: the butterfly-shaped slot radiates the *x*-polarized wave



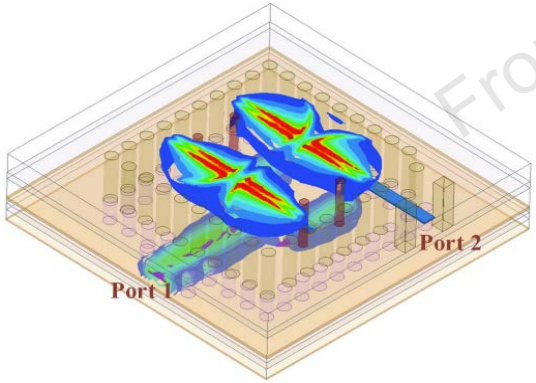


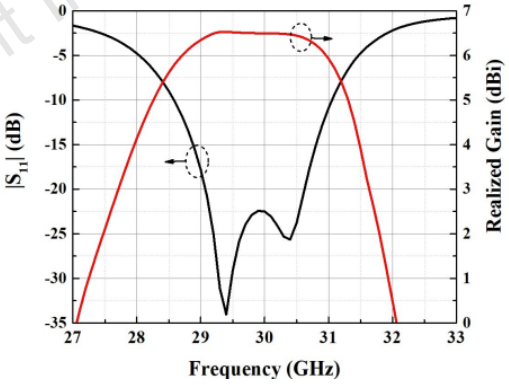
- A stripline in the upper substrate layers with an offset is adpoted (from port 2)
- Four metal vias are placed to obtain strong coupling and good impedance matching

Fractional bandwidth (FBW): 2.26% (18.82–19.25 GHz)

Realized gain: 6.06 dBi

- Ka-band: the slot pair radiates the *y*-polarized wave





- A forked stripline is adopted to excite the SIW cavity through coupling slot reducing unwanted radiation from the butterfly-shaped slot (from port 1)
- Double-point excitation help to generate two resonating peaks

FBW: 8.32% (28.58–31.06 GHz)

Realized gain: 6.53 dBi

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Shared-aperture element antenna

➢ Dual-band and dual-polarization performance

- The butterfly-shaped slot doesn't cut any surface current of SIW cavity when Ka-band element is operated
- The radiation fields are canceled because of opposite radiation phases in the slot pair when K-band element is operated

➢ High isolation due to weak coupling

- Two element support different modes, i.e., the quasi-TE_{120} mode and the TEM-mode.
- Orthogonal polarization

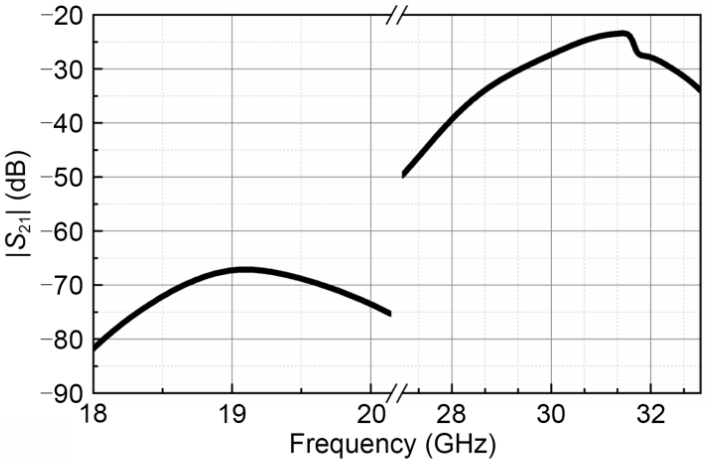

Fig. 6 Simulated isolation between port 1 and port 2 of the antenna element

Isolation: > 65 dB in K-band
> 23 dB in Ka-band

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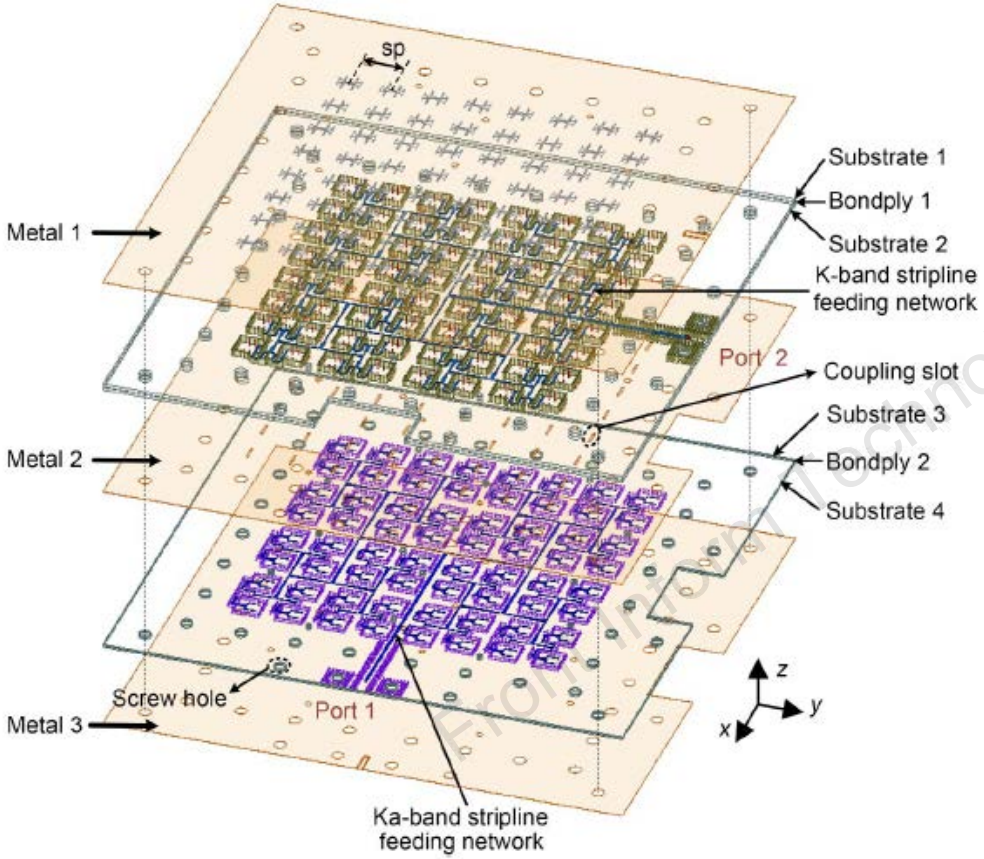
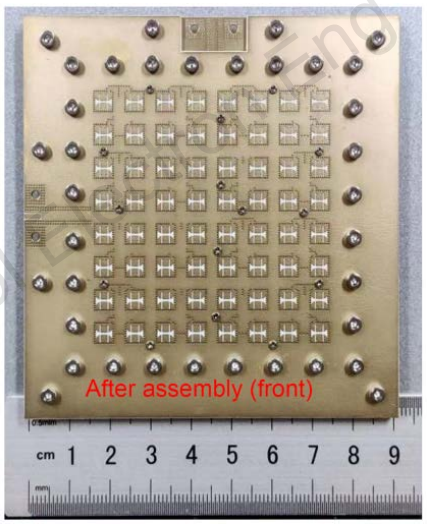
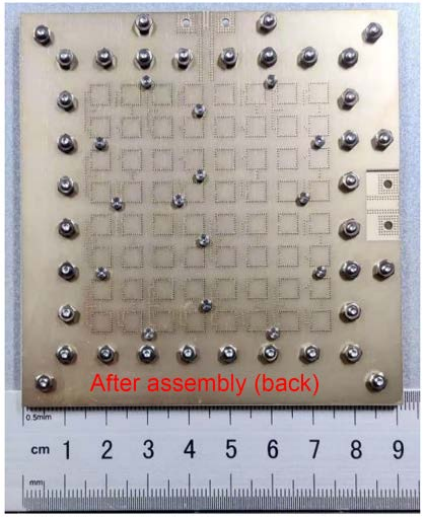
Shared-aperture array antenna

■ 8×8 array with parallel feeding networks







- Top two substrates and the bottom two substrates are fabricated separately and then aligned with screws

- The profile is only 1.91 mm

Shared-aperture array antenna

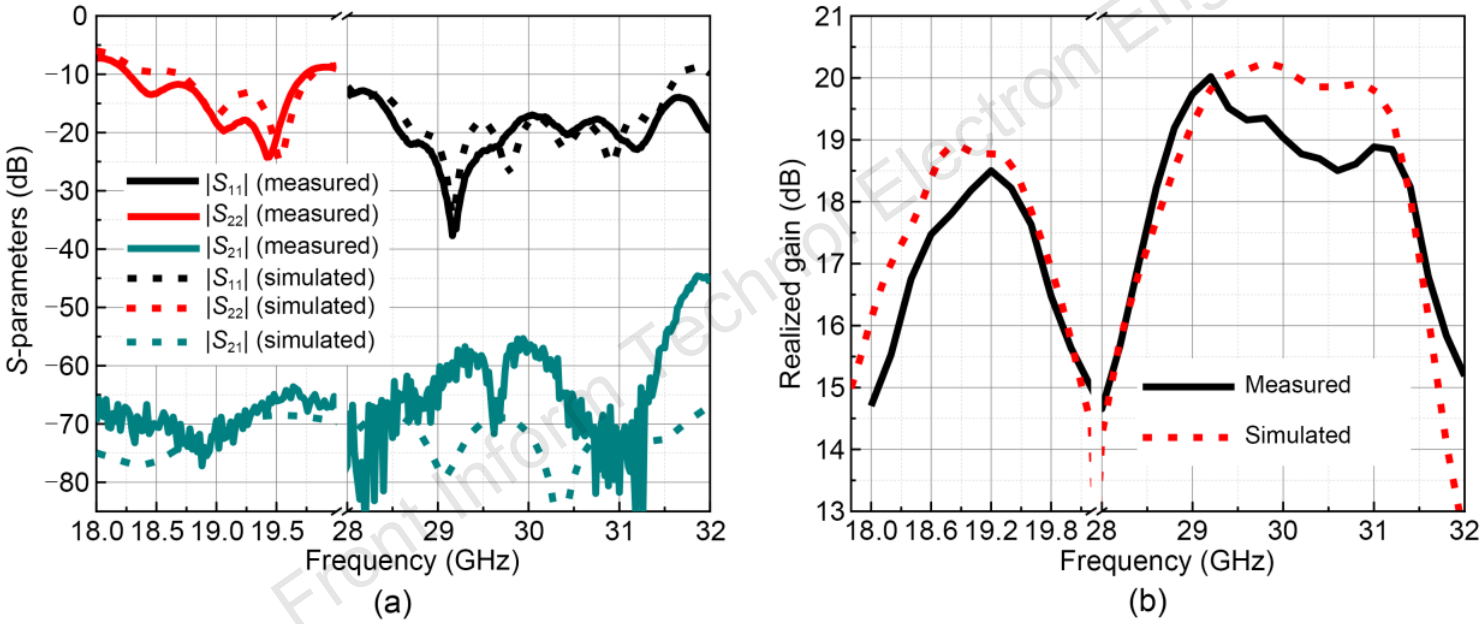


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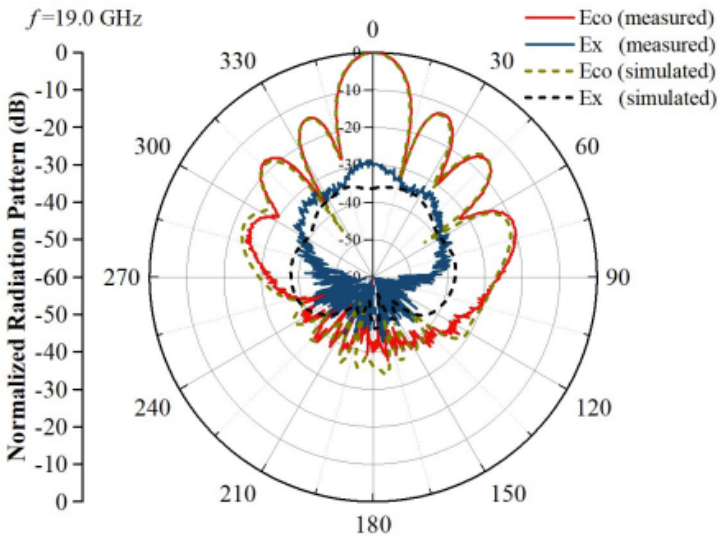
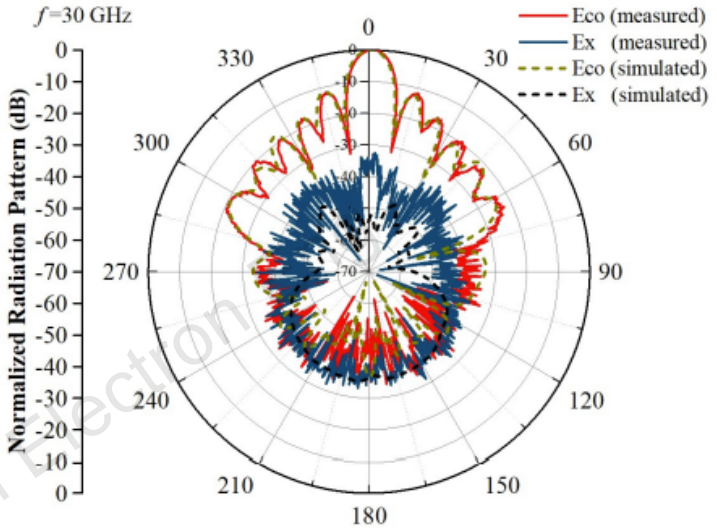
Fig. 11 Simulation and measurement results of the shared-aperture array antenna: (a) magnitude responses for the *S*-parameters; (b) realized gain

Shared-aperture array antenna



(b)



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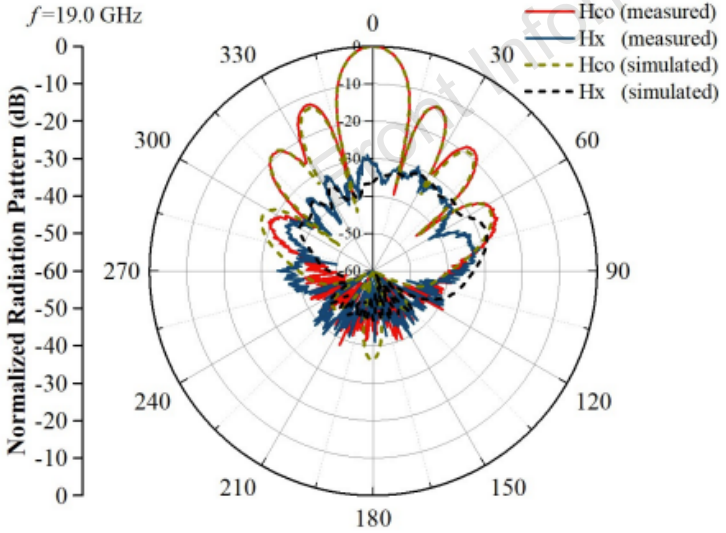

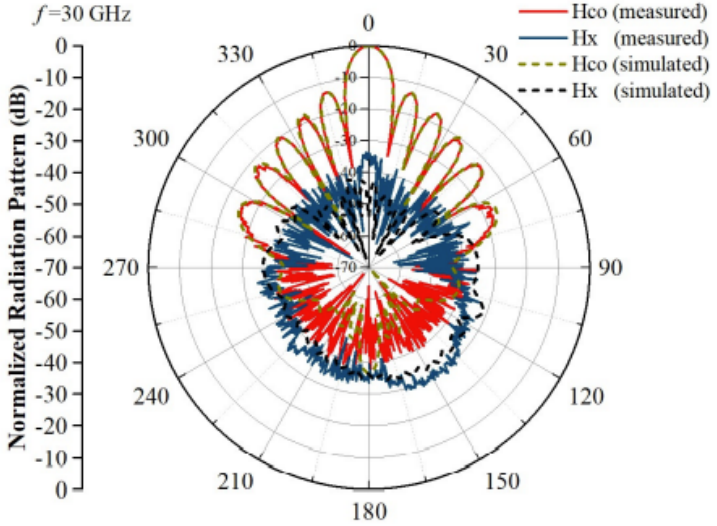

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Comparison & conclusions

Table 1 Comparisons between the proposed and relative millimeter-wave shared-aperture array antennas

Reference	Array scale	Center frequency (GHz)	FBW (%)	Max gain (dBi)	Isolation (dB)	Size ($\lambda_u \times \lambda_u$)
Ferrando-Rocher et al. (2019)	8×8	20/30	10/6	26/29.5	80/50	9.35×9.35
Ding and Cheng (2019)	4×4	16/34.7	12.5/4.1	13.2/17.2	70/28	3.2×1.7
Guo et al. (2021)	8×8	19/29	14.7/20.7	21.4/22	60/50	9.86×8.7
This work	8×8	19/30	7.73/20	18.5/20.02	60/44	5.8×5.8

λ_u is the wavelength of the center frequency of the higher band. FBW is the fractional bandwidth. The numbers before and after "/" represent the corresponding performance of the two antennas with different center frequencies

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- The proposed antenna has the advantages of dual-band operation capability, dual-polarization performance, high band isolation, planar form, and small size, and has great potential to reduce the size of wireless systems.
- The proposed antenna can also be used to support millimeter-wave satellite communication. A cross-radiation slot can be adopted instead of two types of radiation slots to generate circular polarization using a 90° phase feeding network.

Yuyan CAO received the BS degree from Nanjing University of Science and Technology, China, in 2014, and the MS degree in School of Information Science and Engineering, Southeast University (SEU), China, in 2021. Her research interests include millimeter-wave and sub-THz antennas, passive coupler, RF front end system and antenna systems.

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He has served as the TPC Chair/Co-Chair for many international conferences, such as iWat2018, ICMMT 2019. He has served as a Guest Editor for the IEEE T-MTT Special Issue on IWS 2018, an Associate Editor for the *IET Electronics Letters* and the *IET Microwaves, Antennas & Propagation*. He is a Member of the IEEE MTT-21 Terahertz Technology and Applications, Technical Committees.

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